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

Philosophiae Doctor (PhD)
Thesis 2022: 23

Sowing seeds of security: A multilevel perspective on the governance of plant genetic resources and seed systems in Ethiopia

Sikkerhet i Såfrø: et flernivåperspektiv på forvaltning av plantegenetiske ressurser og frøsystemer i Etiopia

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Ås 2021

Thesis number 2022: 23
ISSN 1894-6402
ISBN 978-82-575-1863-9

Acknowledgment

The completion of this Ph.D. research gives me a blended feeling of relief and pleasure. It is the harvest of a seed sown five years ago, which I nurtured with the help of and insight from many people. First and foremost, I was fortunate to have had the wise supervision, advice, and guidance of my principal supervisor, Ola Tveitereid Westengen (Associate Professor), throughout the research process. Ola is passionate about seed and plant genetic resources and a wonderful mentor and brotherlike workmate. After every bilateral meeting we had, I left his office with new knowledge on my research topic, a clear direction, and positive energy for the next task at hand. My co-supervisor, Ruth Haug (Professor), set benchmarks for quality assurance related to social institutions, including gender issues, and contributed to fine-tuning the articles included in my thesis. I am very grateful for their tireless support, invaluable academic insights, and encouragement at all stages of my Ph.D. research.

I am thankful to the Norwegian University of Life Sciences (NMBU) for the scholarship to carry out this research and the Research Council of Norway for the generous funding of my fieldwork in Ethiopia under grant number RCN-277452. I want to thank the International Maize and Wheat Improvement Center (CIMMYT) in Addis Ababa for hosting me, advising, and facilitating my fieldwork. I truly appreciate the Oromia Bureau of Agriculture and Natural Resources and the district Bureau of Agriculture and Natural Resources in Gindabarat and Heexosa for their interest in my research and facilitating household surveys and focus group discussions.

My research would never have been possible if it were not for the understanding, kindness, and willingness of numerous women and men smallholder farmers in the study sites who answered my questions and shared their knowledge and insights. Most of them asked me if my work will help them with the many challenges they face in accessing the plant varieties and seed types they prefer for their crop production. I hope that I have reflected their wisdom and challenges in the articles included in this thesis, and actors in the seed system will consider it in their policies and practices and respond to smallholder farmers' needs and realities. My research also benefited from the knowledge and experiences of respondents from the public, community, non-government, and private seed sector stakeholders from local to national levels and environmental governance institutions at the federal level. I am grateful for their generous participation in discussions and interviews and for sharing their experience and knowledge.

I owe an outstanding debt to scores of individuals who helped me in my fieldwork in Ethiopia. My effort to understand the Ethiopian seed system actors' roles and the complexity of seed systems and genetic resource governance was greatly aided by repeated deep discussions with Ato Tefera Zeray, Drs. Dagne Wegary, Bekele Geleta, Adefris Teklewold, Amsalu Ayana, Mohammed Hasena, Zewdie Bishaw, Yitbarek Semeane, Bedada Girma, Melaku Worede, Regassa Feyissa, and Gemedo Dale. I want to thank all of them for taking time and sharing eye-opening experiences with me. In Gindabarat district, I genuinely appreciate Shanko Firissa, Shimelis Tegegne, Lelisa Melese, Abdata Amare, Bayissa Dhowa , and Tolessa Woyessa for their incredible interest in my field research and assistance in the household survey. Thank you very much, Shime and Ijoollee Gindo. Similarly, I am indebted to Bedilu Tafesse, Desalegn Abera, Mitiku Alemu, Yosef Tewodros, Yeshanew Hailu, and Wubishet Kebede for their tireless assistance in logistics and household survey in Heexosa. I am so grateful that all of you were on my team. I thank Dr. Moti Jaleta for linking me with the right people for the additional

technical support that made my work easier. Minilik Tsega developed a tailor-made Survey Processing System (CSPro) software package for data entry and processing, and Mahlet Tezera assisted me in household survey data entry. Belen Gizachew assisted me in perfectly transcribing some of the interviews from Amharic to English. Thank you, Minilik, Mahlet, and Belen. Reliable transport for the fieldwork would have been hard to access without the assistance of my best friend Gizaw Hailu and his colleague Genanew Jabessa. Thank you, Abba Zige and Genanew, for going above and beyond to secure reliable transport for my team.

Special thanks to Professor Åsmund Bjørnstad and Dr. Trygve Berg of NMBU and Professor Kristin Rosendal of Fridtjof Nansen Institute for providing indispensable inputs to the different sections of this thesis. Many thanks to Marta Morais for helping me with the graphic design of the figures included in the articles. I am grateful to Tola Gemechu Ango of Stockholm University for making the map of the study areas, and Habtamu Alem of the Norwegian Institute of Bioeconomy Research, and my colleague Clifton Makate for their support in quantitative data analysis. Previous and current Ph.D. fellow students and staff at the Department of International Environment and Development Studies (Noragric) at the NMBU deserve thanks for inspiring formal and informal discussions. I extend my appreciation to Josie Teurlings, Ph.D. program coordinator at the Faculty of Landscape and Society (LANDSAM), for all the tips and practical assistance she gave me during the past five years. I also owe a particular debt for service by NMBU librarians, especially Liv T. Ellingsen, for the timely supply of older literature on Ethiopian environmental and agricultural history from other European libraries. These are materials inaccessible locally and on the internet. I thank the finance staff at LANDSAM, especially Anna Holm, for her timely response to my requests while I was on campus and in the field. I do not know what can be achieved without good IT services at NMBU. Thank you to you all at NMBU's IT data staff, especially Anders Dysvik, who helped me a lot at the beginning when I joined the Ph.D. program. At the Tivoli building, Morten Walstad is not only making the working stations neat and comfortable, but he is also the first colleague I find every morning in the corridor, where he welcomes me with a smile and enthusiasm. Thank you, Morten, for the honest and beautiful conversations that always gave me a shimmering spirit to start my working days.

This Ph.D. research would not have been possible without a loving and supportive family. My wife, Sarah Dalle (Ph.D.), who would not allow me to cease the hard work, supported me in every way she could, including taking care of our daughters during my fieldwork. She read a section of my work, provided comments and suggestions, and worked as co-author with me on the second article. I thank Sarah for her undying love and support. I thank Samrawit, who was generous to our daughters and worked with Sarah to cover my share of parenting while I was away for fieldwork in Ethiopia. My daughters, Malifu and Kayo (or, as I call them, Hunduma girls), have become mature young people in the time it took me to complete this Ph.D. research. Hunduma girls, you didn't wait for me to finish the six-month-long fieldwork. You visited me for Christmas in Ethiopia and left me energy to complete my data collection, although we cried on your departure, which was a sweet pain. You provide me with perspective, joy, and purpose in life. I love you! Finally, I thank my parents and family — Batu, Hunde, Kore, Hawi, Qore, Chala, Tujo, Bitew, Shabe, Kisi, and Drs. Dere, Baye, and Bayissa, and other members of our big family for their continued love, support, and encouragement during this Ph.D. journey and for everything I have accomplished in my life.

Abstract

Farmers' and breeders' access to diverse cultivated and wild plant genetic resources for food and agriculture (PGRFA) is crucial for adapting crop production to climate, environmental, and socioeconomic changes and increasing food and nutrition security. This thesis comprises three separate but interrelated articles that contribute to the literature on PGRFA governance, seed security and seed systems, and seed politics and development. At the intersection of the national and international levels, the thesis aims to understand Ethiopia's PGRFA access governance and its implications for different users within and outside the country. At the intersection of the local and the national levels, it investigates farmers' seed preferences and uses and how different seed system actors, institutions, and policies affect farmers' seed security. Finally, crosscutting all levels, the thesis sheds light on the current Ethiopian seed system development politics by exploring how and why the Ethiopian government prioritized some seed system policies and excluded other policies under different political regimes since the 1950s. In the first article, focusing on genetic resource governance, we show that Ethiopia's PGRFA access governance since the early 1990s has shifted from a commons and free access regime to a sovereign ownership and control regime restricting access for international users. Drawing on commons theory, we identify three interlinked historical, political, and economic factors that can explain this development: the economic importance of agriculture, the national narratives about the value of PGRFA, and Ethiopian policy makers' participation in the heated 'seed wars' on the international scene. The second article focuses on farmers' seed preferences and uses at the farm level and relates this to local and national seed system governance. The farm-level research reports evidence of widespread seed insecurity in the study sites, apparent in discrepancies between the plant varieties and types of seeds farmers prefer and those they actually use. Other evidence includes limited availability of improved varieties and specially certified seeds, challenges with seed quality from some sources, and differentiated access to preferred seed and information according to sex, age, and wealth. Analysis of seed system governance shows that the interventions prioritized in Ethiopia's current pluralistic seed system development strategy (PSSDS) on paper address most of these identified seed insecurity issues and seed system dysfunctions, but implementation lags. The third and final article in the thesis provides a historical analysis of Ethiopia's seed policy over the last 70 years. Focusing on power and employing the lens of 'international seed regimes,' the article shows that Ethiopia has gone from almost non-participation in the first colonial seed regime to becoming the "pioneer" of the post-WWII second public seed regime in the horn of Africa and finally to resistance to the third corporate-based neoliberal seed regime. In the current conjuncture in the contemporary Ethiopian seed regime, four different approaches to PSSDS are competing: 1) government-led formalization, 2) private-led formalization, 3) farmer-based localization, and 4) community-based integrative seed system developments. Despite the overarching policies recognizing the need for a pluralistic approach to seed system development to respond to farmers' seed security challenges, government programs and practices continue to emphasize state-led seed system formalization rooted in the earlier second seed regime. The government's vision to modernize smallholder farmers and increase crop production and productivity and the focus on formal seed systems development as the primary pathway to achieve these have ignored opportunities to tap into the strength of other alternatives identified in Ethiopia's PSSDS. In conclusion, the research presented in this thesis shows that PSSDS is a comprehensive policy framework with the potential to deliver seed security for all farmers. However, this will require the government to take leadership and remove existing political, organizational, and economic barriers in order to implement a genuinely inclusive and equitable pluralistic seed system.

Sammendrag

Bønders og planteforedleres tilgang til mangfold av plantegenetiske ressurser for mat og landbruk (PGRFA) — både kulturplanter og deres ville slektninger — er avgjørende for å tilpasse planteproduksjon til miljømessige og sosioøkonomiske endringer, samt for mat- og ernæringssikkerhet. Denne avhandlingen består av tre uavhengig, men sammenkoblete artikler som bidrar til forskningslitteraturen innen PGRFA forvaltning, såfrøsikkerhet og såfrøpolitikk. I skjæringspunktet mellom det nasjonale og det internasjonale nivået, har avhandlingen som mål å forstå Etiopias politikk for tilgang til PGRFA og implikasjoner for ulike brukere i og utenfor landet. I skjæringspunktet mellom lokalt og nasjonalt nivå undersøkes bønders preferanser og bruk (behov) for såfrø og hvordan forskjellige såfrøsystemaktører, institusjoner og politikk påvirker såfrøsikkerhet. Til slutt, på tvers av nivåene, belyser avhandlingen den nåværende etiopiske såfrøsystemutviklingspolitikken ved å undersøke hvordan og hvorfor den etiopiske regjeringen har prioritert noen såfrøsystempolitikker og ekskluderte andre alternativer under forskjellige politiske regimer siden 1950-tallet. I den første artikkelen, med fokus på forvalting av genetiske ressurser, viser avhandlingen at Etiopia siden begynnelsen av 1990-tallet har skiftet sin politikk om tilgang til PGRFA fra et fellesgode- og fri-tilgangsregime til et suverent eierskap og kontrollregime som begrenser tilgang for internasjonale brukere. Basert på «commons» teori identifiserer vi tre historiske, politiske og økonomiske faktorer som kan forklare denne utviklingen. Disse inkluderer landbrukets økonomiske betydning for Etiopia, de nasjonale fortellingene om verdien av PGRFA og etiopiske beslutningstakeres deltakelse i de opphetede «såfrøkrigene» på den internasjonale scenen. Den andre artikkelen setter søkelys på bøndenes såfrøpreferanser og bruk på gårdsnivå og relaterer dette til lokal og nasjonal forvaltning av såfrøsystemer. Forskningen på gårdsnivå viser en utbredt såfrøusikkerhet i to studiedistrikter. Den viser tydelig avvik mellom hvilke plantesorter og såfrøtyper bønder foretrekker og de de faktisk bruker. Andre indikatorer på såfrøusikkerhet inkluderer begrenset tilgang på nye plantesorter, spesielt sertifiserte såfrø av disse, utfordringer knyttet til såfrøkvalitet fra noen kilder og differensiert tilgang til foretrukne plantesorter og såfrøtyper, samt informasjon etter kjønn, alder og rikdom. Analyse av såfrøsystemforvaltningen viser at tiltakene som er prioritert i Etiopias nåværende pluralistiske såfrøsystemutviklingsstrategi (på papir) tar for seg de fleste av disse identifiserte problemene med såfrøusikkerhet og dysfunksjonene i såfrøsystemet, men implementeringen mangler. Den tredje og siste artikkelen i avhandlingen gir en historisk analyse av Etiopias såfrøpolitikk over de siste 70 årene. Basert på maktanalyse og ved bruk av et historisk såfrøregime rammeverk, viser artikkelen at Etiopia har gått fra nesten ingen deltakelse i det første koloniale såfrøregimet til å bli en "pioner" for det offentlige såfrøregimet etter andre verdenskrig på Afrikas horn og avvisning av et tredje nyliberale såfrøregime. I det nåværende økonomiske klimaet i det moderne etiopiske såfrøregimet konkurrerer fire forskjellige tilnærminger til landets pluralistiske såfrøsystemutviklingsstrategi:1) Statsledet formalisering, 2) Privatledet formalisering, 3) Bondebasert lokalisering og 4) Lokalsamfunnsbaserte integrert såfrøsystemutvikling. Til tross for at den overordnede politikken anerkjenner behovet for en pluralistisk tilnærming til såfrøsystemutviklingen for å svare på bøndenes utfordringer med såfrøsikkerhet, dominerer den statsledet formaliseringen. Det legges vekt på offentlige programmer for nye plantesortsutvikling, såfrøproduksjon og distribusjon. Regjeringens visjon om å modernisere småbrukere og øke planteproduksjon og produktivitet prioriterer utvikling av formelle såfrøsystemer som den viktigste måten å oppnå disse og har ignorert muligheter for å utnytte styrken til de andre alternativer identifisert i landets pluralistiske såfrøsystemutviklingsstrategi. Avslutningsvis viser forskningen som presenteres i denne avhandlingen at strategien er et omfattende politisk rammeverk med potensial til å oppnå såfrøsikkerhet for alle bønder. Dette vil imidlertid kreve at regjeringen tar ledelsen og fjerner eksisterende politiske, organisatoriske og økonomiske barrierer for å iverksette et virkelig inkluderende og rettferdig pluralistisk såfrøsystem.

Dedication

I dedicate this thesis to the late artist Hachalu Hundessa, who sang for the freedom of the Oromo people and fought for smallholder farmers that were forcibly evicted from their land in and around Finfine (Addis Ababa), the capital of Ethiopia and Oromia National Regional State.

This Ph.D. research journey started with fieldwork amid Qeeroo (youth) protest in Ethiopia in 2017. The most exciting and hopeful moments occurred following the protest in 2018/2019 when Prime Minister Abiy came to power and made peace with neighboring Eritrea, which earned him the Nobel Peace Prize in 2019 for the peace deal and his commitment to democracy in Ethiopia. This excitement swiftly changed to the saddest times of Ethiopia's recent history due to the ongoing conflict and civil war since 2020. It has been hard to focus on my thesis write-up while following the devastation that engulfed the country. The overall tragedy, especially the assassination of the beloved Oromo Artist, Hachalu Hundessa, drained my energy. The current nationwide conflict and civil war in Ethiopia is a dreadful situation. Still, I remain optimistic that it is not too late for actors involved in the disastrous military conflict to reflect once more on their motives and reconcile with others to restore peace in the country!

Abbreviations

ADLI	Agricultural development-led industrialization
CBD	Convention on Biological Diversity
EBI	Ethiopian Biodiversity Institute
EPRDF	Ethiopian People's Revolutionary Democratic Front
FGD	Focus group discussions
IPR	Intellectual property rights
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
NGO	Non-governmental organization
PGRFA	Plant genetic resources for food and agriculture
PSSDS	Pluralistic seed system development strategy
UPOV	International Union for the Protection of New Varieties of Plants
WWII	World War II or the Second World War

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PART I: Synthesizing Chapter

ON A SEED

"This was the goal of the leaf
and the root.
For this did the blossom burn
its hour.
This little grain is the
ultimate fruit.
This is the awesome vessel of
power.

For this is the source of the
root and the bud . . . .
World unto world unto world
remolded.
This is the seed, compact of
GOD,
Wherein all mystery is
enfolded."

Georgie Starbuck Galbraith

The New York Times
May 6, 1960

1. Introduction

The last lines in both stanzas of Galbraith's poem "On a Seed" — "this is the awesome vessel of power" and "wherein all mystery is enfolded" — suggest a multifaceted feature of seed. Seed is fundamental in agri-food production systems and represents the starting point for growing crops to produce food, feed, fuel, and other plant-based products. It has several functions, such as input for delivering new technology (e.g., new varieties) to enhance crop production systems' resilience and increase production and productivity (Hufford et al., 2019; Lin, 2011; Lewis & Mulvany, 1997). These multifaceted functions make it a critical resource to address some of the challenges currently facing different forms of agriculture production — industrial, organic, and smallholder agroecological farming (Brooker et al., 2021; Fadda et al., 2020; Lammerts van Bueren et al., 2018; Brush et al., 2003). Moreover, seed is a renewable, regenerative resource that farmers have selected, exchanged, and maintained for centuries with practices informed by local cultural values and social organization (Delêtre et al., 2021; Murphy, 2017; Ricciardi, 2015; Ellen & Platten, 2011; Carolan, 2007). In its broader sense, the term "seed" is understood as any propagative part of a plant, including tubers and bulbs, especially as preserved for growing a new crop and sometimes as sperm, offspring, or progeny. In this thesis, I use the term "seed" in its botanical sense, which refers to the characteristic reproductive body of crop plants or a fertilized and matured ovule, consisting of an embryo associated with stored food for its early development after germination. In addition, this thesis emphasizes seed as a key input in plant-based agriculture production (Bewley et al., 2006; Egli, 1998). Because of its diverse functions and associated users' interests, strategic debates around seed related research and development have increased within the context of contemporary global challenges such as ensuring universal food security, safeguarding crop diversity, and adapting crop production to climate change (Kahane et al., 2013; Pascual et al., 2011; Esquinas-Alcázar, 2005). These ongoing strategic debates at national and international levels revolve around seed conservation practices and governance related to ownership and access to cope with these global challenges (Müller, 2014; Eyzaguirre et al., 2007). Accordingly, several factors influence seed governance by governments and access by breeders and farmers.

At the international level, restrictive regulations have had limited germplasm flow or access to plant genetic resources for food and agriculture (PGRFA) during the last three to four decades (Ebert & Engels, 2021; Smith et al., 2021; He & Li, 2020; Galluzzi et al., 2020; Gaffney et al., 2020; Bagley et al., 2019). These restrictions are against the call for a policy and regulatory framework for facilitated access to PGRFA (Singh et al., 2020; Ebert & Engels, 2020; Halewood et al., 2017; Atlin et al., 2017) and rapid plant breeding and cultivar adjustment to adapt crops to climate change (Li & He, 2021; Galluzzi et al., 2020; Challinor et al., 2016). It is also against the call for improving the resilience of the cropping system by enhancing access to diverse "orphan crop" species and varieties and preserving crop diversity for increasing production and productivity or closing the yield gap while improving environmental sustainability (Okolo & Adejumo, 2021; Foley et al., 2011). Ethiopia is one of the few developing countries with restrictive PGRFA access regulations (Finkel, 2009; Kate & Laird, 2002; Rosendal, 2000). However, there has been no in-depth study to explore the reasons why some developing countries implement a restrictive PGRFA access governance regime, other than a few which have mainly reviewed trends in restrictive national access regulations (Bjørnstad & Westengen, 2019; Bjørnstad et al., 2013). The present study examines Ethiopia's PGRFA conservation and utilization strategies, policies, and laws to explain why some developing countries restrict access.

At the local and national levels, farmers' access to seeds — or, more broadly, farmers' seed security — is negatively affected by several factors. One of these challenges is the dwindling basis of crop diversity, especially for indigenous crop varieties (Khoury et al., 2021; Abegaz & Tessema, 2021; Sonnino, 2017; Tsegaye & Berg, 2007a; Teklu & Hammer, 2006), limited farmer-genebank linkages for restoration from ex situ collections (Westengen et al., 2018), and lack of support for farmers' seed system (Louwaars, 2021; Almekinders & Louwaars, 2002). The other challenge is the lack of evidence-based policy and regulatory framework affecting plant breeding, delivery, and adoption in the formal seed system (Beko, 2017; Wattnem, 2016; Munyi & de Jonge, 2015; Alemu et al., 2010). Impacts of these policy challenges are expressed through interventions resulting in farmers' differentiated access (by age, sex, and wealth) to extension services, credit, land, and information on climate change. Access to land and services, in turn, affects farmers' choices of adaptation strategies, e.g., seeds of preferred crops and varieties (Di Falco et al., 2011; Bryan et al., 2009). More importantly, the poor functioning of seed systems is impeding farmers' seed security (Louwaars, 2021; Tekle-Wold et al., 2012; Thijssen et al., 2008). Because of this, seed system development in developing countries, including Ethiopia, has attracted government institutions, policymakers, and donors during the last one and a half decades (Holtzman et al., 2020; FAO, 2020; Borman et al., 2020). At the same time, these actors display diverse interests and strategies for seed system development that are sometimes conflicting (Westengen, 2017; Scoones & Thompson, 2011; McCann, 2011). Given these differences and conflict, developing coherent policies, programs, and practices for robust seed system development have been challenging for policymakers and legislators (Louwaars et al., 2013; Louwaars & de Boef, 2012; de Boef et al., 2010). Nevertheless, in 2013 Ethiopia started implementing a pluralistic seed systems development strategy (PSSDS) as the country's overarching seed policy (Mulesa et al., 2021; MoA and ATA, 2017). The government has officially adopted PSSDS in 2017 as an alternative to the dominant linear formal seed system development to transform its seed sector comprehensively. Therefore, this study focuses on the Ethiopian government's seed policy development and implementation within the context of national interest and other actors' interests and goals.

That said, facilitated access to PGRFA for international breeding activities and a well-functioning national seed system that delivers seed security for all farmers is vital for developing a country's agri-food system. It is even more critical in sub-Saharan African countries, including Ethiopia, where agriculture is the most significant economic sector. For instance, the contribution of agriculture to Ethiopia's real gross domestic product was, on average, 47% between 2004 and 2014. Of this, 32% was contributed from the crop subsector (Bachewe et al., 2018). Agriculture also employs approximately 70.5% of Ethiopia's labor force (UN, 2018a) and provides direct and indirect livelihood activities for 80.4% of the country's total population residing in rural areas (Schmidt et al., 2018). Being the second-most populous nation in Africa, Ethiopia has about 118 million mouths to feed in 2021 (UN, 2018b; CSA, 2013). The food and nutrition insecurity that constitute much of the country's history (Diriba, 2018; Kissi, 2000; De Waal, 1991; McCann, 1988; Pankhurst, 1961) is still a threat to its population, and 21.3 million people were food-insecure at the end of 2020 (UN-OCHA, 2021). About 17.3 million smallholder individual farmers (Diriba, 2018, p. 290) or 13 million smallholder households (Headey et al., 2014), the majority of which (63%) plow less or equal to 0.6 ha of farmland (Paul & wa Gĩthĩnji, 2018; Headey et al., 2014) are responsible for a significant share of total production for main crops (Taffesse, 2019; MoANR, 2016). At the same time, these food growers are often the poorest and food insecure (Thome et al., 2016; Stifel & Woldehanna, 2016). Broadly, studies link food and nutrition insecurity in Ethiopia to drought as well as a

complex interplay of historical, political, and economic factors, which underlie persistent conflicts (Bahru et al., 2019; Diriba, 2018; Keller, 1992; De Waal, 1991; Kumar, 1990; Pankhurst & Johnson, 1988). Other studies identify the dominance of climate-sensitive smallholder farming on diminishing landholdings (Mohamed, 2017; Lewis, 2017) with low use of agricultural technology such as quality seeds of improved varieties, agrochemicals, and soil degradation, as the leading cause of low production and productivity leading to food and nutrition insecurity (Taffesse et al., 2013; Negeri & Adisu, 2002).

In 1991, Ethiopia entered the prevailing political and economic structure, which has had significant implications for its agricultural development. This change was a shift in governance regime and socioeconomic development policy from military government/dominant socialist enterprises (Belete et al., 1991; Cohen & Isaksson, 1988) to an authoritarian developmental state/"free market" economy (Clapham, 2018; Lefort, 2012). The new Ethiopian People's Revolutionary Democratic Front (EPRDF) government, an ethnic federalist political party coalition, introduced an agricultural development-led industrialization (ADLI) strategy as its overarching strategic framework for guiding Ethiopia's economic development and poverty reduction in 1993. In Africa, the Ethiopian and Rwandan governments have been implementing the clearest example of a "developmental state"[1] policy since the 1990s (Clapham, 2018; Goodfellow, 2017; Vaughan, 2011). For EPRDF, this policy involves centralized rent-management, controlled market liberalization, and state-driven smallholder agriculture transformation (Meles Zenawi Foundation, 2017; Zenawi, 2012; Dorosh & Rashid, 2012). The EPRDF framed ADLI strategy and its subsequent policies[2] within the context of Millennium Development Goals — now known as Sustainable Development Goals (Haile, 2015) and the Comprehensive Africa Agricultural Development Program (NEPAD, 2009). ADLI gained considerable popularity in Ethiopia's policy discourse of the state and attracted significant donor support (Berhanu, 2016). ADLI's implementation was ostensibly decentralized based on the country's constitution that deploys agriculture and rural development decision-making to regional government (Vaughan & Tronvoll, 2003). However, in practice, EPRDF has centrally planned and controlled it (Lefort, 2012). In line with the South Asian "Green Revolution" strategy and informed by important country-specific contexts, ADLI has aimed to intensify the use of relevant Green Revolution technologies to boost smallholder farmers' agricultural production and productivity (Spielman et al., 2010). In so doing, it aimed to achieve increased food security, sustainable exports, and import substitution.

Guided by these policies, the government re-initiated massive agriculture and rural development efforts, and Ethiopia registered improved agricultural growth (an average of 7.2% annually) since 2004 (Bachewe et al., 2018; World Bank, 2016), which has positively impacted the country's economic performance (Dorosh & Minten, 2020). Consequently, Ethiopia became the fastest-growing economy in sub-Saharan Africa until 2018 (World Economic Forum, 2018; Berhanu & Poulton, 2014). Ethiopia's gross domestic product growth slowed

[1] The term "developmental state" refers to a state that intervenes and guides the direction and pace of economic development. It is associated with the leading role played by the government in promoting industrialization in Japan and East Asia in the post-WWII era, in which their respective governments pursued a series of policies, including tariff protection, subsidies, and other types of controls aimed at developing selected productive sectors of economic activity (Caldentey, 2008).

[2] National Five-Year Development Plan (2000–2004), Sustainable Development and Poverty Reduction Program (2002–2005), Plan for Accelerated and Sustained Development to End Poverty (2005–2010), The First Growth and Transformation Plan/GTP-I (2010–2015), Second Growth and Transformation Plan/GTP-II (2015–2020), and Homegrown Economic Reform Program (2020–2030).

down from 8.5% in 2017/18 (World Economic Forum, 2018) to 6.1% in 2019/20 due to the COVID-19 pandemic to 2% in 2021 due to an ongoing civil war since November 2020 (Nunis, 2021). However, the agriculture sector improved in 2019/20 compared to 2018/2019 and slightly contributed to gross domestic product growth (World Bank, 2021). Until recently, despite positive trends, at the time of writing this introductory chapter, Ethiopia faces a political rift that has led to the civil war, making the future uncertain (Walsh & Dahir, 2021; Opalo & Smith, 2021).

Ethiopia's agricultural sector also faces several sustainability challenges hampering the food system and its contribution to sustainable development (Woolfrey et al., 2021; Dorosh & Minten, 2020). This challenge relates to the country's climate that varies significantly. It ranges from hot and dry desert lowlands to subtropical wet highlands. For instance, Hurni (Asfaw et al., 2021) categorizes Ethiopia's agroecology into 7 moisture zones and 18 major agroecological zones based on the country's moisture regime and altitudinal range, i.e., from −125 m below sea level to +4,550 m above sea level. The agro-climatic diversity has created distinct agroecological zones favoring different crop and livestock production systems. It has also made agricultural commercialization and mechanization based on improved varieties of commercial crops complex and challenging. According to Abebe (2017) and Kassie et al. (2013), Ethiopia's crop production is also deteriorating owing to global climatic events causing droughts and rain failure. Smallholder farmers are experiencing frequent droughts and are highly vulnerable to climate change-associated impacts (Asfaw et al., 2021).

Furthermore, inappropriate land policies, increasing human population, extreme weather events (e.g., flood), and mismanagement have resulted in severe land degradation such as soil erosion by water (Lanckriet et al., 2015; Hurni, 1993), with annual soil loss rates on average of 42 tonnes/ha for croplands and up to 300 tonnes/ha in extreme cases reducing crop production and productivity (Hurni et al., 2015; Keyzer & Sonneveld, 2001). This severe soil degradation was estimated to cost 44 billion Ethiopian Birr (€1.7 billion) for soil and water conservation structures to reduce the cost of chemical fertilizer (about 14.4 billion Ethiopian Birr/year) and maintain crop production (Hurni et al., 2015; Keyzer & Sonneveld, 2001). The cumulative effect of environmental problems, unfavorable climatic conditions, and inappropriate policies has contributed to low crop production and productivity, leading to frequent food shortages. These problems are partly due to limited access to PGRFA by breeders to develop new cultivars adapted to climate change and farmers' socioeconomic and cultural needs (Bjørnstad & Westengen, 2019; Atlin et al., 2017; Bjørnstad et al., 2013). Moreover, farmers have limited access to seeds of diverse crops and varieties both during disasters (McGuire & Sperling, 2013; McGuire & Sperling, 2008) and normal growing conditions (Sahlu et al., 2012; Gebremedhin et al., 2009) to benefit from their plasticity to environmental regimes and yield stability (Hufford et al., 2019; Lin, 2011; Mercer & Perales, 2010; Jackson et al., 2007; Cleveland et al., 1994; Scheiner, 1993).

Seed systems are vital in crop diversity management (Louwaars, 2021), crop improvement, delivery, and adoption (David & Sperling, 1999). Consequently, this study raises several questions regarding farmers' seed security linked to different seed systems used by diverse groups of farmers (gender, wealth, age groups). The seed system development policies and their implementation is another area of inquiry. Ethiopian seed systems are one of the most frequently studied seed systems in Africa. Ethiopia is a crop diversity hotspot, and a large body of literature exists both on the nature and geography of this diversity and the seed systems farmers use (Pironon et al., 2020; Bishaw et al., 2010; Alemu et al., 2010; Engels et al., 1991; Harlan, 1975;

1969; Vavilov, 1926a). But most literature focuses on the role of formal and farmers' seed systems (McGuire & Sperling, 2016; Tekle-Wold et al., 2012; Thijssen et al., 2008; Almekinders et al., 1994) without linking to the seed security concept. In Ethiopia, there are just a few examples of the use of seed security assessments framework (CRS et al., 2016; Sperling et al., 2007) even if the country has experienced chronic and acute seed insecurity for decades (Sperling et al., 2007; Sperling & Cooper, 2004). Also, the academic literature has rarely engaged with the seed security concept in discussions about the performance of the Ethiopian seed system, which I discuss as part of this thesis's conceptual base and theoretical framework. Most studies on seed security in developing countries also focused on disaster situations rather than normal growing conditions/seasons (Sperling, 2020; Ruediger, 2017; Sperling & McGuire, 2012; McGuire & Sperling, 2011; Sperling et al., 2008). Only a few relate to seed systems farmers use and their performances (McGuire & Sperling, 2016; 2013; Cromwell, 1990). Seed system policy literature focuses on policies and institutions that affect the effectiveness of seed systems in developing countries, including Ethiopia (Beko, 2017; Rohrbach et al., 2003; Tripp, 1997). Gaps exist since only a few of these address the historical and political economy of seed system development (Scoones & Thompson, 2011; McCann, 2011; Alemu, 2011), to which this study aims to contribute. Outside seed system literature is the contested "adoption" (Glover et al., 2016) publications that focus on barriers to and determinants of adoption of improved varieties from the formal seed system sidelining local varieties and farmers' seed systems (Wilkus et al., 2018; Alemu et al., 2018; Shiferaw et al., 2014; Kafle, 2010).

The overall objective of this research is to generate empirical evidence and influence policy, legislation, and actions for inclusive and equitable seed system development that increases farmers' seed security and facilitates access to PGRFA for all users. For this purpose, the study aims to understand Ethiopia's PGRFA access governance and its implications for different users. The study also explores agroecological, socio-cultural, economic, and political variables affecting farmers' seed preferences and use (demand-side) and how the role of actors and institutions in seed systems affects farmers' seed security (supply-side). Moreover, the study aims to understand how and why the Ethiopian government prioritized some seed system policies and excluded other policies during the past seven decades under different political regimes to shed light on the current Ethiopian seed development politics. Specifically, the study aims to answer the following explicit questions, corresponding to the three articles included in this thesis:

1. Why do some countries implement a restrictive PGRFA access governance regime for international users? (Article 1)
2. What historical, political, and economic factors have shaped Ethiopia's PGRFA conservation and utilization strategies, policies, and laws? (Article 1)
3. How does farmers' seed security differ between commercial and subsistence-oriented production systems? (Article 2)
4. How do wealth status, gender, and age affect farmers' access to preferred seeds from different seed systems? (Article 2)
5. To what extent does Ethiopia's pluralistic approach hold potential to improve farmers' seed security, and how do institutional, political, and economic interests condition this? (Article 2)
6. How have seed system development policies been formulated and implemented? (Article 3)
7. How have different actors' interests influenced seed policy formulation and implementation? (Article 3)
8. What are the socio-political and ecological outcomes of the current seed system policies and practices in the country? (Article 3)

2. Theoretical perspective and conceptual base

The articles included in this thesis use different theoretical approaches and concepts to answer the research questions. In Article 1, we draw on a conceptualization of PGRFA as a "New Commons" (Halewood et al., 2013) and relate to traditional Commons theory (Hess & Ostrom, 2007b; Ostrom, 1990). Recent PGRFA governance studies have integrated these two concepts and conceptualized them as Seed Commons (more on this below). Using "Seed Commons," which cuts across New Commons and traditional Commons, Article 1 examines historical, political, and economic factors that have shaped Ethiopia's access governance policies and practices. To analyze farmers' seed preferences and use (demand-side) and how the role of actors and institutions affect farmers' seed security (supply-side), Article 2 uses two closely related concepts — seed systems and seed security (more on this below). Finally, Article 3 combines plural approaches underpinned by broader theoretical traditions in power analysis to understand Ethiopia's seed system politics and development (Leach et al., 2020). The thesis uses different theoretical perspectives, analytical approaches, and concepts to examine a multilevel perspective of PGRFA governance, farmers' seed security, and seed system development politics in Ethiopia. In the following sub-sections, I first present key concepts in the scholarly fields to which the articles in this thesis aim to contribute. Second, I present the theoretical perspectives I draw on in my analysis of the empirical data collected.

2.1 Understanding genetic resources and crop diversity

The concept of genetic resources and crop diversity has their origin in historical constructions of biological diversity and are consequences of political and epistemic confrontations over its use and conservation or management approaches since 1900. Until the late 1890s, the basal taxonomic unit of biological diversity, established in Linnaean taxonomy, the species level (Ereshefsky, 1994), was used by European naturalists to inventory biological resources and administer imperial botanical collections (Bonneuil, 2019; Ereshefsky, 1994). This basal taxonomic unit changed following the confirmation of the 1865 Mendelian genetic principles[3] in 1900 (Bonneuil, 2019) — principles founded on pea breeding (Smýkal et al., 2016). With Mendelian genetic principles, biologists and geneticists developed an epistemic space regarding the heredity of variability at infra-specific levels, e.g., they could isolate distinct stable lineages from a single crop variety and develop methods for pure line breeding and hybridization (Harwood, 2016; Lee et al., 2015; Borém et al., 2002). The "epistemic space" of heredity (Müller-Wille & Rheinberger, 2007) has since shifted the unit of biological diversity from species to varieties, traits, and genes, which laid a foundation for the concept of *genetic resources* (Bonneuil, 2019; Fenzi & Bonneuil, 2016). The idea of genetic resources soon became an object of knowledge and geopolitics following N. I. Vavilov's major foreign expeditions to explore variability in plants (Vavilov, 1926b) after the rediscovery of the Mendelian hereditary principle already during the interwar years, i.e., from 1918–1939 (Bonneuil, 2019). Vavilov's work in plant exploration and germplasm collection in gene-rich regions and conceptualization of these

[3] Three key principles of genetic studies were developed from Mendel's studies on peas. These are 1) fundamental theory of heredity, i.e., the passing of discrete units of inheritance, or genes, from parents to offspring, 2) principle of segregation, i.e., the inherited factors or alleles (two or more alternative forms of a gene that arise by mutation and are found at the same place on a chromosome) that determine traits are separated into reproductive cells by a process called meiosis and randomly reunite during fertilization, and 3) principle of independent assortment, i.e., genes located on different chromosomes will be inherited independently of each other.

regions as centers of origin and diversity brought a geographical dimension to genetic resources. This has, in turn, contributed to the categorization of the Global South as "gene-rich" and the Global North as a "gene-poor" region (Smith, 1969; Vavilov, 1926b). This divide and relationship between the two regions as PGRFA donor and recipient, respectively, became established following the numerous germplasm collection expeditions carried out by the United States and Europe for their "genetic modernization"[4] project in the Global South between 1926 and 1939 (Curry, 2022; Fedorova, 2021; Allan & Kim, 2007; Elina et al., 2005; Flitner, 2003; Harlan & Martini, 1936). At the time, breeders' knowledge was legitimized instead of prior knowledge and practices of farmers for agricultural modernization, leading to the scramble for genes in gene-rich regions by the United States and countries in Europe as they sought to optimize and industrialize their agriculture (Bonneuil, 2019).

With the expansion of commercial varieties in industrial agriculture and the replacement of landraces[5], the emergence of the "genetic erosion" concept brought another line of thought into the historical construction of genetic resources and crop biodiversity concepts (Fenzi & Bonneuil, 2016; Kahane et al., 2013). Although there is no single standard definition, "crop genetic erosion"[6] was recently defined as "the loss of crop diversity in a given area over a given amount of time, typically measured by a decline of species, variety, and/or within-variety (genetic/genomic) variation" (Khoury et al., 2021). The concept of genetic erosion emerged five decades after the early warning by geneticists about the disappearance of ancient varieties owing to the increasing adoption of selected elite varieties (Baur, 1914 and Tschermak 1915 cited by Bonneuil 2019; Harlan and Matini 1936). As a result, genetic erosion became a central topic in policy discussions and brought additional contestation about plant genetic resource conservation approaches in many scientific institutions and international organizations (Curry, 2022; Khoury et al., 2021; Fenzi & Bonneuil, 2016; Pistorius, 1997; Sonnino, 2017; van de Wouw et al., 2010). In response to the loss of genetic resources, the proponents of the "genetic modernization" project emphasized germplasm collection and banking (ex situ conservation) for modern plant breeding to develop improved varieties, i.e., economic exploitation of genes as resources. As an alternative to ex situ conservation, proponents of in situ/on-farm management of crop diversity stressed the importance of farmer-based dynamic management of landraces that allow gene exchange between cultivated plants and their wild relatives in a dynamic interaction with environmental change (Louafi et al., 2013; Thrupp, 2000; Pistorius, 1997). Despite the ex

[4] Genetics played a key role in the state-led agricultural modernization efforts that took place in different industrialized countries during the course of the 1920s and 1930s (Flitner, 2003).

[5] The term landrace is controversial as some actors see the coining of the term as discrediting farmers' roles in crop evolution. Recently, researchers defined a landrace as "a crop variety or population managed by farmers through cultivation, selection, and diffusion, which is typically adapted to a local area and traditional farming systems, has a recognizable identity and geographic origin, and is often genetically heterogeneous." Still, these researchers maintained the term landrace in their analysis (Khoury et al., 2021).

[6] Khoury et al. (2021) found about 50 different definitions or descriptions of loss of genetic resources in the crop diversity literature (232 articles) that have been published over the past 80 years or more. These definitions vary by the type of genetic resources under consideration (landraces, modern cultivars, wild relatives), geographic scope (within regions of crop domestication or also elsewhere), setting (in situ or ex situ), and the degree to which drivers of loss are specified. They analyze the scale of diversity loss (absolute losses, changes in richness, and changes in abundances, frequencies, or evenness) and show evidence of marked losses. However, they also offer proof of maintenance and increases in diversity that have occurred in different contexts, the extent depending on species, taxonomic and geographic scale, and region.

situ dominance of the collaborative international effort for germplasm conservation and exchange among governments, international organizations, and commercial actors post-WWII (RAFI, 1996), the in situ approach gained recognition and was institutionalized in national and international policy after the adoption of the Convention on Biological Diversity (CBD) in 1992 (Sonnino, 2017; Fenzi & Bonneuil, 2016; de Boef et al., 2013).

The concept of crop biodiversity emerged under the framework of CBD, which played an important role in framing genetic resources as biodiversity. As Fenzi and Bonneuil (2016) show, the CBD explicitly distinguishes three levels of biodiversity: genetic diversity, species diversity, and ecosystem diversity (United Nations, 1992, Art. 2 & 8). In addition to placing crop diversity within the broader agroecological systems, the CBD recognized the linkage between crop diversity and indigenous and local communities' traditional knowledge, innovations, and practices (United Nations, 1992, Art. 8j). The CBD's approach differed from that of "genetic modernization" proponents who alienate these two components of biodiversity (Deplazes-Zemp, 2018). Understanding crop diversity under CBD has enabled genetic resource conservation practitioners to recognize the complementarity between in situ/on-farm and ex situ approaches and to integrate them, including linking ex situ collections back to farmers' practices and knowledge, and culture (Westengen et al., 2018; Pautasso et al., 2013). These practitioners, including actors in Ethiopia, implemented various programs across countries to increase access to ex situ collections and sustainably manage crop diversity (Vernooy et al., 2015; de Boef et al., 2013). However, different factors affect national genetic resource conservation policies and management practices (Otieno et al., 2017; FAO, 2010).

In addition to conservation and management practices, access governance of PGRFA varies substantially between countries. The variation is related to overlapping and sometimes conflicting international institutions that governments have adopted or not adopted (Kell et al., 2017; Roa-Rodríguez & Dooren, 2008; Andersen, 2008; Rosendal, 2001). These are the Trade-Related Aspects of Intellectual Property Rights Agreement of the World Trade Organization, Nagoya Protocol on Access to Genetic Resources, and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the CBD, and the Multilateral System of Access and Benefit-sharing under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). At the national level, different actors hold heterogeneous positions regarding these international institutions. For instance, a coalition of peasant organizations and non-governmental organizations (NGOs) reject intellectual property rights (IPR) and focus on collective rights of peasant and indigenous communities over PGRFA to respond to seed enclosures and loss of crop diversity. In recent years, this coalition even moved away from the original concept of farmers' rights (Andersen & Winge, 2013; Brush, 2007) to seed sovereignty in their seed activism campaigns since farmers' rights under ITPGRFA are tied to the IPR framework (Peschard & Randeria, 2020). This change is because a campaign based on farmers' rights is often perceived as legitimizing the inequalities with widely enacted plant variety protection laws or breeders' rights (Borowiak, 2004). Contrarily, commercial seed system actors such as seed companies and breeders support ex situ conservation and a strong IPR regime and concentrate on commercial seed marketing (Tesgera, 2019; Sanderson, 2017; Clancy & Moschini, 2017). These discrepancies explain the ongoing difficulties in international collaboration on access governance of PGRFA, which require an in-depth understanding of countries' different routes to PGRFA access governance based on their historical, institutional, economic, and infrastructural conditions (Aubry, 2019; Halewood & Nnadozie, 2008).

Article 1 of this thesis draws on the distinction between a "New Commons" approach (Halewood et al., 2013) and an "ownership/hyperownership" approach (Safrin, 2004) to PGRFA governance and the concept of design issues (Halewood et al., 2013) to understand the access governance of PGRFA in Ethiopia. After the publication of Article 1 (included in this thesis), recent literature has formulated the "Seed Commons" approach to PGRFA governance (Sievers-Glotzbach et al., 2021; Sievers-Glotzbach et al., 2020). Seed Commons cuts across traditional Natural Resource Commons (Ostrom, 1990) and the collective sharing of the associated knowledge to Knowledge Commons or "New Commons" approach (Halewood et al., 2013; Hess & Ostrom, 2007a) as used in Article 1. Ostrom and colleagues applied traditional Commons theory to the management of natural resources such as water, fish, and pasture, which they characterized as resources that involve a high degree of subtractability[7] and a low degree of excludability[8] (Hess, 2008; Hess & Ostrom, 2007a).

By applying traditional Commons theory to PGRFA governance, Sievers-Glotzbach et al. (2021), in line with Halewood et al. (2013), integrated criticism of the theory that rejects the idea that common-pool resources exist as goods with specific characteristics such as subtractability and excludability. For instance, the subtractability and excludability features of goods are arguably determined by commoning[9] (social practices of production, usage, care, and administration) rather than the physical attributes of the resources (Rattunde et al., 2021; Euler, 2018). In the seed system, the social dimensions of commoning are helpful in understanding actors' roles, policies, and practices in PGRFA governance (Rattunde et al., 2021; Kliem & Sievers-Glotzbach, 2021; Sievers-Glotzbach et al., 2020). *New Commons* refers to commons such as PGRFA that are partially man-made (a result of human-environment interaction) and *local/regional* and *global* in coverage, unlike traditional Commons, which considers limited geographical area and a limited number of actors (Sievers-Glotzbach et al., 2020; Halewood, 2013). It also refers to collective creation and sustainable resource[10] management (commoning) through defined user communities (Halewood et al., 2013; Hess, 2008). Cutting across traditional Commons and New Commons, *Seed Commons* integrates biophysical (the material seed), informational (Deoxyribonucleic Acid or DNA sequences, and farmers' knowledge regarding breeding and cultivation), and socio-cultural elements in their collective governance (Sievers-Glotzbach et al., 2020; Deplazes-Zemp, 2018).

Sievers-Glotzbach et al. (2020) mainly focus on *local* and *regional* Seed Commons, which they describe as "institutions based on common ownership and forms of collective management in plant breeding and seed production, where a community conducts the handling, growing, breeding, and sharing in a needs-oriented and self-organized way." They also identify four core criteria that characterize diverse Seed Commons arrangements at local and regional scales, which include 1) the protection, provision, and development of seeds and crop diversity at the plant species and genetic level — collective responsibility, 2) critique of the private

[7] Highly subractable common-pool resource means the use of a resource by one person diminishes the ability of another person to benefit from it.

[8] Low degree of excludability in common-pool resource management refers to the high cost of excluding potential beneficiaries, owing to its size or characteristics from obtaining benefits from its use.

[9] Commoning involves voluntary and inclusively self-organized activities and mediation of peers who aim at satisfying needs (Euler, 2018).

[10] In New Commons, resource includes integrated biophysical (the material seed), informational (DNA sequences, and farmers' knowledge regarding breeding and cultivation), and cultural elements in their collective governance (Sievers-Glotzbach et al., 2021).

enclosure through legal and biological means and commodification of seeds and genetic resources — protection from the private enclosure, 3) collectively devised rules, norms and shared practices for management of seeds, combined with several independent operations and decision-making structure — collective, polycentric management, and 4) the sharing of formal and practical knowledge in seed exchange networks. These local-level Seed Commons arrangements are helpful to understand factors that have shaped national policies and practices of PGRFA governance in Ethiopia.

The *global level* Seed Commons comprises states, national (public and private) and international genebanks and research institutions, farmers' communities, commercial actors (seed industry and breeders), and NGOs involved in the production, usage, care, and governance of PGRFA (Sievers-Glotzbach et al., 2020). There are overlaps rather than a clear-cut distinction between local/regional and global Seed Commons regarding participant stakeholders and actors. However, global Seed Commons refers to a specific type of New Commons in international, supranational, and global resource domains, such as PGRFA (Halewood, 2013; Dedeurwaerdere, 2013; Dedeurwaerdere, 2012). Recently, Louafi et al. (2021) suggested the need to consider the local/regional and global levels simultaneously to connect the two different conceptualizations of commons. Specifically, they propose the concept of "crop diversity management system commons" as a holistic and inclusive framework to cover a broader range of actors' concerns and needs. That is to say, connecting global commons governance of crop diversity with local commons governance of seed systems.

In PGRFA governance, contracting parties to the ITPGRFA designed the current multilateral system of access and benefit-sharing in response to New Commons features. This system recognizes countries' sovereign rights over their respective PGRFA, in harmony with the CBD; however, governments have used this sovereign right to pool and share PGRFA held in their jurisdictions through the multilateral system. To operationalize the multilateral system of access and benefit-sharing, contracting parties developed tools such as the Standard Material Transfer Agreement and established the Benefit-Sharing Fund. By signing the Transfer Agreement, users access the biophysical material (seeds) and make direct payment (upon commercialization) to the benefit-sharing fund, administered by the Governing Body and the Secretariat of the ITPGRFA. Countries access these funds by competing in calls for proposals for projects on PGRFA management as part of strengthening their farmers' seed system.

However, drawing on Ostrom's (1990) concept of design principles of commons governance, Halewood et al. (2013) highlight two "design issues" in the ITPGRFA's multilateral system, which currently is affecting the engagement of actors in the system (Brink & van Hintum, 2020). These issues are 1) unclear boundaries (unlike commoning by defined user communities) and the inability to enforce reciprocity, and 2) the hybrid nature of financial benefit-sharing in the multilateral system, somewhere between a multilateral and bilateral approach (Halewood et al., 2013). The first design issue refers to the "free-rider" situation in which non-members have access to material from the multilateral system even if they do not participate in the system. The second design issue problem is the "de-linking" of direct monetary benefit-sharing from the countries, communities, or legal individuals who provided access to PGRFA (multilateralism). At the same time, financial benefit-sharing is linked directly to the IPR holders and their sale of the new varieties incorporating PGRFA from the system (bilateralism). Moreover, the monetary benefit-sharing is paid to the benefit-sharing fund of the ITPGRFA. These two design issues can explain why contracting parties show reluctance to fully participate in the multilateral system's governance regime. Moreover, they can help us

understand why some countries adopt a "hyperownership" approach, exercising extensive national government control over PGRFA and restricting access by international users (Halewood et al., 2013; Aoki, 2008; Safrin, 2004). In addition, the emerging debate on the governance of the informational aspect of Seed Commons, i.e., definitions, and access and benefit-sharing, of digital sequence information contributes to further deterioration of actors' engagement in the system (Brink & van Hintum, 2021; Laird et al., 2020) unless suggested pathways are followed up (Wynberg et al., 2021).

This thesis uses the ownership/"hyperownership" approach and New Commons theory to examine PGRFA access governance in Ethiopia. In addition to institutional analysis based on these approaches, the thesis explores the historical and political context in which Ethiopia's position on access governance of PGRFA has developed (Article 1).

2.2 Understanding seed systems and seed security

Researchers have increasingly conceptualized access to diverse seeds that meet farmers' needs and preferences in terms of seed systems and seed security. The two concepts are closely related. The *seed system* concept is deep-rooted in various fields of study such as crop science, agricultural anthropology, and economics. In crop science, researchers combine analysis of farmers' knowledge, their seed management practices, and the effects of those practices on the genetic structures of populations to understand how local seed systems determine crop diversity (vom Brocke et al., 2003). In agricultural anthropology, the seed system is an essential concept for a holistic study of the material nature (seed) and of actors' (e.g., farmers') knowledge and the values they attach to the material nature (Martínez-Flores et al., 2017; Carolan, 2007). In this regard, researchers relate the seed system concept in light of seed diffusion within and between different ethnolinguistic groups, to the crop population structure that different groups manage, or to the ecology of crop diversity (Westengen et al., 2014; Brush & Perales, 2007).

Moreover, the seed system concept is popular in economics. Most economic studies focus on the relationship between farmers' adoption of new varieties and determinants of adoption, e.g., seed extension, participation in decision-making, seed availability, and supply system (Cafer & Rikoon, 2018; Fisher et al., 2015; Shiferaw et al., 2008; Alene et al., 2000). Other economic studies examine determinants of crop diversity at household and community levels in light of seed system parameters such as distance to the seed source, road density, seed replacement rate, and seed-to-grain price ratio (Nagarajan et al., 2007). Economic studies also examine farmers' willingness to pay for improved varieties and certified seeds (Maredia et al., 2019) and maintain crop diversity (Wale et al., 2011; Pascual et al., 2011; Wale, 2008; Bezabih, 2008). Overall, these different disciplines have contributed to the current understanding of seed systems as the activities, institutions, and actors involved in developing, distributing, and using seeds. Overall, a seed system refers to the physical, organizational, and institutional components, their actions, and interactions that determine seed conservation, improvement, supply, and use (Scoones & Thompson, 2011; Cromwell et al., 1992). Seed systems farmers use include informal, formal, and emerging "intermediate" seed systems (Mulesa et al., 2021; CGRFA, 2021).

The *farmers' seed system* is based on farm-saved seeds and involves farmers' seed selection, production, storage, dissemination, and use (Almekinders & Louwaars, 2002; Cromwell et al., 1992). Local markets and social seed networks, i.e., seed exchange and barter among friends, neighbors, and relatives, mediate seed dissemination in this system. The farmers'

seed system delivers almost all portfolios of crop varieties and large quantities of seeds compared to the other seed systems (CGRFA, 2021; McGuire & Sperling, 2016; Coomes et al., 2015; Pautasso et al., 2013; Atilaw & Korbu, 2011; Almekinders & Louwaars, 2002). The *formal seed system* includes public and private sector institutions and a linear series of activities along the seed value chain, including germplasm conservation in genebanks, new plant variety development, variety release and registration, quality seed production, and distribution (Louwaars et al., 2013; Jaffee & Srivastava, 1994; Cromwell et al., 1992). The core characteristics of the formal seed system are varietal identity and purity and seed certification for quality, i.e., seeds of optimal physical, physiological, and sanitary quality (CGRFA, 2021; van Gastel et al., 2002; Tripp & Van der Burg, 1997). In Ethiopia, the seed supplied by the formal seed system is limited to a few portfolios of crops such as vegetable and hybrid maize seeds, for which it is the primary source (Ayana et al., 2014; Alemu, 2011). The *intermediate seed system* has recently emerged from market-oriented farmer groups who produce and market non-certified seeds of improved varieties and farmer-preferred local varieties in developing countries (Waithaka et al., 2021; Kansiime et al., 2021; Kansiime & Mastenbroek, 2016). In Ethiopia, these include community-based seed producer groups such as community seed banks who produce good quality uncertified seeds (MoA and ATA, 2017) and Seed Producer Cooperatives, who produce quality declared seeds of improved and preferred local varieties (Mulesa et al., 2021; Sisay et al., 2017). Quality declared seed is a simplified certification scheme in which seed-producing farmers are responsible for seed quality and meet a minimum standard. The minimum standard indicates that the certification scheme does not involve a formal inspection by regulatory authorities except when training and monitoring farmers' seed production and processing activities (FAO, 2006). In Ethiopia, farmers have been using the informal seed system since the dawn of agriculture. Farmers started to use the formal seed systems when the Imperial Ethiopian Government started agricultural modernization in earnest in the 1950s. The intermediate seed system has grown during the past decade (Mulesa et al., 2021; Sisay et al., 2017).

The *seed security* concept arose from Northern-based NGO-supported seed aid projects implemented in Africa, Asia, and Latin America since the late 1970s (Cromwell et al., 1993) based on the food security concept that received global attention during the same period (Maxwell and Smith, 1992; Cochrane, 2021). One of the earliest projects was seed security centers (village seed stocks and household seed stores) established in Mali in 1976/77 by the Agency for Cooperation and Research in Development (ACORD), a European and North American consortium of agencies working in 18 African countries. ACORD, Oxfam-UK, and Concern Worldwide, an Irish NGO, implemented similar projects in different parts of Sudan and helped internally displaced Sudanese and refugees from Eritrea to resume their agricultural production on available land in the 1980s (Cromwell et al., 1993). With these seed stocks and seed stores, NGOs aimed to increase household seed security following disaster situations such as drought and conflict and to free farmers from the burden of debts incurred by buying expensive seeds from traders or landlords at planting time (Louwaars, 1995; Cromwell et al., 1993). Specifically, they targeted poor communities with insufficient seed stocks, who are exploited by powerful groups and lack suitable seeds to reduce risks or increase yield (Cromwell et al., 1993, p.101). In this way, the NGOs acknowledged the importance of local access to enough quantity seeds at an affordable price for vulnerable populations to produce food for subsistence.

After the 1994 civil war in Rwanda, donors, NGOs, and public institutions working in agricultural research and development (e.g., the Consortium of International Agricultural

Research Center) mobilized 1.871 million USD for emergency seed aid to revive the country's farmers' seed system (Sperling, 1997; Scowcroft, 1996; Varma and Winslow, 2005; Buruchara et al., 2002). Since then, the seed security discussion has intensified, primarily owing to the wrong matching of seed demand with demand for food, and the lack of needs assessments in seed relief efforts (Dalle & Westengen, 2020). In the mid-1990s, in collaboration with other development actors, the FAO organized several workshops to develop strategies and mechanisms for restoring farmers' seed systems in post-disaster situations. These workshops promoted seed security concepts and implementation practices among practitioners and governments in developing countries (FAO, 1998a; 1998b; Scowcroft, 1996; Amstel et al., 1995). The FAO defines seed security as "ready access by rural households, particularly farmers and farming communities, to adequate quantities of quality seeds and planting materials of crop varieties, adapted to their agroecological conditions and socioeconomic needs, at planting time, under normal and abnormal weather conditions" (FAO, 1998a). Initially, humanitarian organizations inferred three key seed security parameters — *availability*, *quantity*, and *quality* indirectly from food security parameters (*availability*, *access*, and *utilization*) when implementing seed relief interventions (McGuire & Sperling, 2011). Recently, the FAO specified *varietal suitability,* previously included under the "quality" parameter and *resilience* to their framework, constituting the current seed security parameters (FAO, 2015a; Table 1).

Table 1. Key seed security parameters

Seed security parameters	Description
Varietal suitability	Varietal suitability refers to agronomic and quality traits that meet farmers' specific needs and preferences. These traits can include yield, storability, marketability, tolerance to environmental stresses, pests, diseases, and culinary and cultural preferences (FAO, 2015a; 2015b).
Availability	Seed availability is adequate when farmers can source enough seed at the right time to meet their needs from available sources (FAO, 2015a).
Access	Access to seed refers to farmers' ability to acquire seed, e.g., through purchase, exchange, loan, or social networks (FAO, 2015a). It also involves access to extension services and seed dissemination/delivery channels (e.g., transportation and distance) and sufficient information/awareness about how and where to get preferred seed and information on prices (CGIAR, 2016).
Quality	Seed quality includes the seed's physical, genetic, and physiological properties, including germination, vigor, varietal purity, and freedom from disease and impurities, enabling farmers to establish robust plant stands and harvest higher yields (FAO, 2018).
Resilience	Resilience is the degree to which the seed system that farmers use can resist, adapt to, and recover from shocks and stresses which threaten the integrity of household seed security (FAO, 2015a).

Based on seed security parameters and seed systems that farmers use in developing countries, researchers and practitioners have developed frameworks and tools for understanding barriers and options for strengthening farmers' seed security (Shrestha, 2020; FAO, 2016a; 2016b; CGIAR, 2016; FAO, 2015a). Most seed security studies used these concepts, frameworks, and tools to understand the performance of seed systems in an emergency context (Sperling, 2020; Madin, 2020; McGuire & Sperling, 2016; McGuire, 2007; Sperling, 1997), despite their applicability also to normal growing conditions. This thesis used some of the seed security frameworks (CGIAR, 2016) to analyze the roles and interactions between different actors in the seed system to understand policy, institutional, socio-economic, technical, and household-level factors that underly seed security challenges in the study sites (Article 2).

2.3 Understanding power and politics of seed system development

Like many public policies (Shonhe, 2018; Gurmu & Saiyosapon, 2018), seed policy development and implementation produce winners and losers. This inequality results from a political process that defines one particular pathway for the future, which benefits one group more than the other (Scoones & Thompson, 2011). In this regard, examining seed system development policies helps reveal important power dynamics and contested politics. Seed as material carries different interests and values for different actors, making seed system politics complex and dynamic. In developing countries, the rural population's social, cultural, and economic structure is intertwined with seeds, varying with agroecological conditions (Orozco-Ramírez et al., 2016; Blancas et al., 2013). At the same time, seed production and marketing activity are lucrative for corporate groups (Clapp, 2021; Bonny, 2017). The rural livelihoods and corporate interests linked to seeds are the main contentions in seed system development politics (Nizam & Yenal, 2020). Despite this tension, corporate groups assume that the farmers' seed system would be replaced by a private sector-led formal seed system when the public sector gradually withdraws (Louwaars et al., 2013; Louwaars & de Boef, 2012). In reality, the political process in particular countries in Africa led to divergent seed policy outcomes (Westengen et al., 2019; Scoones & Thompson, 2011). For example, Kenya's seed sector is more liberalized and privatized than Ethiopia's (Erenstein & Kassie, 2018). These countries' seed policy outcomes are related to historical, political, and governance factors influencing the seed system development dynamics according to different power structures in their agricultural research and development during the colonial, post-modern, and recent neoliberal agricultural policies (McCann, 2011; 2005).

Against the backdrop of differing historical, political, and institutional factors within each country, this thesis (Article 3) adopted the power analysis used in the food politics and development study by Leach et al. (2020) to examine seed politics and development in Ethiopia. The power analysis in seed/food politics and development combines plural approaches/concepts underpinned by broader theoretical traditions such as political science, neoliberal economics, governance institution, institutional economics, political economy, world-systems theory, social movement theory, socio-technical and socio-ecological systems, and power/knowledge and discourse theory (Leach et al., 2020). From Leach et al.'s (2020) list of approaches to power analysis in food politics and development, *food regimes* (Harriet & Philip, 1989), *food institutions* (Clapp, 2012), *food contentions and movements* (Patel, 2009; Borras et al., 2008), *food innovation systems* (IPES-Food, 2016; Scoones & Thompson, 2009) and *food discourses* (Sumberg et al., 2012) are suitable for analyzing seed system policy development and

implementation. Power is located and conceptualized in each of these approaches, which allows us to examine the seed system development politics.

While power is embedded in historically shaped political, social, and value systems, in *seed/ food regimes*, it operates through multilevel formal and informal institutional arrangements or the "rules of the game" in the *food institutions* approach (Leach et al., 2020). For instance, European colonization expanded and introduced a new set of "relationships, norms, and regulations" to commodify crops in North America. During this first colonial seed regime, settler crops (e.g., wheat) expanded at the expense of indigenous people's crops (e.g., beans, squash) and agricultural practices (Lyon et al., 2021; Kuyek, 2007). Later with the commercialization of transgenics in the 1990s, the third corporate seed regime replaced the second seed regime or post-WWII state-led seed research and development program for developing high-yielding varieties during the first Green Revolution in the 1960s. The third corporate seed regime was realized through state-facilitated seed control and enclosure using IPR laws that became a global instrument after the entry into force of the World Trade Organization's Agreement on Trade-Related Aspects of Intellectual Property Rights (Lyon et al., 2021; Phillips, 2008; Kuyek, 2007; Stein, 2005). In *food/seed contentions and movements,* power and agency are expressed in resistance to institutional changes through grassroots social mobilization and collective action, countering dominant force and interests. Studies show increasing seed contestation and movements in the Global North and South since the 1980s (Coulibaly et al., 2021; Peschard & Randeria, 2020; Demeulenaere & Piersante, 2020; Mooney, 2011; Carolan, 2007). These studies reveal that actors contest policies and practices in public spaces at local, national, and global levels (Gaventa, 2006). The actors use the power of people, institutions, or systems and their ideas to counter the dominant *seed/ food discourses* and promote their own interests (Lyon et al., 2021; Carolan, 2007). Related to this is the power in actors' narratives, beliefs, values, practices, and rules to analyze multiple trajectories of seed system development in the food innovation systems approach. *Seed/food innovation* systems emphasize socio-technical and ecological systems and their dynamic and complex interactions involving different actors or institutions that challenge path dependencies or "lock-ins" (Smith & Stirling, 2010; McGuire, 2008; Ojiem et al., 2006). For instance, a study by McGuire (2008), which examined the historical development of the Ethiopian sorghum improvement program, shows that the main established criteria for new variety development (yield) poorly suited Ethiopian sorghum farmers in stressed environments, limiting new variety adoption. Despite this problem, the established breeding routines and actor networks reinforced the past breeding approach, resisting another research and variety development line, such as a collaborative plant breeding approach (Westengen & Winge, 2019). Combining different conceptualizations and power locations through Leach et al.'s plural approaches helps us to understand historical change and transformation of seed system development.

In addition, I have found it useful to engage the "*4D pathways approach*" questions in Leach et al. (2020) as an integrative analytical lens for examining multiple trajectories of system change, which this thesis does. With the 4D pathways approach*,* Article 3 of this thesis raises critical questions about the overall *direction* and *diversity* of technical and institutional innovation pathways, their *distributional* consequences, and the extent of *democratic* inclusion in decisions about Ethiopia's PSSDS. As Leach et al. (2020) elaborate, the 4D pathways approach helps draw attention to narratives, actors, power, and rules and analyze multiple system change trajectories, complementing the power analysis approach discussed earlier. The framework helps understand the outcomes of a system change involving interacting social, technological, and

ecological dimensions (McCann, 2011; Ojiem et al., 2006), shaped by the interventions of multiple actors, their politics, and power relations (Leach et al., 2020; STEPS Centre, 2010). Moreover, the 4D pathways approach recognizes risks (e.g., climate change, drought, pest, diseases, and political instability) and the insecurities associated with its authentic and perceived threats. Studies show that seed systems' political and social outcomes hinge on managing such risks and the interacting technical, economic, social, and organizational trade-offs and synergies (Nabuuma et al., 2020; Westengen et al., 2019). In this regard, the 4D pathways approach challenges the tradition that treats technological, social, economic, and environmental changes as separate domains or analyses and recommendations that are underpinned by linear and equilibrium world views (Thompson & Sumberg, 2012). Overall, 4D questions are used in order to reveal how dependency on agricultural modernization policy affects opportunities to tap into other alternatives for seed system development or the implementation of already identified options supported by seed policies.

3. Methodology

This thesis section provides the philosophical and methodological foundations, research strategy and design, description of the study area, methods, data collection and analysis, validity, positionality, and ethical considerations.

3.1 Critical realism as a philosophical and methodological framework

Questions concerning what exists in the human world that researchers can acquire knowledge about (ontological beliefs), how people create knowledge and what is possible to know (epistemological assumptions), and how people study reality (methodological choices) are crucial when selecting relevant research paradigms to use in particular research (Guba & Lincoln, 2005). Therefore, an appropriate philosophical and methodological framework that can inform data collection and analysis methods for answering central research questions adds rigor to a research project. In this thesis, I use critical realism as the basis of my research design and methods for data collection and analysis. Since emerging in the 1970s as an intellectual movement by Bhaskar (1998), researchers have increasingly used critical realism as a comprehensive philosophical approach to understanding science in recent years (Hoddy, 2019; Fletcher, 2017; Modell, 2015; Gerrits & Verweij, 2013). Critical realism combines perspectives from two extreme schools of thought, namely positivism and constructivism. From the positivist ontology view, critical realists accept the existence of a "real" world independent of our observation, perceptions, and beliefs about it. They also share constructivist epistemology with the idea that knowledge about reality is socially constructed (Collier, 1994). However, they also differ from positivists and constructivists. Positivists and constructivists separate quantitative and qualitative research methodologies in research (Moon & Blackman, 2014). Constructivists reduce reality (ontology) to human knowledge (epistemology). However, critical realists combine quantitative and qualitative research methodologies in social science. They are also non-reductionists in that they assume human knowledge captures only a tiny part of a more profound and vast reality, which can be understood through broad critical examination (Fletcher, 2017; Bhaskar, 1998). Therefore, critical realism is positioned as a transcending alternative theoretical assumption to positivism and constructivism.

Critical realism has a novel approach to ontology in that it draws attention to a layered nature and social reality (Sayer, 1992). Critical realism identifies multiple levels and modes of

engagement between the percipient and what is perceived by stratifying ontology into 1) the *real* — natural/social objects, structures, and their mechanisms that have the power to generate phenomena at the level of the actual, 2) the *actual* — the events that occur independent of whether we experience them or not, and 3) the *empirical* — our perception and experience of those events (Bhaskar, 2008). These stratified levels are part of the same reality. The stratification shows that an entity may possess powers that are not actualized, and/or these powers may be actualized but go unrecognized because of the co-determination of events in open systems (Bhaskar, 2008). That is to say, societal structures and mechanisms are irreducible to a person, household, or community (Collier, 1994). The social structures have causal powers capable of generating investigable events or external processes and visible behaviors of people, systems, and things as they occur, such as resource allocation and privileging people in ways that they do not alone determine. Consequently, it is vital to acknowledge the limitations of purely interpretive accounts of social action for uncovering a complete and balanced understanding of the reality of social structures. This understanding makes the critical realism approach to ontology relevant for scientific investigation (Easton, 2010).

Critical realists' epistemological position embraces causal mechanisms to explain natural and social phenomena by going beyond describing and gaining better access to the causal mechanisms behind events, processes, or behavior (Bhaskar, 2008). In other words, explaining events involves identifying the necessary contextual conditions or understanding relevant circumstances for a particular causal mechanism to affect and result in empirical trends observed (Fletcher, 2017). Causal mechanisms in critical realism refer to underlying entities, processes, or structures that operate in particular contexts to generate outcomes and are often hidden and sensitive to variations in context (Astbury & Leeuw, 2010). Fletcher (2017) argues that causal analysis and explanation compared to an empirical description in a given context make critical realism applicable to analyzing social problems and suggesting solutions for social change. In this way, critical realist research methods focus on context influences and dare to look inside the "black box" at the level of details and complexity to explain a phenomenon. This unpacking of complexity involves asking the questions: "What? How? Why? For whom? To what extent? In what circumstances?". Asking such questions helps us to focus on critiques of the prevailing social conditions and system of constraints. It allows us to consider the complex relationships between human interests, knowledge, power, and forms of social control, challenge prevailing communities of assumptions and established social practices, have an ethically based stance, and suggest individual emancipation and improvements in society.

The current research looks for critical inquiry into the socially and politically constructed layer of the phenomena studied (e.g., politically constructed narratives from the international PGRFA movement affecting Ethiopia's access governance) in the process of gathering and evaluating information, ideas, and assumptions from multiple perspectives to produce a well-reasoned analysis. For this purpose, articles included in this thesis provide causal analysis and contextual explanation for the observed trends and events. For instance, Article 1 establishes a causal relationship between a range of political, historical, and economic explanatory factors (e.g., IPR) and the Ethiopian government's restrictive PGRFA access regulations. It then suggests the need for increased awareness of such factors among actors in international negotiations to enhance access to germplasm for users. Similarly, Article 2 demonstrates a positive causal relationship between agricultural research and development actors' density and women empowerment among commercial-oriented smallholder female-headed households. It recommends a gender-responsive extension for women in male-headed households and

marginal areas for a more significant impact. Article 3 identifies a causal relationship between political and economic interests in key institutions and government policies and practices that mainly support the state-led formalization of seed systems. This article suggests the need for political leadership to take action toward inclusive and equitable seed system development by implementing its current PSSDS.

In line with constructivists, critical realists view social phenomena as being concept-dependent (Sayer, 1992). However, critical realists emphasize the role of "real" structures and mechanisms operating beyond people's conceptions of their actions and intentions, distinguishing them from constructivism (Hoddy, 2019). That is to say, social reality depends on people and their conceptions/theories, but people and their concepts/ideas do not determine reality. Because of this, critical realists aim to find the best explanation of reality by using plausible existing theories that account for observations while recognizing that all explanations of reality are potentially fallible, including the explanations provided by research participants, theorists, and scientists (Fletcher, 2017; Bhaskar, 1998). Through the lens of rational judgment, theories can help us get closer to reality or identify the causal mechanisms driving a phenomenon. Using multiple concepts, approaches, and theories, the articles included in this thesis explain events and empirical trends observed in connection with PGRFA access governance, farmers' seed security, and seed system development politics in Ethiopia.

Furthermore, critical realists offer a philosophical and methodological framework for knowledge creation processes. We find four epistemological processes in critical realist informed research projects (Hoddy, 2019; Sayer, 2000). These processes are description, analytical resolution, abduction and retroduction, and concretization and contextualization. The description stage involves exploring literature to identify existing concepts and arguments, historical evidence, empirical studies, tentative relationships and connections, ideas, and categories to unfold an event or situation. The analytical resolution refers to identifying and specifying demi-regularities, rough trends, or broken patterns in the collected data to identify core objects/components of the phenomenon of interest and begin laying out their connections. Abduction and retroduction involve theoretically re-describing a phenomenon of interest and identifying mechanisms that may account for it. It also involves conceptualizing empirical data (confronting data with theory) about our concrete phenomenon while drawing on insights from pre-existing knowledge and experiences of the same phenomenon elsewhere. Concretization and contextualization involve engaging theory with data and testing against previous cases, which allows examining the combined effect of abstract components. Although not strictly following this order, my literature review, data collection, analysis, and interpretation in the three articles included in this thesis use these philosophical and methodological frameworks.

3.2 Research strategy and design

To investigate the performances of seed systems and farmers' seed security in the study areas, Article 2 employs comparative case study research: a seed security case study from commercially-oriented and subsistence-oriented smallholder farming areas. It treats the case studies from two contrasting study sites as nested seed security case studies for comparison. Articles 1 and 3 represent country case studies in PGRFA access governance and seed system development politics, taking Ethiopia as a case country. According to Easton (2010), a case study of a single or a small number of entities can provide a great deal of predominantly qualitative data from multiple sources, which can be written up as a case study, offering insights into the nature of

the phenomenon. Although critics within the analytical movement of generalization, specification, and abstraction raise concerns about its validity, the case study is a popular research method for investigating a contemporary phenomenon in depth and within its real-life context (Lund, 2014; Yin, 2009). It is conducive to explore issues that are difficult to measure or where statistical methods are weak in a given research project, e.g., actors' beliefs, practices and actions, and power relations in line with the chosen theoretical concepts by the researcher (George & Bennett, 2005). However, a case study can also utilize supplementary quantitative data to enhance the understanding of the case (Guetterman & Fetters, 2018).

Context-dependent knowledge produced through case studies constitutes an important foundation for human learning and a basis for developing expert knowledge (Flyvbjerg, 2006). The study areas were chosen as case sites owing to their distinct features representing smallholder farming and the potential to generate a rich and nuanced understanding of farmers' seed security to inform seed system development policies in Ethiopia and beyond. Similarly, Ethiopia was selected as a case country in order to understand a developing country's PGRFA access governance because it is one of the centers of diversity for food crops. Moreover, Ethiopia has restrictive regulations that discourage international PGRFA users, and it holds a prominent position as a vocal actor in global biodiversity negotiations. Finally, Ethiopia has sidelined farmers' seed systems and supported a formal seed system for decades, a similar policy choice in many developing countries. As a case country, the PGRFA governance study in Ethiopia provides valuable knowledge and insight into the ongoing dynamic and contentious negotiation on the multilateral system of access and benefit-sharing under the ITPGRFA.

Consequently, this study has no desire for "replication" of findings, e.g., of seed security case studies from the two districts to other districts or national level. It also has no desire to replicate results about Ethiopia's PGRFA governance case to other developing countries with restrictive practices, as advocated in positivist understandings of case studies (Yin, 2009). Instead, the case study design attempts to provide knowledge that can explain why some national policies and practices restrict access to PGRFA despite the call for facilitated access and the interdependence of countries for PGRFA. It also attempts to explain why governments continued to dominantly support formal seed systems despite persistent farmers' seed insecurity and opportunities to tap into other alternatives for seed system development or the implementation of already identified systems. Before presenting the data and methods used for the study, the following section provides a brief description of the study area and scope of the study.

3.3 Study area

The studies on PGRFA access governance (Article 1) and seed system development politics (Article 3) focus on national policies and institutions; therefore, the scope of the study in both articles is national. Assessment of the performance of seed systems that farmers use and farmers' seed security at the local level covered eight *gandas*[11] in Gindabarat and Heexosa districts (four *gandas* per district) in the central highlands of Ethiopia (Figure 1). Selected *gandas* in Gindabarat include Qilxuu Sanbataa and Bakkee Fayyinaa from the midland (moist subtropical) agroecological zone and Haroo Beerbaaboo and Mudhii Hulaa Baroo from the highland (temperate) agroecological zone. In Heexosa, the selected *gandas* include Anolee Saallan and

[11] *Ganda* (Oromo) is the smallest administrative unit in Oromia National Regional State of the Federal Democratic Republic of Ethiopia and is called *Kebele* (Amharic) in other parts of the country.

Dayya'aa Dabbasoo from the midland (dry subtropical) agroecological zone, Odaa Jilaa from the midland (moist subtropical) agroecological area, and Dabayyaa Adaree from highland (temperate) agroecological zones. I selected the two study districts to represent the different degrees of seed system formalization and commercialization in the Ethiopian context. The districts differ in infrastructure and seed system actor density, access to market, agricultural extension, and modern agricultural technologies (more on this below). The *gandas* mentioned above were selected in consultation with district experts in agriculture bureaus to capture the agroecological diversity in each district. A detailed selection criterion for the study districts, including institutional and physical infrastructure density, main crops, seed system actors, and key demographic and agroecological characteristics, is also presented in Article 2 (Mulesa et al., 2021).

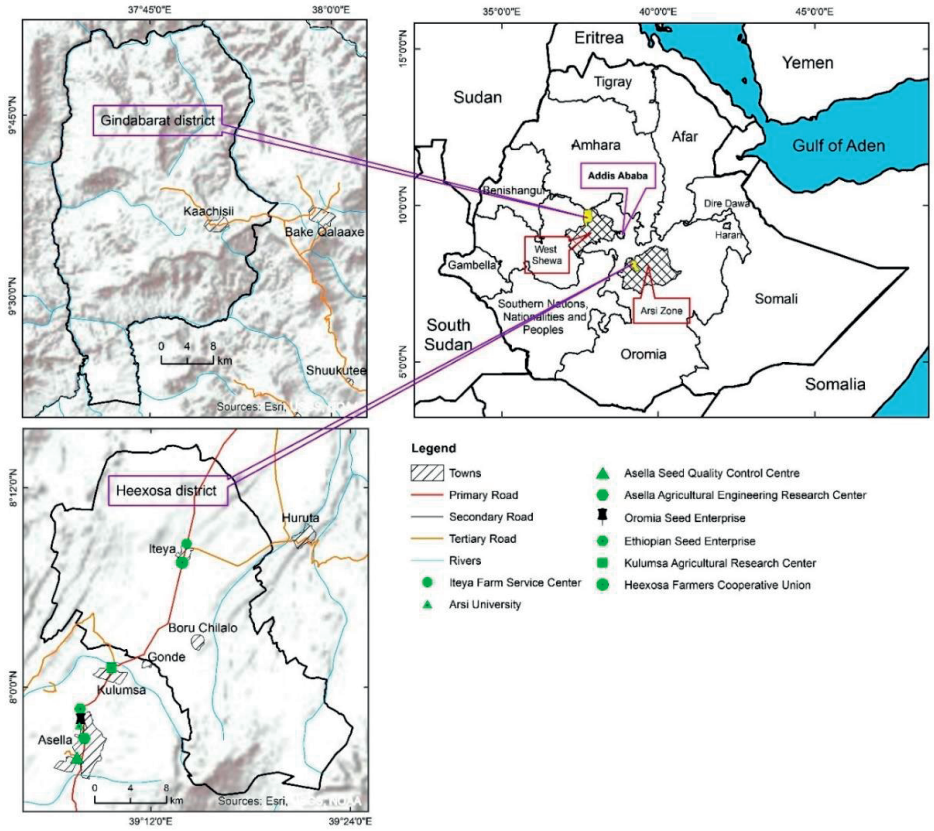

Figure 1. Map of Ethiopia and study sites

Gindabarat

Gindabarat is located about 193 km west of Ethiopia's capital, Addis Ababa, and 138 km north of Ambo, the capital of the West Shewa Zone of Oromia National Regional State (Figure 1). Gindabarat represents the rain-fed subsistence agriculture and smallholder mixed farming system[12] in Ethiopia. The district has a distinct geographical feature. It is separated from the neighboring Amhara National Regional State by the Blue Nile River and all other districts in West Shewa Zone (except Abuna Gindabarat) by lowland gorges and rivers. It is connected to urban areas only by one road in the south leading to Addis Ababa. The district is remote as it has only a substandard tertiary road that leads to Addis Ababa and feeder village roads that are hardly passable during the rainy season (Bogale, 2016). In 2017, the tertiary road was the only means of connecting the district's agricultural input and output traders to urban markets. The district is also one of the poorest in Ethiopia in terms of institutional services. There are no nearby research and training centers that can facilitate farmers' access to and use of agricultural technologies. Credit and marketing services are also lacking.

Teff is the most important food crop, with over 40% of the total cereal production and cultivation area in Gindabarat (Bari, 2018; Mulesa, 2006). As a cultural keystone species (Garibaldi & Turner, 2004), teff forms a vital part of the culture and diets of the people and has shaped the Ethiopian cultural identity. In Ethiopia, the teff agro-processing industry is still premature. Globally, it belongs to "orphan crops,"[13] which are neglected by mainstream research since they are not economically significant in the global market. However, more recently teff, and other hardy crops in Africa such as millet, are "considered a healthy wheat alternative in the Global North and [are] sought-after by health aficionados and those with coeliac disease or gluten sensitivity" (Anitha et al., 2021; Cheng et al., 2017). In Gindabarat, there is no research or proper institutional services to increase teff productivity by increasing access to agricultural technologies, including fertilizer and improved seeds. The closest input access point is Ambo Farmer Union, 138 km on the poor tertiary road. The input delivery from the Farmer Union to its member Primary Multipurpose Cooperatives in Gindabarat is highly unreliable. Commercial seed producers are absent in the district despite the government's recent seed system transformation strategy to expand market-based seed production and distribution (MoA and ATA, 2017). The Haroo Berbaboo community seed bank was established in 2014 by local and western NGOs, namely MELCA-Ethiopia and the Development Fund of Norway (Mekonnen, 2019; SwedBio, 2016). The community seed bank complements local seed systems, which farmers use for most crops except hybrid maize, by providing seed loans of indigenous crops and local varieties (Development Fund, 2019; SwedBio, 2016).

Major environmental and agronomic challenges include land degradation, unreliable rain, and prevalent plant diseases. As a result, crop yields and productivity is generally low (SwedBio, 2016; Takele et al., 2014). A considerable number of people in the district live in extreme poverty (Schmidt, 2014). In Gindabarat, many farmers with enough land practice fallowing and crop rotation, although cereal–legume–oilseeds crop rotation is more widespread

[12] Mixed farming system is the cultivation of crops and the raising of cattle, sheep, goats, and equines by the same economic entity, such as a household or a "concession," with animal inputs (e.g., manure, draft power) being used in crop production and crop inputs (e.g., residues, fodder) being used in livestock production (Powell & Williams, 1995).

[13] "Orphan crops" refers to crops that are not extensively traded and receive little attention from researchers compared to some major crops such as maize and wheat. However, the concept is controversial for crops like teff, which is a national staple crop.

agronomic practice than fallowing. While these agronomic practices improve soil fertility as part of the traditional farming system, fallow lands are used for grazing from planting to harvest. During this period, the movement of livestock is limited for free grazing/browsing land until plowing. Rotation of animal enclosure or kraal (*dallaa loonii*) and manure application is mainly used for soil fertilization of home gardens and nearby farms. Most of the farming community in Gindabarat are Oromo protestant Christians, followed by Orthodox Christians, and few people practice *Waaqeffanna,* the indigenous thanksgiving ritual typical of the Oromo ethnic group (Regassa & Zeleke, 2016; Ta'a, 2012).

Heexosa

Heexosa is located about 150 km southeast of Addis Ababa and 25 km north of Asella, the capital of the Arsi Zone of Oromia National Regional State (Figure 1). In the early 1800s, the area was a fertile grassland before the Arsi-Oromos occupied the site. Arsi-Oromos practiced pastoralism and mixed farming (Cohen & Isaksson, 1987). In 1886, Emperor Menelik II conquered the area and confiscated the Arsi-Oromo's land, including that of the Heexosa clan (Hassen, 2011; Degu, 2008), and appropriated the land to allied landlords from the North, which gave rise to the expansion of the ox plow and crop cultivation intensification (Cohen, 1975). The present farmers in the highland areas of the district are mainly descendants of Amhara and Shewa-Oromo Christians who occupied the area during Emperor Menelik II's regime and later years. In contrast, most farmers in the midland and lowland areas are primarily Arsi-Oromo Muslims (Cohen, 1975).

Heexosa district represents a modernized rain-fed smallholder farming system with a long history of support from the state and non-state actors regarding access to credit, inputs, and marketing facilities (Bruno, 2016; Bechere, 1995). Farm mechanization of cereal crops assisted with tractor and combine harvester started with Swedish aid in 1969 (Jonsson, 1972). In 1972, about 150 landowners operated more than 250 tractors and 50 combines on approximately 30,000 ha of land in the Arsi area (Cohen, 1975). Nowadays, 97% of farmers in Heexosa use combine harvesters; only 3% of the farmers thresh their wheat crop manually (Challa, 2018). The district is centrally located in terms of access to primary and feeder roads, major agricultural research centers (regional, national and international), universities, the Farmers Union, farm input and output markets, and rural banks (Tefera et al., 2019). As a result, the generation and transfer of improved agricultural technologies, including improved wheat varieties, is higher than in most districts of Ethiopia (Tefera et al., 2019; Yiemene, 2001).

Wheat is the major crop that constitutes over 60% of the total cereal production and cultivation area in Heexosa (Kalsa, 2019; Mulugeta et al., 2010). Wheat cultivation by linguistically and socially diverse communities has a long history (over 5,000 years) in Ethiopia (Tesemma & Bela, 1991). These diverse communities have developed various uses of wheat, as expressed in their rich cultures and food traditions (Tsegaye & Berg, 2007b). Heexosa lies in the wheat belt highlands of southeastern Ethiopia, where the first Green Revolution started (but had limited success) in the late 1960s (Cohen, 1975). A significant amount of genetic erosion is believed to have resulted from continuous monoculture cropping of bread wheat that replaced durum wheat (Teklu & Hammer, 2006; Worede, 1983). In 2016, the Gadissa community seed bank was established in Heexosa by a local NGO called Ethio-Organic Seed Action with financial support from a Canadian NGO called SeedChange, to combat the loss of diversity by introducing local varieties of durum wheat from the national genebank and other wheat growing communities. Compared to many other areas in Ethiopia, the district enjoys high rainfall and

soil fertility, making it one of the country's most productive districts (Bogale et al., 2002). The high grain yield among commercially oriented smallholder producers (4–5 t/ha) in Heexosa and surrounding districts in Arsi (Endeshaw, 2019) contributed to a higher regional average grain yield for Oromia National Regional State (2.7 t/ha) compared to the national average of 2.5 t/ha (Minot et al., 2015). According to a recent ranking, Heexosa was one of Ethiopia's central 25 wheat-producing districts between 2010 and 2013 (Warner et al., 2015).

The wheat industry is relatively well-developed in and around Heexosa, creating market opportunities for producers (Brasesco et al., 2019). Wheat grain and flour sales to Addis Ababa and other urban areas in central Ethiopia constitute the district's main economic activity (Mulugeta et al., 2010). Wheat is also an important food crop for farmers and their families in Heexosa. Despite relatively high wheat productivity and a long history of government support, 10% of the total population were classified as poor owing to high population density and small size land holdings, and high dependency on rain-fed cropping systems (Gizachew & Shimelis, 2014; Bogale et al., 2005). Most households raise livestock, which constitutes cereal–livestock mixed farming (Amade et al., 2017). However, the livestock population, including draft animals, is low in Heexosa as a result of the mechanization of wheat farming (Yiemene, 2001; Challa, 2014) compared to the Gindabarat district, where the majority of farmers depend on draft animals for plowing their fields (Mulesa, 2006). The current study found that 86% of respondents own two or more oxen in Gindabarat compared to 67% in Heexosa. In Heexosa, the emergence of the new strain and variants of Ug99 (lineage of stem rust) and the yellow rust epidemics since 2010 posed a severe risk to wheat producer farmers and sometimes required emergency seed supply following crop failure (Bishaw, 2016; Aliy, 2016). Most bread wheat varieties in Ethiopia are resistant to leaf rust, but they have been susceptible to stem rust and yellow rust, significantly reducing wheat production. Digalu was one of the mega varieties in yield that succumbed to a new stem rust race (TKTTF) since 2013 (Badebo & Hundie, 2016). Since the prevalence of wheat rust, farmers have been advised to practice crop rotation and diversification. In 2014, about 94% of farmers reported practicing cereal-highland-legume crop rotation by growing wheat alternately with faba bean or field peas every two to three years in Ethiopia's wheat belt region where Heexosa lies (Ellssel et al., 2018). Research shows that this agronomic practice significantly improves soil organic matter, reduces soil-borne diseases and weed pressure, and enhances wheat yield (Tadesse et al., 2018).

As the description of the study areas shows, the two districts are different in the key crops (major cereal crops) they grow and institutional and physical infrastructure development supporting agricultural production. Therefore, the districts and crops represent different features of seed security in terms of biological, social, cultural, economic, and political factors, which can provide additional insights for strengthening the existing seed system in Ethiopia and beyond.

3.4 Methods, data, and analysis

Critical realists suggest starting with empirical data to observe events as the first epistemological process in a research process. Moreover, they offer extensive and intensive research methods to collect empirical data that will help to identify demi-regularities and their further analysis. The extensive method employs large-scale surveys, formal questionnaires, and statistical analyses, looks for regularities, patterns, and similarities, and accepts taxonomic categories. However, it has limited explanatory power, for which critical realists suggest the intensive method. The intensive method focuses on individual agents in context using interviews, ethnography,

qualitative analysis of questions asked about agency and change, employs causal groups and produces causal explanations that are limited to the situation studied so that testing is by corroboration (Fletcher, 2017; Easton, 2010; Sayer, 2000).

Article 2 uses the extensive and intensive research method to assess farmers' seed security in study areas in this thesis. Articles 1 and 3 use the intensive method to examine Ethiopia's PGRFA access governance and seed system development politics. These articles explore the policy implication of seed access from different conceptual and theoretical angles, and at different levels, and comprise a multilevel perspective on PGRFA access and seed system development. In line with critical realist thinking, the thesis approaches farmers' seed security situations (observed key parameters) in the study districts as being ontologically "nested" within a wide range of historical and contemporary social, political, economic, and agroecological contexts that affect policy formulation and implementation. Specifically, it includes actors' interests and politics, roles and practices, and farmers' dynamic agroecological, socioeconomic, and cultural contexts in the study areas. Hence, the nested cases from the two study sites that form part of the seed security case study (Article 2) are to various extents investigative, critical, exemplifying, and predictive depending on the specific focus of the analysis.

In this comparative case study research, I use extensive and intensive methods for data collection using a two-tiered research approach: perspectives "from below"[14] and "from above."[15] From below, I employed extensive methods to collect quantitative data using household surveys and intensive methods to collect qualitative data using focus group discussions (FGDs) with household heads. From above, I employed intensive methods to collect qualitative data using semi-structured key informant interviews with actors that make up the seed systems in the study sites. For the country case study research on PGRFA access governance and seed system development based on the Ethiopian case, Articles 1 and 3 primarily used intensive qualitative data collection methods using semi-structured key informant interviews. In addition, all articles draw on literature and document reviews for in-depth analysis.

Household survey

Since its first use to study family budgets 225 years ago in England, researchers, analysts, policymakers, and development actors have used a multi-topic household survey as the main instrument to understand development (Grosh & Glewwe, 2000). In critical realist research, a household survey is vital to generate quantitative data that helps to measure events (Yirenkyi-Boateng, 2010). It is clear that quantitative methods are merely descriptive. Still, quantitative summaries and correlations between variables provide valuable information for uncovering evidence; therefore, they complement qualitative data that explain the causal mechanisms capable of generating the actual events we observe or our future predictions (Zachariadis et al., 2013). For answering research questions in Article 2, I used structured questionnaires for household surveys covering farmers' varietal preference and availability, seed use and management, seed sources, seed availability, access, and quality to generate quantitative data from below, in addition to gathering household socioeconomic data (Appendix 1). With the aid of trained enumerators, I administered the household survey questionnaire to a stratified random

[14] From below refers to an in-depth analysis of the dimensions of seed security experienced by smallholder farmers.

[15] From above refers to mapping key seed system actors in the study areas and analysis of their roles and performances in seed supply and seed system governance.

sample of 432 household heads — 223 in Gindabarat and 209 in Heexosa. The survey emphasized teff and wheat growing households during the 2017/2018 growing season in both districts. Article 2 reports on the sampling frame and household selection methods used, the number of household participants in the survey (Mulesa et al., 2021). Handwritten data on the structured questionnaire were entered into the Survey Processing System (CSPro) software package (Bureau of the Census, 2020) and converted to a database compatible with STATA. Quantitative data were analyzed using STATA version 15 (Kohler & Kreuter, 2005) to generate descriptive tables and figures. Following critical realist's epistemological processes, the case study described farmers' seed security situations using quantitative data from the household surveys. Specifically, the quantitative analysis helped explain and predict interest variables related to farmers' seed preference and use from different sources and the resulting farmers' seed security parameters. The seed security study also used descriptive statistics to identify similarities and differences between the two contrasting districts.

Focus group discussion

FGD involves discussing a specific issue with a predetermined group of people, usually between six and eight individuals with similar backgrounds, in an interactive manner based on carefully designed semi-structured questions. The moderator uses these questions as an interview guide to stimulate discussion (Hennink, 2013). The critical realist approach to analyzing FGD enables qualitative transcript material to help explain how actors' qualitative perceptions and experiences give rise to narratives that arise from the interaction between agency and structure in a particular material context (Crinson, 2001). To provide a causal explanation for farmers' seed insecurity, the FGDs were conducted with household heads in all eight survey *gandas* (16 FGDs). The high number of FGDs was intended to maximize meaning saturation to fully understand farmers' perspectives on factors affecting observed seed insecurity (Hennink et al., 2019). FGD participants were purposively selected from the stratified random sample used for the household survey. Separate FGDs were held with women and men, with representation from all wealth and age groups. Summary points were noted to reflect on emerging findings and to adjust interview guides daily for discussion in succeeding groups. As the in-depth key informant interviews with local seed system actors were conducted parallel with the FGDs in both districts, I had the opportunity to discuss emerging research findings with interviewees and triangulate and verify the data. All FGD sessions with farmers were recorded using an audiotape recorder. All data (audio and written) were transcribed verbatim to generate transcript qualitative material using Nvivo 12 (qualitative data analysis computer software) on a slow playback speed. As the analysis and write-ups proceeded, I found it beneficial to repeatedly read through the transcript material, identify important points, categorize them according to topical themes and actors, and write summaries under main thematic areas (e.g., seed security parameters and actors' roles). Overall, following the critical realist's epistemological processes, the comparative case study of the two districts was used first to describe farmers' seed security situations using quantitative data from the household survey. I then explored causal links and explanations for the observed seed security parameters using qualitative transcript material from FGDs. In Article 2, the qualitative transcript material analysis revealed agroecological, socio-cultural, economic, and political factors that underlie the seed insecurity experienced by farmers.

In-depth key informant interviews

Key informant interviews involve interviewing a selected group of individuals who are likely to provide needed information, ideas, thoughts, memories, and insights about their subjective understandings of events, social relations, and social contexts. In this way, key informant interviews help researchers gain access to information to understand a social phenomenon from actors' perspectives (Kvale & Brinkmann, 2009). Article 2 used key informant interviews with seed system actors (50 key informants) in the respective *gandas* and districts to complement the FGDs for assessing actors' roles and performances in seed supply and seed system governance. Articles 1 and 3 primarily used intensive qualitative data collection methods, i.e., semi-structured key informant interviews (about 26 informants each) to understand actors' policies and practices in PGRFA access governance and seed system development. The key informants were drawn from several environmental governance and seed system institutions. These include the Ministry of Environment, Forest and Climate Change (now Commission), Ethiopian Biodiversity Institute (EBI), Ministry of Agriculture, Ethiopian Institute of Agricultural Research, Consortium of International Agricultural Research Centers based in Addis Ababa (CIMMYT[16], ICARDA[17], and ICRISAT[18]), NGOs, representatives of parastatal seed companies, farmer primary multipurpose cooperatives, seed producer cooperatives, farmer unions, local extension/development agents, farm service centers and retailers of agricultural products. In-depth interviews were tape-recorded, transcribed (using Nvivo 12), and analyzed in the same manner as described above for the FGDs. All articles included in this thesis provide additional information on the selection method of key informants, interviews, and qualitative analysis techniques. Following the critical realist's epistemological process, which integrates abstract theories and in-depth empirical observations as a profound way of "capturing" reality (Modell, 2015), all articles use plural concepts and approaches to condition actors' narratives captured through the interview and scholarly knowledge claims.

Document review

Primarily used in historical research, document review involves synthesizing and extracting evidence from past events considering the context within which they occurred to learn about the topic of interest (Letts et al., 2007). Articles included in this thesis used document analysis of a range of literature and policy documents. The articles draw on peer-reviewed papers, gray literature, archival studies, policy, and legal documents in English and Amharic languages, including relevant reports archived online from international biodiversity and PGRFA related negotiations and gray literature such as minutes from a high-level policy meeting. The document review helped analyze and compare the historical context and information with the empirical findings from the household survey, FGDs, and key informant interviews to arrive at a valid conclusion. The insights gained from the review enabled me to engage my data with the broader theoretical perspectives and corroborate, a process that sharpened my findings.

[16] CIMMYT is the International Maize and Wheat Improvement Center.
[17] ICARDA is the International Center for Agricultural Research in the Dry Areas.
[18] ICRISAT is the International Crops Research Institute for the Semi-Arid Tropics

3.5 Reliability and validity

Research ethics are fundamental in demonstrating and communicating the reliability and validity or trustworthiness, rigor, and quality of research processes and findings (Golafshani, 2003). In this thesis, I use methodical and investigator triangulation as a strategy (test) to ensure a more valid and reliable construction of realities. Triangulation is compatible with the critical realists' perspective of eliminating bias and increasing the truthfulness of the research results (Maxwell, 2017; McEvoy & Richards, 2006). Methodical triangulation refers to "a validity procedure where researchers compare and contrast data generated by different methods and search for convergence among multiple and different sources of information to form themes or categories in a study" (Golafshani, 2003). In the current research, the farmers' seed security study at the local level started with a careful selection of representative districts (commercially-oriented and subsistence-oriented) through discussion and consultation with researchers in Ethiopia to ensure the relevance of research data from these districts in discussing national scale issues. Local experts helped select agroecological representative *gandas* at the district levels, which enabled the collection of relevant biophysical, seed use, and household information. Unambiguous survey questions were administered to a stratified random sample of 432 household heads from sampling frames using local language in eight *gandas* to collect accurate data.

In Ethiopia, the authoritarian government's vision and actions for agricultural transformation and economic growth are accompanied by the elites' pressures and demands on rural people to implement what the government wants (Lefort, 2012; Lefort, 2010). In this regard, I used my insider experience and knowledge and probed for clarification on contradictory issues in FGDs to ensure the accuracy of information. This approach was successful because my knowledge and understanding of local language, culture, and norms helped me mitigate the researcher–informant power imbalance, build trust, and avoid the potential for "informant bias" and fear to supply the correct information. I employed a similar technique for the key informant interview with representatives of selected stakeholders and actors. As an insider, I cannot detach myself from socially constructed knowledge concerning seed system development, PGRFA governance, and rural livelihoods in Ethiopia (see positionality below about this). However, I probed respondents and FGD participants during the interview to obtain clarity on innuendos and vague statements they made or "taken-for-granted" assumptions that were familiar to me as an insider. Prolonged fieldwork (from October 2017 to March 2018), follow-up telephone and skype call with experts and researchers, and recent documents released after my fieldwork helped me clarify and update some of the policy developments, increasing the validity of the information used. I used data from different sources (quantitative description, key informant interviews, FGDs, and documents) for triangulation to examine the empirical observations from different perspectives in the articles included in this thesis. I used this methodical triangulation because the mixed method (combination of quantitative and qualitative data) is helpful to counteract the biases associated with single-method studies. That is to say, quantitative and qualitative findings can corroborate each other and support a more robust conclusion than either source of data could support alone, giving the inquiry a greater sense of balance and perspective (Maxwell, 2013; McEvoy & Richards, 2006).

Investigator triangulation (Creswell & Miller, 2000) is another step I have taken to involve several investigators or peer researchers in data interpretation. Specifically, my advisors and peer researchers participated as co-authors in Articles 1 and 2. During the inquiry process, while working on Article 3, I continuously discussed progress with my advisors to triangulate my ideas and explanations with theirs as a verification and self-correcting strategy.

3.6 Positionality

My upbringing in one of the study areas, together with my experience as a staffer of the national genebank of the EBI, and of a Norwegian NGO supporting projects for community-based agrobiodiversity management in developing countries, is directly related to my Ph.D. research. Since I have learned about smallholders' livelihoods, seeds and the seed systems they use, and interacted with Ethiopian seed system actors, I can see the importance of becoming aware of what I had learned to ignore. Researchers are encouraged to turn to and reflect on "taken-for-granted" understandings to acquire a new, refreshed, and richer meaning of the phenomenon by separating their assumptions and beliefs (Hopkins et al., 2017; Van Manen, 2016).

As a young man from a smallholder farming family in one of the current study areas (Gindabarat), I knew little about the relevant field of studies for my future career when I joined Bahir Dar Teaching College (currently University) in the mid-1990s. I studied a two-year pedagogy program in biology education at the College. At the time, Ethiopia's economy was recovering after a decade and a half of civil war between the socialist government and opposition forces, and the government embarked on a massive higher education expansion with support from donors such as the World Bank after the regime shift in 1991. Although I was trained to teach at elementary schools, the lack of trained human resources in newly created universities and faculties in existing universities allowed me to secure a practical teaching assistant position in one of the pioneering agricultural universities, Haramaya University. In addition to biology courses that I took as part of my pedagogy training, the educational encounters at Haramaya University made me see situations from a strong natural science focus. I now understand this as positivism from courses I have taken in the philosophy of science and research methods. Eager to learn more and develop my skills in biological sciences, I left the agricultural university to join a bachelor's program in applied biology at Addis Ababa University. The natural science ontology and epistemology influenced me through this program, as it does to most people with natural science training (Moon & Blackman, 2014).

After hard science training, I joined the EBI, also called the national genebank, where I fell in love with seeds. Through my work at EBI, I encountered an overwhelming diversity of crop species and varieties that I had neither previously observed in my home districts nor in other places I visited in Ethiopia. I was exposed to the work of N.I. Vavilov and geopolitics of PGRFA. I read and heard stories about Ethiopia as one of Vavilov's eight centers of origin and diversity for several food crops (Vavilov, 1926b). People I interacted with talked about these stories time after time, especially those in the environmental research and governance institutions, specifically the national herbarium of Addis Ababa University, the federal environmental protection authority, and the EBI. They often linked these stories of Ethiopia as a "biodiversity hotspot" country (Pironon et al., 2020) to biopiracy. This link mostly implied that rich countries' experts came to Ethiopia to collect plant genetic resources for their agricultural and industrial development without sharing a fair benefit. These stories overshadowed Ethiopia's dependence on other countries' genetic resources for agricultural research and development, which I learned of later (Fowler et al., 2003; Palacios, 1997). Awareness of the interdependence of countries for genetic resources is not something I can recall people talking about from my experience working in Ethiopia. I also learned from renowned Ethiopian geneticist–biologists Dr. Melaku Worede (Worede, 1989) and Dr. Tewolde-Berhan Gebre-Egziabher (Gebre-Egziabher, 2000) about their work in international policy advocacy for biodiversity conservation and the rights of communities to their own genetic resources. Dr. Tewolde-Berhan's moving speeches at annual Ethiopian Biological Society meetings and

national conferences often highlighted Ethiopia as a biodiversity treasure trove. His framing of these resources (such as coffee) as not adequately utilized to reduce Ethiopia's poverty while other countries benefited from them impacted my knowledge of PGRFA geopolitics. It did not seem fair. Overall, these exposures shaped my understanding of global biodiversity politics in terms of seeing the Global South as a genetic resource provider and the Global North as a user without sharing fair benefits.

My knowledge about the geopolitics of PGRFA from Ethiopia was soon to encounter tests at the Department of International Environment and Development Studies (Noragric) of the Norwegian University of Life Sciences when I joined a masters' program in Management of Natural Resources and Sustainable Agriculture. At Noragric, I was taught a "plant genetic resources policy and law" by two internationally renowned plant genetic resource experts, Dr. Trygve Berg and Dr. Cary Fowler (2020). For the first time, they taught me about countries' interdependence for crop diversity. Without hiding existing power imbalances between poor and prosperous nations, corporates, and smallholder farmers, they explained the global germplasm exchange, adaptation, and diversification of several crop species outside their centers of origin. Their compelling evidence of why governments should collaborate for germplasm exchange and research for development was a test of my prior understanding of the need to protect "own" genetic resources from "biopiracy." I will never forget the following story by Dr. Fowler: "I was surprised when I saw gun-carrying guards watching over a coffee field genebank during my visit in west Ethiopia in the 1980s. When I asked the director of the national genebank why they don't collaborate with other countries like Brazil for coffee research and development instead of guarding the coffee field genebank, he replied: Don't ask me that question." These are real stories that go together with my experiences of the country's genetic resources protection. However, I have also wondered how the collaboration Dr. Fowler suggested can be realized internationally. My overall training at Noragric changed the way in which I acquired knowledge by understanding the perspectives of all actors in a particular situation. I moved from hard science studies and the one-sided story of biodiversity geopolitics to engaging with issues from an interdisciplinary perspective. A transition to interdisciplinarity required examining the points of difference and the intersection between the philosophical approaches adopted in social sciences and the natural sciences to generate critical reflection and debate regarding what we can legitimately acquire knowledge about, how we acquire it, and its effect on development (Moon & Blackman, 2014). With this interdisciplinary orientation, the current study integrates knowledge and methods from different disciplines. It constructs knowledge from various fields, including anthropology, agronomy, economics, genetics, political science, and law. Moreover, my study is founded on critical social science, as expressed in my research questions to understand social processes.

After studying at Noragric, I joined the Development Fund of Norway, a Norwegian NGO, following a trainee position at the Fridtjof Nansen Institute that exposed me to farmers' rights issues as defined under the ITPGRFA. I worked as a program coordinator and a policy advisor in agrobiodiversity management at different times in Africa and South and Southeast Asia, including policy advocacy targeting international institutions such as ITPGRFA, the International Union for the Protection of New Varieties of Plants (UPOV), and the European Patent Organization. My work at the Development Fund exposed me to diverse actors' politics and practices in the field. I was also one of these actors. Working with local partners and target groups (farmers) to understand their problems and needs and co-design project interventions, the seed system's technical, institutional, and policy challenges were always vital. Overall, my

understanding of farmers' needs and realities on the ground was incomplete. My colleagues and I sometimes made assumptions and believed that what we promoted was perfect for solving farmers' problems.

We made minimum effort to understand farmers' seed preferences and uses and national seed systems in our program countries. For instance, we mostly ignored improved varieties and supported crop diversification based on local varieties, although we knew farmers also used improved varieties and certified seeds. We chose the community seed bank approach as the primary intervention for seed security and agrobiodiversity management. We did not prioritize market-based local seed production and distribution to increase farmers' access to seeds in our projects. But we perceived the lack of interest of some farmers, and sustainability challenges in some of our projects, to be mainly the result of a lack of immediate and higher economic benefits (Andersen, 2019; Mulesa & Ortiz, 2015). Without asking ourselves and sometimes ignoring what we had learned, we continued supporting these projects. In policy advocacy, our engagement with experts and policy actors was also contentious. National governments work to increase farmers' use of commercial seeds and modernize subsistence farmers. We did not support their mission as we favored promoting local biodiversity conservation and strengthening local institutions. We had minimal contacts and collaboration with mainstream agriculture institutions as we preferred to work through local NGOs. We advocated for farmers' rights and against genetically modified organisms and stringent IPR. Amidst these, my background as a son of smallholder farmers and NGO experience has kept me interested in exploring and learning how to benefit smallholder farmers in developing countries and ensure agrobiodiversity management and sustainable use.

As a researcher at the Norwegian University of Life Sciences (NMBU), I have acknowledged that one can use sources of knowledge supportively or critically in one's research work. A researcher endeavors to offer an impartial, balanced, and truthful presentation of expertise (Creswell, 2013). As a researcher, I cannot detach myself from socially constructed knowledge in PGRFA governance and seed system development since I have been an actor in the field. However, I strive to handle pre-understandings using reflexivity and by engaging with research participants' stories using interpretation, i.e., actively constructing interpretation by going beyond mere reporting of "facts" and questioning how those interpretations came about (Hopkins et al., 2017; Creswell, 2013; Guillemin & Gillam, 2004). Therefore, my positionality is a negotiation between my pre-understandings as a genebank and NGO staffer and my social, cultural, environmental, and political understandings to be an impartial, balanced, and truthful researcher. My everyday discussions with colleagues and supervisors have helped me learn how to engage with and understand actors' perspectives in my research based on the historical, social, and political factors that shaped their beliefs and actions. In this Ph.D. research, I attempt to communicate based on this contextual understanding to avoid any uncertainty — primarily because of my study's objective to contribute to society, i.e., to influence policies, legislation, and actions in Ethiopian seed system development.

3.7 Ethical considerations

Ethical issues which occur during fieldwork are complex. However, a researcher can reduce unintended harm to research participants by following appropriate ethical principles and clearly understanding how to conduct fieldwork (Aluwihare-Samaranayake, 2012). In this study, I regarded ethical issues seriously at all stages of the research project. I conducted the field research following the guidelines for research ethics of the NMBU (NMBU, 2015) and Norway's guidelines for research ethics in the social sciences, humanities, law, and theology (Etikkom, 2014). Based on these guidelines, I submitted a notification form to the Norwegian Center for Research Data (NSD) before commencing data collection in Ethiopia. I received approval from NSD on September 18, 2017. The guidelines did not require explicit ethics approval in Ethiopia. I informed the Oromia National Regional State of the Federal Democratic Republic of Ethiopia, which granted me a research permission letter that I submitted at the respective district agricultural bureaus. The districts notified authorities in my study *gandas*. These authorities gave me their permission and assistance to carry out the surveys, interviews, and FGDs.

During the fieldwork, I ensured the protection of the rights of research participants, showed respect for local culture, and protected participants' personal information. In this research, voluntary informed consent (Christians, 2005) was obtained from all research participants after explaining the research project's objectives, the implication of their participation, how their information is used, and the benefits and possible risks. I used disguised identities in my writings whenever I predicted that insiders could be recognized and noted for potentially sensitive political issues that attract some actors' interests. That said, this research primarily aims to increase social justice in Ethiopia's seed system development and facilitate access to PGRFA for international users and fair and equitable sharing of benefits from its use.

3.8 Limitations of the study and future research direction

Article 2 used a household survey, FGDs, key informant interviews, and document analysis on discussing farmers' seed security as an outcome of seed systems' performances. The quantitative and qualitative data came from eight *gandas* representing different agroecologies in two distinct districts — commercially-oriented and subsistence-oriented. Although these characteristics and the diversity of research participants (different groups of farmers and representatives of seed system actors) can offer rich data, limitations which affect representativeness at a broader scale are unavoidable. Ethiopia is highly diverse in agroecology, and a variety of crops with different means of propagation grow in these diverse agroecologies. However, the current study covered only two cereal crops in two districts in the country's central highlands. Obtaining data relating to non-cereal crops, and using broader agroecological coverage, socio-cultural and economic settings than these two districts, would depict more of the detailed seed security issues in the country to inform national policy. This would link to possible discrepancies between seed security research at the local level and policy research relating to the national level and beyond. However, the current in-depth case study in two contrasting districts (highlighting the functioning of seed systems and farmers' seed security status for the two crops), which traces the implementation of prioritized interventions in the country's seed system development strategy, has helped bridge this discrepancy. Still, a meta-study with national coverage (spacial and crops) exploring seed systems' performances and farmers' seed security can provide detailed evidence to inform national seed system development policy and practical interventions.

Qualitative research on PGRFA access governance in Ethiopia (Article 1) primarily used primary and secondary data, including historical information from within Ethiopia. Although the article has no validity problem concerning conclusions, the recommendation would have benefited from interviewing international PGRFA users and incorporating their perspectives to aid future international negotiations. For instance, the study on seed system development politics (Article 3) used information from representatives of multinational seed companies and seed associations representing commercial actors' interests in this regard. In so doing, it incorporated their perspectives, which enhanced the broader validity of the conclusions.

4. Summary of the articles

This section summarizes the three research articles in this thesis, covering Ethiopia's access governance of PGRFA, the performance of seed systems farmers use, farmers' seed security in the two study districts, and seed system development politics. The contributions from the articles cover several actors' policies and practices along the seed value chain in the formal and informal institutions. In addition to farmers' practices to fulfill their seed demand, the articles also cover interactions between local, national, and international level actors and institutions, representing the multilevel perspective of PGRFA access governance, seed security, and seed system development discussions.

Article 1

Against the grain? A historical institutional analysis of access governance of plant genetic resources for food and agriculture in Ethiopia

This article describes and analyzes Ethiopia's policies and practices related to access governance of PGRFA and its implications for different users. Specifically, it discusses the intricacies of IPR and access and benefit-sharing issues in the international interacting regimes central to governing germplasm transactions. In addition, the article uses Ethiopia's case to understand why some developing countries implement a restrictive access governance regime. Finally, it shows the importance of this understanding in ongoing international negotiations to enhance the multilateral system of access and benefit-sharing of PGRFA under the Food and Agriculture Organization (FAO) of the United Nations' ITPGRFA.

The study shows that the Ethiopian government issued comprehensive policies and legislation to ensure national control over genetic resources within its jurisdiction. Ethiopia's access legislation demonstrates an ownership approach to PGRFA governance, i.e., liberal toward national users and restrictive toward international users. In addition, the government policies and regulatory frameworks promote the rights of farmers and communities and encourage in situ conservation and on-farm management of PGRFA, which was less prioritized than ex situ in the past. The country resisted stringent IPR (e.g., patents, plant variety protection laws based on UPOV 1991) and is reluctant to join neoliberal IPR institutions such as the World Trade Organization and UPOV convention. The explanation for Ethiopia's policies and practices toward restrictive access governance, in situ conservation, on-farm management, and farmers' rights approaches is found in historical, ideational (normative and cognitive), political, and economic factors.

Historically, Ethiopian scientists and policymakers have been inspired to conserve and control their seed heritage more than many other countries. This inspiration is mainly due to early plant exploration, including that of Vavilov, who identified Ethiopia as one of the centers of origin and diversity for several food crops. The awareness among Ethiopians as a biodiverse nation and the global significance of their genetic resources has affected the country's policies and practices for PGRFA governance. Economically, the value of crop diversity in Ethiopia's highly varied agroecology and diverse agricultural practices, especially PGRFA with origin in the country, has been central. Consequently, the value of crop diversity has been high on the government's political agenda. Ethiopia has been a vocal actor in international biodiversity governance fora and has adopted several international agreements for conservation, sustainable use, and access and benefit-sharing, including domestication in its national policies and legislation. However, the government's current reluctance to provide access under the multilateral system of access and benefit-sharing of the FAO's ITPGRFA and the choice of access and benefit-sharing of the Nagoya protocol under the CBD for germplasm transactions are related to unsettled imbalances between IPR, access and benefit-sharing, and the country's ambition to increase economic benefit from its PGRFA.

In conclusion, this article encourages actors to understand Ethiopia's current restrictive access regime in connection with, and not in isolation from, international IPR regimes and the historical, political, and economic role of PGRFA in the country. It also encourages similar research to look beyond the frameworks of international agreements on PGRFA governance in other developing countries and try to understand the particular historical, political, and institutional factors affecting their policies and regulations. Such research can bring new insights and lessons into PGRFA governance, specifically for a balanced and trustworthy negotiation between gene-poor and gene-rich countries to enhance international cooperation for germplasm transactions and equitable benefit-sharing.

Article 2

Pluralistic Seed System Development: A Path to Seed Security?

This article investigates farmers' seed preferences and use (demand-side), in addition to the roles of supply-side institutions and actors, to understand how different elements of seed systems affect farmers' seed security. The article uses a comparative case study design with two contrasting districts — commercially oriented wheat production and subsistence-oriented teff production systems — to explore and analyze the performance of seed systems and seed security outcomes, i.e., varietal suitability, seed availability, access, and quality. In addition, it discusses the relevance and implementation of the new PSSDS policy in terms of addressing farmers' challenges with access to enough quality seeds of preferred crops and varieties. By analyzing the performance of different seed systems in relation to seed security outcomes, the article aims to deepen the understanding of the context-specific conditions and vulnerabilities that affect seed security and inform policy formulation and implementation. The article reveals some of the socioeconomic, technical, political, and institutional constraints and opportunities (as they apply to seed system operations) underlying farmers' chronic seed insecurity. Accordingly, it contributes to seed security and seed system literature, showing their interconnections and suggesting the application of a seed security framework for research in both disaster situations and normal growing conditions.

The study shows that farmers use a range of seed sources but primarily obtain their seeds from informal sources in both districts. It also documents evidence of seed insecurity in both commercially oriented and subsistence-oriented districts. This includes insufficient availability of and access to improved varieties and specially certified seeds, poor seed quality related to lack of varietal purity and storage facilities for farm-saved seeds, lack of new disease-resistant varieties, lack of access to preferred traditional varieties, and differentiated access to preferred seed and information according to sex, age, and wealth groups in both districts. The study from the commercially oriented wheat-producing district shows that seed access differs between socioeconomic groups. Female-headed households have equal access to certified seeds due to seed system actors' heavy presence promoting gender-sensitive agriculture in the district. In subsistence-oriented districts, these actors are absent. Moreover, wealthy farmers aligned with the government and in privileged positions as model farmers and out-growers have better access than other groups.

The analysis of Ethiopia's PSSDS concerning its relevance to farmers' seed security challenges and identified seed system dysfunctions shows that the government's strategy and policy are moving in the right direction. Analysis suggests that these policies are appropriate for developing countries. The PSSDS puts farmers at the center of seed system development by promoting complementarity between value-chain components of each seed system (informal, formal, and intermediate) and integrating their activities, in contrast to the dominant linear model to seed system development in most developing countries. However, the implementation of prioritized interventions in the PSSDS lags, particularly for the informal seed system, and is neglected by government programs despite its role in supplying large quantities of seeds and most of the crops and varieties farmers use. Implementation of identified interventions to improve the performance of the formal seed system is lacking, mainly as a result of political, organizational, and economic interests within key seed system institutions and insufficient resources and capacity. In conclusion, the article calls for action to overcome these obstacles to achieve truly integrative and inclusive seed system development.

Article 3

Politics of seed in Ethiopia's agricultural transformation: pathways to seed system development

This article aims to understand why and how the formal seed system has been prioritized over other alternatives (farmers' and community-based seed systems) by government policies and programs since the beginning of Ethiopia's agricultural modernization in the 1950s. For this purpose, the article uses multiple power analysis approaches to investigate the history of the seed system's evolution in terms of economic and agricultural development policies under three different governance regimes: imperial, socialist military, and authoritarian developmentalism. In addition, the article analyzes the effects of actors' politics on the opportunities and challenges in creating more equitable and sustainable seed systems in the current PSSDS. In exploring historical seed system development by considering different governance regimes' political and economic ideologies, the article illustrates a distinct patterning of seed regimes in Ethiopia.

The historical patterning of Ethiopian seed regimes shows that all political regimes maintained government-led seed system development since the beginning of agricultural modernization in the 1950s, despite differences in their agricultural development ideologies. Prior to the 1950s, the first colonial seed regime did not take hold because the country was not colonized, while the third post-1980s corporate-based neoliberal seed regime has never been anchored in the

formal seed system owing to government resistance to the seed sector liberalization and privatization. The article identifies four competing approaches to the current conjuncture in the contemporary Ethiopian seed regime: 1) government-led formalization, 2) private-led formalization, 3) farmer-based localization, and (4) community-based integrative seed system developments. Of these approaches, government-led formalization still dominates despite awareness, recognition, and policies on paper about how farmers' use of diverse seed systems can increase access to enough good quality seeds of suitable plant varieties. The government also continues to marginalize private-led formalization despite the push by neoliberal financial institutions and donors who support agricultural research and development in Ethiopia. Notwithstanding its "progressive" positions in environmental governance, climate change, and United Nations development goals to empower grassroots participation in decision-making and development, the Ethiopian government has failed to support the farmer-based seed system development.

The article argues that the nature of the Ethiopian state (centralized planning and execution of agricultural development and state control of rural constituencies), elite interests, and agricultural modernization path dependency have contributed to the lack of inclusive and equitable seed system development. In conclusion, the article argues that an integrative and inclusive seed system is possible if the government takes leadership and removes the current political, organizational, and economic barriers for developing a truly pluralistic seed system.

5. Synthesis, conclusions, and contribution of the research

In three separate but interrelated articles, this thesis examines multilevel PGRFA governance and seed system development and explains the historical, economic, institutional, and political factors that underlie seed and development politics in Ethiopia. The country-specific historical, economic, cultural, and political factors contributing to Ethiopia's restrictive PGRFA access governance show the challenges of reconciling countries' and actors' interests in global PGRFA governance. Specifically, it points to the difficulties of establishing a balanced and trustworthy agreement to enhance international cooperation for facilitated access to germplasm and equitable benefit-sharing. While commercial actors and industrial countries advocate for facilitated access and promote IPR for protecting innovation, PGRFA provider countries in the global south are reluctant to provide increased access before securing monetary benefit-sharing and farmers' rights. Besides, the diversity of historical, economic, and political settings of PGRFA provider countries further complicates their relationships and cooperation with PGRFA users, as the empirical contribution of this thesis from the Ethiopian case demonstrates. In this regard, actors' arguments about countries' interdependence for PGRFA and IPR issues related to innovation and plant genetic resources (e.g., Smith et al., 2021) are not enough to deal with the contentious global PGRFA access governance. From the current study, it is clear that increasing breeders' and farmers' access to a diversity of PGRFA for adapting crop production to changing climate and improving global food security does not resonate with the actors' divergent realities and interests. However, a compromise for mutually acceptable and beneficial PGRFA governance arrangements can be attained if actors understand the factors behind provider countries' restrictive practices in PGRFA access governance and show a willingness to work for an alternative situation in which each party benefits. For this purpose, the Ethiopian case study presented in this thesis and similar in-depth studies in different countries with restrictive access policies and practices could bring more knowledge and insights to the negotiation table.

This study on PGRFA access governance also contributes to the literature on policies and practices in national and global PGRFA governance. The current research benefited from the New Commons conceptualization of PGRFA, which enabled understanding of PGRFA governance by focusing on the frameworks of international agreements, specifically by looking at access regimes that Ethiopia has practiced before and after the CBD. Analysis of the framework using the New Commons approach has been helpful to identify design problems related to the functioning of international agreements for PGRFA provider countries interests, for example, the multilateral system of ITPGRFA (Halewood et al., 2013). This current study is also one of the few PGRFA governance studies to analyze access, benefit-sharing, and IPR issues simultaneously, in comparison to a dozen other studies that have examined them separately. In addition, the current research made an additional contribution to the country-specific understanding of PGRFA access governance situations by using historical institutional analysis. The analysis revealed how historical, political, and economic factors changed actors' perceptions, institutional goals, and status of commons governance over time, i.e., from Commons to hyperownership. Similar future PGRFA access governance studies can benefit from using the current study approach of historical institutional analysis and identifying factors underlying countries' restrictive PGRFA access policies and regulations to help future international negotiations.

This thesis also presents widespread seed insecurity both in subsistence and commercially oriented production systems rooted in agroecological, socioeconomic, institutional, and political factors based on the analysis of farmers' seed preferences and use and seed system actors' roles and performances. Examination of Ethiopia's proposed priority interventions in its pluralistic seed system development strategy shows good alignment with identified farmers' seed security challenges. However, findings show that the operationalization of the policy lags, with investments in the informal seed system largely missing from government programs and lack of incentives for the private sector, is not encouraging investment. The historical analysis that examined seed and development politics shows that the lack of policy implementation is not new in Ethiopia. Since agricultural modernization started in earnest in the 1950s, the Ethiopian government began implementing the post-WWII second seed regime, i.e., supporting government-led seed system formalization and resisted the post-1980s corporate-based neoliberal seed regime. Despite being a "progressive" actor in international negotiations concerning farmers' rights to seeds and sustainable biodiversity conservation, the Ethiopian government sidelined both farmer- and community-based seed systems. Similarly, despite being one of the biggest international aid recipients and approving policies and strategies on paper in favor of a free-market economy, including privatization, the government refused to privatize and liberalize the seed sector. In resisting the implementation of the corporate seed regime, the Ethiopian government practices are grounded in the notions of independence, sovereignty, skepticism against foreign forces, liberalization, and free-market ideology. Overall, the findings show that decades of government centralized planning and execution of agricultural development, state control of rural constituencies, elite interests, and agricultural modernization path dependency are the main reasons for the lack of inclusive and equitable seed system development in Ethiopia. The evidence generated on farmers' seed insecurity and challenges facing the implementation of identified policy interventions can directly inform government program support toward realizing inclusive and equitable seed system development in Ethiopia.

In addition to the empirical contribution that can benefit policy revision and implementation in Ethiopia, this thesis makes a methodical contribution to existing knowledge in seed system

development and improving farmers' seed security in developing countries. Using a seed security framework, the combined analysis of farmers' seed preferences and use and the role of actors and institutions in seed systems helped reveal the social, political, and institutional constraints underlying chronic seed insecurity among smallholder farmers. To the best of my knowledge, this is the first study to have comprehensively integrated existing knowledge in seed security with seed system literature and related it to policy, informing policies and practices for inclusive and equitable seed system development in Ethiopia and beyond. In addition to combining seed security and seed system analysis for nuanced understanding, the thesis demonstrates the applicability of the approach to normal growing conditions for long-term seed system development and addressing chronic seed insecurity instead of limiting it to disaster situations. Overall, this study demonstrates the use of a comprehensive conceptual framework and generating empirical evidence for changing or improving operational models (underlying policies, legislations, and actions) for inclusive and equitable seed systems development in the Global South that can be sustained over time. However, studies of this nature are needed from different countries with differing political and economic contexts in order to inform national and international development policies and practices in seed system development. The plural power analysis approach used for analyzing policies and institutions involved in seed system governance is a powerful methodological tool for understanding historical, political, and institutional factors within each country and for getting a more nuanced picture by going beyond existing institutional, infrastructural, and financial limitations in seed system development. Therefore, this study also makes a unique contribution to seed politics and development literature.

Finally, this thesis uses a multilevel perspective on improving international collaboration for germplasm exchange for crop improvement and national seed system development policy to increase farmers' seed security and show areas of intervention for a comprehensive seed system development. If implemented, facilitated access to PGRFA for farmers and breeders and inclusive and equitable seed systems can improve the resilience of the farmers' production system and increase crop production and productivity by enhancing access to diverse crops species and varieties. In conclusion, this study contributes to the growing national and international knowledge base on context-specific policymaking and actions for socially just and sustainable seed system development.

6. References

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PART II: Compilation of articles

Article 1: Against the grain? A historical institutional analysis of access governance of plant genetic resources for food and agriculture in Ethiopia

DOI: 10.1111/jwip.12142

ORIGINAL ARTICLE

THE JOURNAL OF WORLD INTELLECTUAL PROPERTY WILEY

Against the grain? A historical institutional analysis of access governance of plant genetic resources for food and agriculture in Ethiopia

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Funding information
Research Council of Norway (RCN), Grant/Award Number: NFR 277452/H30

Abstract

Farmers' and breeders' access to a genetic diversity is essential for food system sustainability. The implementation of international agreements regulating access to plant genetic resources for food and agriculture (PGRFA) varies substantially between countries. Here, we examine why some countries implement a restrictive access governance regime, taking Ethiopia as a case. Drawing on commons theory and historical institutional analysis, we analyze historical, political, and economic factors that have shaped Ethiopia's access regime. Based on interviews with key actors and stakeholders and document analysis, we identify three overarching ideational and material factors that can explain Ethiopia's current policy: (a) the influence of narratives about Ethiopia as a biodiversity treasure trove on the Ethiopian cultural identity; (b) the economic importance of agriculture based on PGRFA with origin in the country; and (c) the political influence of the genetic resource movement that promotes farmers' rights as a counter measure to stringent intellectual property rights (IPR), and on-farm PGRFA management as complimentary to ex situ conservation and formal seed system development. The Ethiopian case illustrates that countries' governance of access to PGRFA must be understood in connection with,

and not in isolation from, IPR regimes and the historical, political, and cultural role of PGRFA in the country in question.

KEYWORDS

Access and Benefit Sharing (ABS), Commons governance, Intellectual Property Rights (IPR), International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA)

1 | INTRODUCTION

Sustainable food production depends on cultivated and wild plant genetic resources for food and agriculture (PGRFA) for crop improvement. Farmers and breeders need access to plant genetic resources (PGRs) from both within and outside their borders; indeed all countries rely on crop diversity that originated on territories under other jurisdictions (Khoury et al., 2016; Palacios, 1997). Despite the empirical evidence for the interdependence and the benefits of well-adapted crop varieties, access to genetic resources is restricted in several ways, and in ways that differ between different user groups. The limitation can be practical, economic, political, or legal—or a combination of these. Three types of laws and regulations explicitly restrict access to PGRs. These are (a) intellectual property rights (IPRs) on cultivars; (b) access and benefit sharing (ABS) regulations related to the Nagoya Protocol of the Convention on Biological Diversity (CBD), and to the Multilateral System for ABS under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA)—hereafter referred to as the MLS; and (c) plant health regulations. IPRs only apply to new varieties while the two latter apply to all PGRFA exchanged across national borders.

Concerns over the negative effect of IPRs on farmers' interests and needs in relation to seeds is a long-standing research theme and a bone of contention in public debates (Aoki, 2008; Borowiak, 2004; Correa, 2015). IPRs such as patents, plant breeders' rights acts, and even contract law for the protection of new plant varieties are becoming increasingly stringent and restrictive on access, causing concern to advocates of farmers' rights and plant breeders alike (Bandyopadhyay, 2018; Correa, 2015; Dutfield, 2017, 2018; Luby, Kloppenburg, Michaels, & Goldman, 2015; Wan & Perry, 2019). Less debated in the public are the potential and actual negative effects of different ABS regulations on PGRFA, however their effects on basic biodiversity and applied life sciences research are of considerable concern in the research community (Bjørnstad, Tekle, & Göransson, 2013; Neumann et al., 2018; Prathapan, Pethiyagoda, Bawa, Raven, & Rajan, 2018; Rourke, 2018). The most wide-ranging ABS regulations are those of the Nagoya protocol, which apply to all biodiversity and associated traditional knowledge covered by the CBD.[1] The CBD reconfirmed the resolution 1803 (XVII) on the "Permanent Sovereignty over Natural Resources" adopted by United Nations General Assembly at its 17th session in 1962 and established the principle that nation states have "sovereign rights" over the biodiversity within their jurisdiction (Nijar, 2011; Safrin, 2004).

The principle of nation states' sovereign rights over PGRs within their jurisdiction "reshaped and transformed the global genetic commons" into something states could claim ownership over (Roa-Rodríguez & Dooren, 2008). Arguably, the CBD objective about "fair and equitable benefit sharing" came about due to increased use of IPRs to protect the ownership of the products based on biodiversity (Byerlee & Dubin, 2010; Fowler, 2002). The debates at the time of negotiation of the CBD focused on the asymmetrical power relation between genetic resource "providers" and "users," typically referring to countries in the Global South as providers and countries in the Global

[1]As of June 2019, the Nagoya Protocol had 117 contracting parties out of 196 contracting parties to the CBD: https://www.cbd.int/abs/nagoya-protocol/signatories/default.shtml

North as users. This notion inspired many countries in the Global South to demand more equitable ABS rules globally and to implement stricter policies nationally (Correa, 1995; Fowler & Hodgkin, 2004; Halewood, López Noriega, & Louafi, 2013b; Roa-Rodríguez & Dooren, 2008).

Thus, restrictive access policies can be seen as a reaction from countries in the Global South toward an increasing enclosure of various genepools by IPRs, with little or no economic benefit flowing back to the countries in whose jurisdiction the genetic resources originated (Andersen, 2017; Timmermann & Robaey, 2018; Tsioumani, 2018). Through access policies and sui generis IPR laws, these countries intend to recognize the importance of farmers' varieties, and to provide appropriate mechanisms for ABS (Robinson, 2008). The other intention is to prevent the misappropriation of farmers' varieties, and safeguard farmers' rights to freely save, use, exchange, and sell all seeds (Lewis-Lettington, 2008a, 2008b). As such, sovereign rights over PGRFA are being used as a freedom to determine the condition under which access occurs (Correa, 1995, 2015). This freedom soon became other actors' restriction as international germplasm access was limited following the CBD ratification (Correa, 2005; Falcon & Fowler, 2002; Sullivan, 2004).

The ITPGRFA was negotiated as an attempt to balance fair and equitable benefit sharing with a rational system for facilitated access to genetic resources. In addition to agreements on sovereign rights, farmers' rights and benefit sharing, the ITPGRFA's MLS aims to increase access to PGRFA for crop improvement programs (Byerlee & Dubin, 2010). Research shows that the availability and exchange of germplasm has indeed increased following the adoption of the ITPGRFA (e.g., Dulloo et al., 2013) when compared with research results from before its adoption (e.g., Dudnik, Thormann, & Hodgkin, 2001).

According to some legal experts, the ITPGRFA and its MLS are “high-water marks for how countries can work together under the United Nations to tackle complicated transnational conservation and access issues” (Halewood, López Noriega, & Louafi, 2013a). However, the same analysts are the first to acknowledge that the MLS is working suboptimally, and that there are some major “design issues” limiting full engagement of all actors (Dedeurwaerdere, 2012; Halewood et al., 2013b). Many countries, even member countries, have shown reluctance to implement the multilateral system, and access to genetic resources from institutions in these countries is restricted or nonexisting. The continuation of restrictive access regimes among some contracting parties is a source of tension and debate in the biannual Governing Body meetings of the ITPGRFA (Finkel, 2009). Ethiopia is often mentioned as an example of a country that does not provide access according to the MLS. In this article, we take Ethiopia as a case and ask: Why do countries, in spite of the empirical evidence for interdependence and mutual benefits of open access to genetic resources, implement a restrictive governance regime for access to genetic resources?

Ethiopia is internationally recognized as a hotspot for wild and cultivated plant genetic diversity and is a vocal actor in international biodiversity governance fora. The country is a party to the CBD, the Nagoya Protocol, and the ITPGRFA. Furthermore, Ethiopia is home to many national and local projects for PGRFA conservation and sustainable use in accordance with the objectives of the ITPGRFA (e.g., Alemu, 2011a; Balemie & Singh, 2012; Dalle & Walsh, 2015; Fukuda, 2011; Mulesa & Ortiz, 2015; UNDP, 1994). As mentioned above, Ethiopia's fame as a center of important crop diversity is accompanied by a reputation for strict access regulation. This reputation is for the most part informally shared in the PGRFA community, but it also sometimes percolates into statements and anecdotes in the research literature, media reports, and the gray literature. Plant breeders have singled out Ethiopia and a few other countries (i.e., China, India, Iran, and Turkey) for not complying with ITPGRFA norms regarding access, or for restrictive access policies toward PGRFA users outside their territories (Finkel, 2009; Gewin, 2019; Kate & Laird, 2002; Kloppenburg & Kleinman, 1987). For instance, a scientist from Kew Botanical Gardens was cited in an article in *Scientific American* as saying:

> *The country where coffee originated curates a large collection of coffee plants that exist nowhere else in the world. But the government keeps them under lock and key and will not allow foreign researchers access. There's been a lot of bad blood between Ethiopia and the coffee industry (…) it's no wonder they're guarded about their genetic resources (Rosner, 2014).*

Along the same vein, in a feature story in *Science* from 2009, scientists working in an international research center and breeding program singled out Ethiopia as one of the most restrictive countries when it comes to access to genebank material: "Ethiopian durum wheats could help thwart a fungus (Ug99) now sweeping the globe, but Ethiopia is reluctant to share seeds" (Finkel, 2009). In their review of the global availability of PGRFA, Fowler and Hodgkin (2004) reported: "Ethiopia provided virtually no samples to foreign researchers or institutes but distributes about 2000 a year internally."

Since Ethiopia is a party to the Plant Treaty, the reputation for being a country with a "closed genebank" (Finkel, 2009; Gewin, 2019, p. 1376) equates to noncompliance with the rules of the multilateral system. This is not the only international seed-related policy in which Ethiopia is going against the grain. Indeed, compared with most other countries, Ethiopia has a less liberal seed market, less involvement of multinational seed companies (MoA, 2019b; Scoones & Thompson, 2011), less stringent IPR laws (Alemu, 2016), and seed policies that accommodate a "pluralistic" seed sector (Otieno, Reynolds, Karasapan, & López Noriega, 2017).

The objective of this article is to describe and analyze Ethiopia's governance of PGRFA access and its implications for different users. We analyze historical, political, and economic factors that have shaped the country's conservation and utilization strategies, policies, and laws.

By outlining the historical trajectory of PGRFA conservation for plant breeding and germplasm transfer, we show how the path has changed from ex situ to in situ conservation/on-farm management in the late1980s, following Ethiopia's worst drought and famine. We discuss how increased awareness from local on-farm projects and international activism in favor of farmer-based conservation, coupled with growing distrust of stringent IPRs, as well as massive germplasm requests from outside, contributed to restrictive national practices in providing access for international users. The rest of the paper is structured as follows. We start by introducing the theory and methods underpinning the study. Second, we provide an analysis of the development of Ethiopia's current PGRFA governance system, with a particular focus on access to PGRFA for national and international users. Third, we explore the long-term historical political and institutional developments and their influence on Ethiopia's current policies and practices. Finally, we conclude with a summary of the main findings of the study and highlight the importance of the historical institutional approach to understand differences among countries in PGRFA governance.

2 | THEORY AND METHODS

To understand Ethiopia's position on access to and management of PGRFA, we draw on Halewood et al. (2013a) analytical approach, conceptualizing PGRFA as a "new commons." Halewood et al. (2013a) conceptualization of PGRFA relates to Ostrom (1990) commons theory in general, and "new commons" theory in particular (Hess & Ostrom, 2007b). The first has commonly been applied to the management of "traditional" common-pool resources (e.g., irrigation, pasture, fish) that are rivalrous[2] and nonexcludable[3] in a limited geographical area and involving a limited number of actors (Hess, 2008; Hess & Ostrom, 2007a; Stern, 2011). The new commons term refers to commons such as PGRFA that are partially man-made (result of human-environment interaction) and global in coverage (Halewood et al., 2013a).

Contracting parties to the ITPGRFA designed the current MLS in response to these new commons features of PGRFA. The MLS is based on a recognition of countries' sovereign rights over their respective PGRFA, in harmony with the CBD, but through the MLS countries have used this sovereign right to pool and share PGRFA held in their

[2]A rivalrous good is a common-pool resource whose size or characteristics makes it costly, but not impossible, to exclude potential beneficiaries from obtaining benefits from its use (e.g., fishing grounds).

[3]A nonexcludable good is a common-pool resource whose use by one person diminishes the ability of another person to benefit from it (e.g., pasture or grazing land).

jurisdictions (Halewood, 2013). In an institutional analysis of Ethiopia's access governance, we draw in particular on two concepts from this literature: the distinction between a "new commons" approach and a "hyperownership" approach to PGRFA governance, and the concept of design issues. Halewood et al. (2013a) argue that although most member states and Consultative Group on International Agricultural Research (CGIAR) centers have moved away from "common heritage" thinking or free access and embraced the "new commons" approach, some countries espouse a "hyperownership" approach, exercising extensive national government control over a wide and increasing range of PGRFA. Drawing on Ostrom's (1990, pp. 90–102) concept of design principles of commons governance, Halewood et al. (2013a) highlight two "design issues" in the ITPGRFA's MLS which currently are affecting engagement of actors in the system: (a) unclear boundaries and inability to enforce reciprocity; and (b) the hybrid nature of financial benefit sharing in the MLS, which is somewhere between a multilateral and bilateral approach. The first design issue refers to the "free-rider" situation in which nonmembers have access to material from the MLS even if they do not participate in the system. The second design issue refers to the way monetary benefit sharing is "de-linked" from the countries, communities or legal individuals from whom the material was collected (multilateralism) while the requirement to share the monetary benefits is directly linked to the IPR holders and their sale of the varieties incorporating PGRFA from the system (bilateralism). According to Halewood et al. (2013a) analysis, these two design issues can explain why parties show reluctance to fully participate in the governance regime of the MLS.

Expanding on the institutional analysis and the focus on design principles, we explore the historical and political context in which Ethiopia's position on governance of PGRFA access has developed. Historicizing institutional development allows us to bring out how the "prior history of conflict or cooperation; the incentives for stakeholders to participate; power and resource imbalances; leadership and institutional design; shared understanding and trust" (Ansell & Gash, 2008) have shaped the present governance regime. Our empirical material includes interviews, database information and analysis of a range of literature and policy documents. We draw on peer-reviewed articles, gray literature, archival studies, policy, and legal documents in English and Amharic languages, including relevant reports archived online from international biodiversity and PGRFA related negotiations (IISD, 1993–2019; UPOV, 1973–2019), and GENSYS database (GCDT, 2019). Our narrative analysis utilizes key informant interviews ($N = 26$) with key actors and stakeholders, conducted during fieldwork in Ethiopia from October 2017 to March 2018, as well as government of Ethiopia's public statements and documents, including statements at international negotiations.

3 | ETHIOPIAN PGRFA AND ITS GOVERNANCE

3.1 | Ethiopia's relationship to PGRFA and binding international agreements

Ethiopia is a high biodiversity country (FDRE, 2012a),[4] and PGRFA form the basis of its economy and food security. Economically, Ethiopia's exports are almost entirely agricultural commodities based on PGRFA, with coffee, oilseeds, and pulses being the largest foreign exchange earners (Taffesse, Dorosh, & Gemessa, 2012; Wale & Mburu, 2006). The country's farming sector is dominated by smallholder subsistence farming (Mellor, 2014), and depends on a considerable proportion of seed inputs that are derived from locally accessible planting materials (Bishaw, Sahlu, & Simane, 2008; Sahlu, Simane, & Bishaw, 2008; Spielman & Mekonnen, 2018). PGRFA have been important for improving agricultural productivity and farm-level resilience to agricultural production shocks, especially for farmers facing highly variable production conditions (Cavatassi, Lipper, & Hopkins, 2006; Di Falco &

[4]FDRE in this paper stands for Federal Democratic Republic of Ethiopia.

Chavas, 2009; Di Falco, Bezabih, & Yesuf, 2010; Di Falco, Chavas, & Smale, 2007; Lipper, Cavatassi, & Winters, 2005; Zander & Gemessa, 2011).

Ethiopia has strong public agricultural research and development institutions, including the national genebank of the Ethiopian Biodiversity Institute (EBI). As of June 2019, EBI holds 86,599 accessions, of which 79,354 are conserved as base/active collections under cold storage, and the remaining 7,245 are maintained in field genebanks,[5] including 5,644 accessions of coffee germplasm conserved in two agroecological areas (FDRE, 2012a). Internationally, PGRFA originating from Ethiopia is recognized as an important reservoir for crop improvement, and international conservation institutions have prioritized the country for extensive germplasm collections and conservation (Asfaw, 1999; Engels, Hawkes, & Worede, 1991; Sylvain, 1958). In the 446 genebanks reporting their holdings through the GENESYS database, there are 60,110 accessions of different crop species collected from Ethiopia and conserved in CGIAR and other national genebanks worldwide (Figure 1). There is some duplication between what is held in EBI and in the other genebanks reported in Figure 1; but since EBI does not publish its data through GENESYS, the degree of overlap is unknown.[6]

PGRFA is a resource that is kept high on the political agenda of the government of Ethiopia (FDRE, 1997a, 1998a, 2012a, 2014). Table 1 and Figure 2 provide an overview of central policies and developments in Ethiopia relating to PGRFA. The country has ratified binding international agreements related to the conservation, sustainable use, access to and benefit sharing from use of PGRFA, including the CBD in 1994 (FDRE, 1994), the ITPGRFA in 2003 (FDRE, 2003), and the Nagoya protocol on Access and Benefit-sharing in 2012 (FDRE, 2012b). Ethiopia has taken a keen interest in the global negotiations of these agreements (Gebre Egziabher, Matos, & Mwila, 2011; Richerzhagen, 2013; Yifru, 2003; Zerbe, 2007), and played a leadership role within the African Group, as illustrated by the following statement of Ethiopia's former chief negotiator for CBD and ITPGRFA, Dr. Tewolde B. Egziabher:

> *The intimacy of African [Ethiopian] delegations with the agricultural systems of the smallholder farmers enabled the African Group to have a marked impact on the negotiations of the ITPGRFA in spite of Africa's financial poverty which could have limited our chances of having preparatory meetings (Gebre Egziabher et al., 2011).*

It was with this knowledge of smallholder farming that the African environmental negotiators of Agenda 21 entered the international negotiations (Frison, López, & Esquinas-Alcazar, 2011, p. xvi). Ethiopia influenced the African Group's position during the negotiation (Zerbe, 2005), and through the process that led to development of the African Model Law,[7] a sui generis IPR model law adopted by the African Union (OAU, 2000). This process has been instrumental to promulgate the Ethiopian position on PGRFA in Africa (Zerbe, 2005).

Historical records of Ethiopia's participation in international negotiations show that debates related to PGRFA governance have focused on IPRs that restrict farmers' access to PGRs, and possibilities of increasing benefit sharing from commercial actors to farmers and communities (Gebre Egziabher et al., 2011; Zerbe, 2005, 2007). Concern over IPRs potential negative effects on farmers' rights is one of the main reasons that Ethiopia is not party to UPOV. However, the country has recently initiated a national process to become member of the World Trade Organization (WTO) and accede to its Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement.

[5]Official data from the EBI, per June 2019.

[6]Our historical analysis indicates that germplasm collected before the establishment of the Ethiopian genebank (PGRC/E) in 1976 and conserved in national genebanks outside Ethiopia may not exist at EBI except in the case of repatriation. However, Ethiopian germplasm conserved in CGIAR genebanks can be duplicates due to collaboration that has existed between Ethiopia and IBPGRI/CGIAR since the establishment of PGRC/E.

[7]The African Model Law for the Protection of the Rights of Local Communities, Farmers and Breeders, and for the Regulation of Access to Biological Resources adopted by the African Union was first drafted by Dr. Tewolde B. Gebre Egziabher, the chief negotiator on international environmental agreements for Ethiopia in the 1990s and early 2000s. He led the African Group during negotiations that lead to adoption of CBD and the revision of the International Undertaking on Plant Genetic Resources that culminated with the adoption of ITPGRFA in 2001.

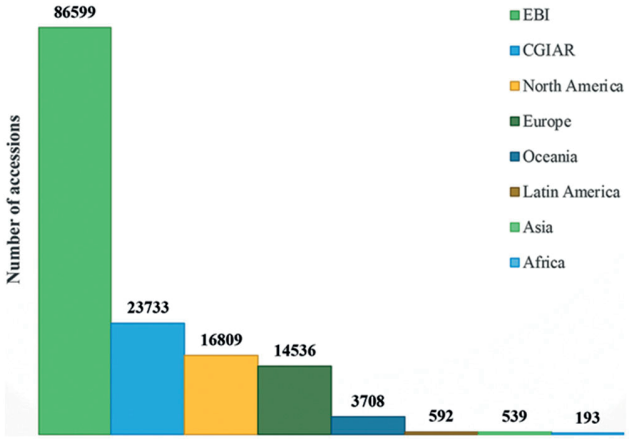

FIGURE 1 Overview of Ethiopian PGRFA conserved in genebanks worldwide. The accessions represent a wide range of taxa that were collected and conserved in the national genebank at EBI from 1976 to 2019 (*N* = 86,599). They also represent accessions distributed to CGIAR genebanks and national genebanks around the world for long-term conservation and use until early 1990 (*N* = 60,110). *Source:* EBI for accessions conserved in Ethiopian genebank and GENESYS online database for accessions conserved outside Ethiopia (GCDT, 2019). CGIAR, Consultative Group on International Agricultural Research; EBI, Ethiopian Biodiversity Institute; PGRFA, plant genetic resources for food and agriculture [Color figure can be viewed at wileyonlinelibrary.com]

3.2 | National access legislations: Toward an hyperownership approach

As shown in Table 1, the debate surrounding IPRs has been central to the development of national policies and legislations in Ethiopia. We see an early convergence between Ethiopia's active participation in international environmental negotiations that led to the adoption of the CBD and the ITPGRFA, and national policy development processes for PGRFA governance. Already in the early 1990s, Ethiopia started to include additional clauses in policies and laws related to PGRFA, such as the National Seed Industry Policy and the proclamation to provide for the establishment of the National Seed Industry Agency (FDRE, 1992, 1993b). Similar provisions were included in the draft bill for the establishment of the National Biodiversity Board to invoke restrictions on exports of PGRs (Rosendal, 2000, p. 241). At the time, these inclusions were a matter of urgency to control export of germplasm until the legislative issued laws for the ratification of the CBD, regulation of access, and establishment of a competent authority on biodiversity matters. In so doing, Ethiopia became one of the first countries to issue restrictive access policies and start moving toward state ownership of PGRFA (Lewis-Lettington, 2008a), contributing to the international trend in the early 1990s of restricting the global commons (Byerlee & Dubin, 2010).

During this period, Ethiopia underwent a regime shift from socialism to federal democratic state, and a new constitution was introduced (FDRE, 1995b). The constitution declared that the ownership of natural resources resides with the state and the people, to maintain coherence with the international guiding principles of states' sovereign rights to control the access to biological material under their jurisdiction. The government also made a decision to upgrade the Plant Genetic Resource Center/Ethiopia (PGRC/E) or the national genebank to the Institute of Biodiversity Conservation and Research (IBCR)—hereinafter EBI[8]—as "an autonomous body" of the Federal Government on biodiversity matters (FDRE, 1998b). The environmental policy (FDRE, 1997a) and national

[8]The institutional rearrangement and coordination has changed since the creation of PGRC/E and the center assumed different names: Institute of Biodiversity Conservation and Research (IBCR) in 1998, Institute of Biodiversity Conservation (IBC) when the government removed its research mandate in 2004 and EBI in 2015. The answerability of EBI has also changed from Ethiopian Agricultural Research Organization in 1998 to Ministry of Agriculture and Rural Development in 2004 to Ministry of Environment, Forest and Climate Change in 2015 and to the Environment, Forest and Climate Change Commission under the Office of the Prime Minister in October 2018.

TABLE 1 Overview of goals, targets, and positions relating to PGFRA governance in Ethiopia's national policies and laws

Policy framework	Global commons perspective	National ownership perspective
National Seed Industry Policy (FDRE, 1992)	• Encourages the participation of farmers in germplasm conservation, seed production, and distribution • Aims to ensure the collection, conservation, evaluation, and use of PGRs by national research and development programs	• Affirms farmers' rights to share benefits arising from the use of local varieties they have developed over generations
A National Seed Industry Agency Establishment Proclamation (FDRE, 1993b)		• The Agency was mandated to "issue regulations and procedures regarding import and export of seeds; and prepare a list of non-restricted and restricted crops, varieties and hybrids for use of foreign seed companies and joint ventures."[a]
Draft bill for the establishment of National Biodiversity Board (FDRE, 1993a)		• "No plant genetic resources shall leave the country without permission, either in the form of licensing, or contract" (Rosendal, 2000, p. 241)
The Constitution of the Federal Democratic Republic of Ethiopia (FDRE, 1995b)	• Asserts the importance of peoples' rights to full participation in the planning and implementation of environmental policies and development plans • Stipulates law enactment for the conservation and sustainable utilization of natural resources for healthy ecosystem and the wellbeing of the people	• Establishes that the ownership of natural resources lies with the state and the people of Ethiopia • Stipulates the deployment of these resources for the benefit and development of the people
Environmental Policy of Ethiopia (FDRE, 1997a)	• Ensures community participation and use of their traditional methods and knowledge to promote in situ systems as the primary target for conservation and sustainable use of wild and domesticated biological diversity; also promotes ex situ systems	• Ensures that the import, export, and exchange of genetic resources is subject to legislation, for example, to ensure the safeguarding of community and national interests, the fulfilling of international obligations (CBD) and national plant quarantine regulation
Patent law—Inventions, Minor Inventions and Industrial Designs (FDRE, 1997b)	• Prohibits the exclusive appropriation of any life form or patentability of "plant varieties" and "essential biological processes" for the production of plants	
National Policy on Biodiversity Conservation and Research (FDRE, 1998a)	• Asserts the importance of community participation to ensure that Ethiopia's biological resources are conserved, developed,	• Asserts national sovereignty over genetic resources and develops mechanisms (ABS, biosafety, plant breeders' and

(Continues)

TABLE 1 (Continued)

Policy framework	Global commons perspective	National ownership perspective
	managed, and sustainably utilized for the country's overall socioeconomic development	farmers' rights regulations) to ensure the effective control of the movement and management of genetic resources • Supports the implementation of international conventions (CBD), agreements and obligations on biodiversity to which Ethiopia is a party based on national legislation • Ensures that local farming communities share the benefits that accrue from the use of indigenous germplasm
National Biodiversity Strategy and Action Plan (IBC, 2005)	• Ensures the conservation and sustainable utilization of Ethiopia's biodiversity and ecosystems for improving food security and alleviating poverty	• Asserts national sovereignty over genetic resources and establishes targets to develop laws and regulations to control access to genetic resources and ensure equitable benefit-sharing
Access to Genetic Resources and Community Knowledge, and Community Rights (FDRE, 2006a) and Council of Ministers Regulation (FDRE, 2009)	• Intends to facilitate farmers' and communities' access to ex situ and in situ/on-farm PGRFA • Provides a special access permit for the same resources (for noncommercial purpose) for national public research institutions and intergovernmental institutions based in Ethiopia to enhance research and development of the country	• Establishes that the ownership of genetic resources lies with the state and that the ownership of community knowledge lies with those communities • Asserts that access to PGRFA is subject to (a) prior informed consent of the competent authority (EBI); (b) benefit sharing agreement; and, (c) for international users, a letter from the competent authority of the applicant's domicile assuring that it shall uphold and enforce the access obligations[b]
The second Growth and Transformation Plan/GTP II (FDRE, 2016)	• Ensures community participation to increase conservation and sustainable use of biodiversity	• Aims to increase access and benefit sharing licenses to meet food security goals and economic growth
National Biodiversity Action Plan (EBI, 2015)	• Sets target to increase by 35% access to potential genetic materials for research and development or for noncommercial purpose	• Sets target to increase by 39% access to potential genetic materials for access and equitable benefit sharing or for commercial purpose
Plant Breeders' Rights Proclamation (FDRE, 2006b, 2017)[c]	• Recognizes the enormous contribution of smallholder farmer and pastoral communities in conserving PGRFA, and provides them the right to save, use, exchange, and sell farm-saved seed	• Gives plant breeders the right to protect new plant varieties, and exclusive rights to produce for market and/or sell the protected seed or the propagating material of the protected variety

(Continues)

TABLE 1 (Continued)

Policy framework	Global commons perspective	National ownership perspective
	of any variety (including protected varieties) at noncommercial scale	
Draft National seed policy (MoA, 2019a)[d]	• Ensures conservation and sustainable use of PGRFA, promotes diverse seed systems, protects community knowledge and farmers' and pastoralists' rights in agreement with international agreements • Require participation of farmers and pastoralists in the identification, registration, conservation, and sustainable utilization of traditional varieties as well as development of new plant varieties	• Asserts national sovereignty over genetic resources and stresses the need to ensure benefit sharing from these resources for the stewards • Aims to establish a traceability mechanism for identification of PGRFA used in new plant varieties that plant breeders wish to protect

Abbreviation: ABS, Access and Benefit Sharing; CBD, Convention on Biological Diversity; EBI, Ethiopian Biodiversity Institute; PGR, Plant Genetic Resource; PGRFA, Plant Genetic Resources for Food and Agriculture.
[a]The proclamation was enacted mainly to promote implementation of National Seed Policy objectives. But an additional clause was included as a matter of urgency to control export of germplasm until the Access law was enacted.
[b]The access obligations include disclosure of the origin of the genetic resource and/or community knowledge used for developing commercial products in cases of application for commercial property protection and sharing of the benefits derived from the commercial product.
[c]Revised in 2017 to conform with WTO's TRIPS agreement.
[d]Revised in 2019 to accommodate policies and regulations adopted during the last two decades.

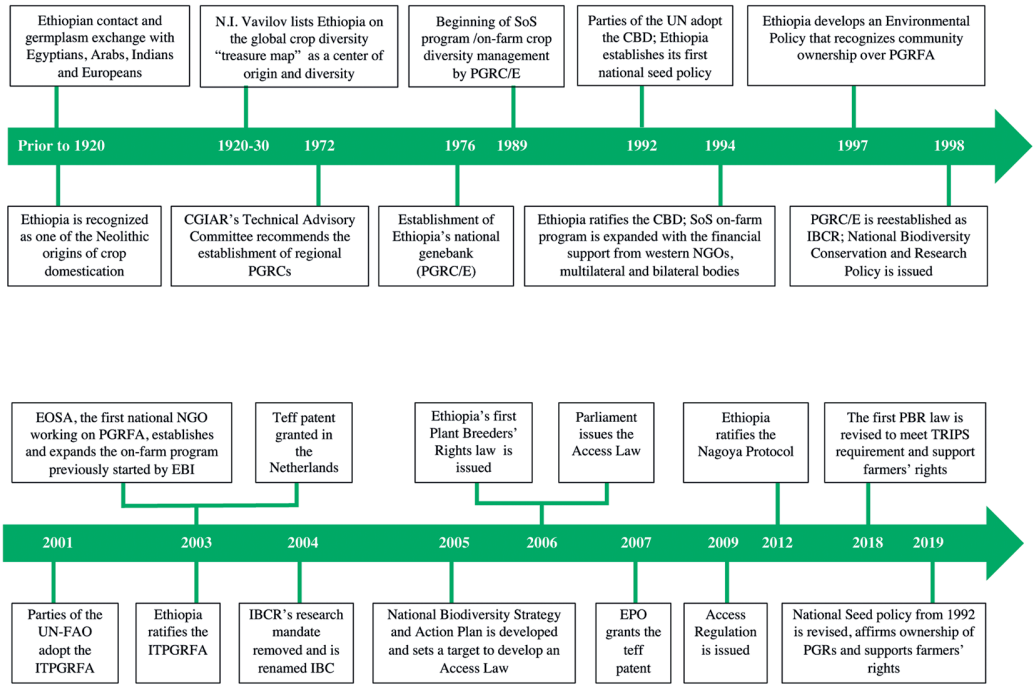

FIGURE 2 Timeline of major historical landmarks of the plant genetic resources movement in Ethiopia [Color figure can be viewed at wileyonlinelibrary.com]

biodiversity conservation and research policy (FDRE, 1998a) were the first formal documents to clearly assert national sovereignty over genetic resources within the country's jurisdiction. These policies outlined the need to promulgate necessary legislations and regulations on ABS, biosafety, and plant breeders', farmers', and community rights. Later in 2005, the national biodiversity strategy and action plan (IBC, 2005) established clear targets for creating these laws and regulations. This led to the implementation of two access legislations: the Proclamation to provide for Access to Genetic Resources and Community Knowledge, and Community Rights—hereinafter the Access Law (FDRE, 2006a)—and the Council of ministers Regulation on Access to Genetic Resources and Community Knowledge, and Community Rights—hereinafter the Access Regulation (FDRE, 2009).

According to the access legislations, EBI is mandated to issue permits for export and import of genetic resources, to develop directives and guidelines on ABS (e.g., IBC, 2012b), to promote high-value genetic resources for benefit sharing and to advise the government (FDRE, 2004). To implement this, EBI created a new directorate for genetic resource ABS in addition to four other directorates for conservation and sustainable use (crop and horticulture, forest, animal, and microbial). The access laws are designed based on the African Model Law (Ekpere, 2000; OAU, 2000) and the Bonn Guidelines on ABS (CBD, 2002) that were developed to assist parties, governments, and other stakeholders to commit to the triple objective of conservation, sustainable use, and fair and equitable sharing of benefits deriving from the use of genetic resources. Ethiopian policy makers and technocrats consider that the Nagoya Protocol on ABS, which Ethiopia ratified 6 years later after its access law was issued (FDRE, 2012b), is in harmony with the ABS objective of MLS under the ITPGRFA. As the statement below shows, they believe that these laws are key to regulate access and export of germplasm out of Ethiopia and ensure equitable benefit sharing for its people:

> *We developed our Access Law before the Nagoya Protocol was adopted and fortunately, the Protocol was very much in line with our access law. The MLS under the ITPGRFA has no problem in principle. We think the Nagoya Protocol is fairer than the MLS of the ITPGRFA, and we prefer to use it for genetic resource transfer.*[9]

Ethiopian access legislations are unique in Africa in that they aim to harmonize access regulation and implementation of breeders', farmers', and community rights by combining elements of the CBD and ITPGRFA. Lewis-Lettington (2008a) has argued that the legislations are biased toward the implementation of the CBD, but that they also include provisions aimed to simultaneously implement the MLS of the ITPGRFA. We agree with this argument. For example, PGRFA users can opt either for the Standard Material Transfer Agreement (SMTA) of the Treaty or for the Material Transfer Agreement (MTA) of the Nagoya protocol. However, the operation is different. Through the legislations, Ethiopia recognizes the importance of access to PGRFA; however, Ethiopia's main priority is to maximize benefits from germplasm export using ABS agreements. According to Gebre Egziabher et al. (2011):

> *Most African countries [including Ethiopia] do not consider access to PGRFA as a major benefit of the MLS mainly due to their limited financial and/or technological capacity to utilize PGRFA, both conserved in their own genebanks and those they could access from other countries.*

As a result, Ethiopia rarely uses SMTA of the MLS of the ITPGRFA for authorizing access to PGRFA, as explained by our informant at EBI:

> *At EBI, we use both SMTA and MTA for genetic resource transfer and ABS. However, most of the agreements, especially ABS agreements for commercial purposes, are signed using MTA of the Nagoya*

[9]Personal interview with a government official of the EBI (Addis Ababa, January 24, 2018).

> *protocol. Very few agreements are made using SMTA, and it is mostly for germplasm transfer for breeding, education and training purposes.*[10]

In practice, the preferred option are bilateral ABS agreements as provided for by the Nagoya Protocol, since these are made directly with commercial actors and allow the government to obtain monetary benefits that can be used to strengthen the national capacity for ex situ conservation and on-farm management of PGRFA.[11] This is because the MLS de-links the germplasm provider country and its PGRFA stewards from direct benefit sharing from a commercial actor. Furthermore, the appropriateness of a competitive project proposal approach to meet challenges related to distributional equity have been the subject of debate in the past few years (Louafi, 2013). This constitutes one of the design problems identified by Halewood et al. (2013a), which we discuss later in this paper.

The outstanding question surrounding this strategy lies in how Ethiopia can create a market for its genetic resources and implement benefit sharing (especially monetary benefit sharing) from use of these resources. We turn to this question in the next section, distinguishing between access for national users of Ethiopia's PGRFA (i.e., Ethiopian local communities, national public research institutions, intergovernmental institutions, companies, and other users based in Ethiopia) and access for international (nonresident) users.

3.3 | A PGRFA access paradox?

The Access Law grants exemption from obtaining permits for customary PGRFA use by and among Ethiopian local communities (FDRE, 2006a, Article 4). This exemption is meant to facilitate farmers' access to ex situ collections conserved at the national genebank and strengthen the link between the genebank and on-farm management of crop diversity by farmers,[12] an approach that has existed in Ethiopia since before the enactment of the access legislations (Westengen, Skarbø, Teshome & Berg, 2018; Worede, 1998). In addition, national public research institutions, including universities and intergovernmental institutions based in Ethiopia, get a special access permit (not exemption) for facilitated access to PGRFA to enhance research and development of the country, that is, for the noncommercial purpose (Article 15). However, they are required to ensure participation of relevant local institutions as a precondition for access.[13] Two key informants describe the rationale for giving facilitated access for local PGRFA users as follows:

> *The most precious resource we have is genetic resources. We believe that Ethiopia has unique genetic resources, although our knowledge of them is incomplete, and we have not used all of them meaningfully for the country's development—socially and economically. These resources are the basis of all our economic relations, in particular coffee, beans and oilseeds are a few important export crops to mention. Therefore, we believe that we need to maximize use of these important resources locally and manage them carefully.*[14,15]

Facilitated access for local PGRFA users is an effort to implement national targets for food security and economic growth as outlined in the country's growth and transformation plan (FDRE, 2016). As a result, the enactment of the Access Law maintains the same access to PGRFA for national users as before, except adding

[10]Personal interview with a government official of the EBI (Addis Ababa, January 24, 2018).

[11]Personal interview with a government official of the EBI (Addis Ababa, January 24, 2018).

[12]Personal interview with a government official of the EBI (Addis Ababa, January 24, 2018).

[13]Personal interview with a government official of the EBI (Addis Ababa, January 24, 2018).

[14]Personal interview with a government official of the Ministry of Environment, Forest and Climate Change (Addis Ababa, January 15, 2018).

[15]Personal interview with a government official of the Ministry of Environment, Forest and Climate Change (Addis Ababa, January 15, 2018).

administrative burden, and, in the case of access for commercial purpose, the requirement to share benefits. The government of Ethiopia also expects that nonmonetary benefits (i.e., knowledge, skill, products and technologies, equipment, and infrastructure) will increase due to the requirement for intergovernmental institutions and companies based in Ethiopia to ensure participation of local institutions in their research (Article 19).

For international PGRFA users, the access legislations stipulate several conditions, which make access much more restrictive.[16] First, no international users shall access genetic resources or community knowledge unless in possession of a written access permit granted by EBI based on prior informed consent (FDRE, 2006a, Article 11). Second, to obtain the access permit, international users "must present a letter from the competent authority of (their) national states or that of (their) domicile assuring that it shall uphold and enforce the access obligations of the applicant." The intention is to transfer the responsibility for implementing specific ABS agreements made with international users to the authority in the applicant's own country (Article 12.4). For instance, in cases of change in use of genetic resources (e.g., from research to commercial purpose, requiring IPR protection), the applicant's country is expected to ensure the applicant's compliance with Prior Informed Consent and Mutually Agreed Terms of the provider country, and share benefits with the donor country based on the MTA (Nijar, 2011, p. 24). Third, after the permit is granted, international users must be accompanied by personnel from EBI or another relevant Ethiopian institution during exploration and collection of PGRFA and associated traditional knowledge (FDRE, 2006a, Article 12). In addition, local communities, regional administration units at different levels, postal service institutions, quarantine control institutions, and customs officers bear specific responsibilities to control access based on the permit provided by EBI (FDRE, 2006a, Article 28–30). While this surveillance can be viewed as distrust toward international PGRFA users, EBI argues that it is an effort to implement the obligation to ensure Prior Informed Consent with the local communities.[17] The final condition that makes access to Ethiopian materials stringent is the rigorous penalty for infractions, which ranges from 3 months to 12 years of imprisonment or a fine of 5,000 to 100,000 ETB,[18] depending on the type of genetic resources involved (e.g., endemic or nonendemic) and the "circumstance and the gravity of the offence" (FDRE, 2006a, Article 35).

One top government official explains Ethiopia's restrictive policy measures concerning access for international PGRFA users as a reaction to shortfalls in transparency, trust and accountability at the international level:

> *Some people overstate Ethiopia's position and blame us for a global challenge we have common responsibility for. The preconditions for users of our germplasm are fulfilment of the requirements specified in our Access Law and the international agreements. We do not understand the basis for some of their accusations. Ethiopia's door has been, and will always be, open for all PGRFA users. However, we follow a precautionary approach. In other words, we need to have awareness and develop trust before we give germplasm to international PGRFA users. Unfortunately, we do not see that western countries are ready for honest, transparent and accountable ABS arrangements. Rather they increase our suspicion from time to time by delaying decisions we need to make about benefit sharing. They do this by denying clear, responsible and accountable commitments in ABS agreements. Our best example is the patent granted by the European Patent Office (EPO) on Ethiopian* teff *in Europe. International agreements can govern us, but not gentlemen's agreements. Western actors often push the international agreements to the side and try to have a gentlemen's agreement. The conditions for the agreements we make on access, and the support we get for conservation of PGRFA, are different. But, they want to link and mix everything in bilateral and other agreements.*[19]

[16]In addition to the Access legislations, EBI developed an access guideline (IBC, 2012b) for detailed information on various procedures for access.

[17]Personal interview with a government official of the Ministry of Environment, Forest and Climate Change (Addis Ababa, January 15, 2018).

[18]At the time of writing, 1USD = 28.5 ETB.

[19]Personal interview with a government official of the Ministry of Environment, Forest and Climate Change (Addis Ababa, January 15, 2018).

EBI officials indicated to us that between 1976 and 2018, a total of 200,234 accessions of different crop species were distributed to international (20%) and national (80%) PGRFA users for crop improvement programs and research purposes. However, we could not obtain more detailed information about germplasm distribution from EBI to examine whether access to Ethiopian germplasm by different users changed following the enactment of the Access Law in 2006.

We see that Ethiopia, like many other countries in the Global South, holds deep distrust toward the current systems. This is due to past experience of extremely divergent views between the Global North and South during negotiation on farmers' rights and ABS at the international level (Gebre Egziabher et al., 2011; Gebreselassie, 2009; Joseph, 2010; Tully, 2003; Zerbe, 2007). It is also due to the lessons Ethiopia learned from failed ABS agreements after a Dutch company patented genetic resources of its cultural keystone crop species, *teff* (see Andersen & Winge, 2012; Dalle, 2010). However, this same strategy for restricting access appears to have also limited the monetary benefits gained. Indeed, Ethiopia has not yet received monetary benefit sharing using either SMTA or MTA, which, according to an informant at EBI, may lead to a relaxing of the regulations:

> *At the beginning, everybody thought there would be many companies that could be interested in our PGRFA. In the past years, we have signed a few ABS agreements with local companies who shared monetary benefits with local communities for accessing wild plant genetic resources for industrial application. There has been no monetary benefit from PGRFA. Because of this, an internal process started in September 2018 to revise the Biodiversity Policy and the Access Law. There will be many changes. One of the major changes will be to remove the requirement for a letter from international users' competent authority of (their) national states for granting access permits.*[20]

3.4 | Balancing plant breeders' rights and farmers' rights: Complementarity for the new commons

We have shown that the Ethiopian access legislations have imposed increasing restrictions for international users' access to PGRFA, while national users' access has remained largely unchanged. At a national level, Ethiopia also does well in terms of protecting the rights of farmers, through two legislations that deal with IPRs. The first is the Inventions, Minor Inventions and Industrial Designs proclamation of Ethiopia—hereinafter the patent law (FDRE, 1995a). This law prohibits patentability of "plant varieties" and "essentially biological processes" for the production of plants (Chapter 2, Article 4.1b). The Ethiopian government position is clear in that patenting lifeforms is prohibited, and the lack of patent application confirms this position.[21]

The second law, issued by the government in 2006, is the Plant Breeders' Rights Proclamation—hereinafter the PBR law (FDRE, 2006b). This law was revised in 2017 (FDRE, 2017) to better harmonize with the TRIPS requirement for "effective" sui generis[22] IPRs protection of plant varieties due to the country's plan to accede to the WTO.[23] These laws and other legal frameworks related to PGRFA access were reiterated in the government seed system development strategy (MoA & ATA, 2013) and harmonized in a recent draft seed policy documents (MoA, 2019a). In general, the purpose of the PBR law is twofold. Primarily, it aims to encourage breeding of new varieties of plants and to attract the private sector, as a complement to the dominant public research and parastatal

[20]Skype interview with a government official of the EBI (May 1, 2019).

[21]Personal interview with a government official of the EBI (Addis Ababa, January 24, 2018).

[22]The TRIPS agreement of the WTO permit member countries to refrain from stringent plant variety protection laws, namely patent and adopt an effective sui generis system of protection. Known literally as "its own kind" or "unique," a sui generis system is an IPR system that is enforceable, nondiscriminatory with respect to the country of origin of the applicant and granting protection of new plant varieties (Repetto & Cavalcanti, 2000).

[23]Personal interview with a government official of the Ministry of Agriculture (MoA; Addis Ababa, February 1, 2018).

seed companies, particularly for the emerging flower and horticulture industry (Alemu & Ayele, 2018; Beko, Hospes, & de Jonge, 2016). In addition, it aims "to maintain the centuries old customary knowledge and practice of saving, using and exchanging seed by farmers (…) to conserve agrobiodiversity (…) for future use to develop new plant varieties [while] side by side promoting plant breeders' rights" (FDRE, 2017: Preamble; Lewis-Lettington, 2008b). Similar to the Access Law, Ethiopia's PBR law was developed based on the African model law (Ekpere, 2001), designed to put a check on expansive PBRs and to ensure rights of communities, farmers, breeders, and access to biological resources and benefit sharing. As sui generis rights (Louwaars, 1998), the new PBR law (FDRE, 2017) recognizes farmers' rights to noncommercial use of protected varieties. Smallholder farmers, whose livelihoods depend predominantly on agriculture, use family labor, and own 10 ha of land or less "shall have the right to save, use, exchange and sell farm-saved seed of any variety on the non-commercial marketing" (Article 2.13 and 7.1). In addition, "any farmer shall have the right to save and use farm-saved seed of any variety of food crops and other species that directly [supports] his/(her) livelihoods" (Article 7.1 and 7.2). Moreover, breeders' exemptions allow the use of protected varieties for further breeding, research, and educational purpose (Article 6.2 and 6.3). From this point of view, we do not find the Ethiopian PBR law is "inhibitive and a failed instrument in providing sufficient guarantee for farmers' rights" as argued in recent studies (Gobena & Rao, 2019a, 2019b).

Unlike many individual African countries and the African Intellectual Property Organization with its 17 members, the government of Ethiopia has no plan to join UPOV and adopt its 1991 act,[24] which provides expansive plant breeders' rights. As one top government official phrases it, this position is due to national socioeconomic priorities:

> *Ethiopia is interested to accede to WTO, not UPOV. It is very clear that UPOV stands for the private sector interests (…) it is a Union for plant breeders and seed industry, and it suits multinationals and developed countries. However, WTO is the main body for global trade rules between all nations. Therefore, we are interested in domesticating WTO's TRIPS, as it requires a system of "effective"* sui generis *for plant variety protection. TRIPS is flexible, and it suits our needs to support public seed sector and national small and medium private companies. We are aware that our export market can expand for some products if we become a UPOV member. However, we have more pressing priorities than just market in limited plant products. In fact, we used UPOV's tools for developing our PBR law where it suited our situation. But not all of it. UPOV does not support the idea of giving full rights to farmers to use all seeds. This is contrary to our biodiversity policy, seed policy, seed sector strategies, plans and PBR law. Joining UPOV 91 means putting millions of Ethiopian smallholder farmers' livelihoods and the country's food security in jeopardy. So, we have a problem with UPOV, and it is improper for Ethiopia's situation.*[25]

The Ethiopian patent and PBR laws tend to support the new commons approach by prohibiting patent on lifeforms and making protected varieties accessible for smallholder farmers instead of the stringent ownership trend through IPRs. The legislations also conceptualize farmers' rights as an important protection for smallholder agricultural production and food security. Indeed, the government is committed to implement farmers' rights (Feyissa, 2006) and its policy of pluralistic seed system that aims to ensure complementarity of formal and farmers' seed systems (MoA and ATA, 2013; Otieno et al., 2017). This makes Ethiopia exceptional with regard to a global survey recently conducted by the ITPGRFA Secretariat that concluded that the conflict between national and international policies (e.g., MTAs, IPRs, and Farmers' Rights) is one of the major bottlenecks in the Treaty's MLS (Kell, Marino, & Maxted, 2017). Ethiopia's effort to create synergy between its Access Law and PBRs Law is, thus, an attempt to resolve this conflict, which has been created by overlapping international policies. For instance, the

[24]The 1991 act is the only UPOV act open for new membership and the older version of the UPOV acts are not open for new countries who want to join the Union.

[25]Personal interview with a government official of the MoA (Addis Ababa, February 1, 2018).

World Intellectual Property Organization's (WIPO) patent system has been unwilling to include ABS mechanisms under the MLS of ITPGRFA and the CBD, nor has it found other ways to actively approach the interface between commercial use of PGRFA and ABS (Andersen et al., 2010). Similarly, the UPOV system has not taken clear measures to put in place obligations on users of PGRFA. In 2013, the Governing Body of the ITPGRFA (through the Treaty's Secretary) requested UPOV and WIPO to jointly identify possible areas of interrelations among their respective international instruments (FAO, 2013b). Since then, negotiations and consultation have been on-going without results (Medaglia, Oguamanam, Rukundo, & Perron-Welch, 2019). As a result, countries like Ethiopia have attempted to resolve conflicts between national and international policy by developing national IPR protection systems that require disclosure of origin or legal provenance of source material for IPR applications.

4 | HISTORICAL, POLITICAL, AND ECONOMIC FACTORS INFLUENCING PGRFA ACCESS GOVERNANCE IN ETHIOPIA

We have seen that from the early 1990s until the present, Ethiopia decided to go against the grain by establishing restrictive access policies and a sui generis PBR law. In this section, we explore the historical, political, and economic factors that have influenced Ethiopia's governance of access to PGRFA. We identify three main factors that underlie this position: the influence of narratives about Ethiopia as a biodiversity treasure trove on the Ethiopian cultural identity; the economic importance of agriculture in general and of agriculture based on genetic resources with origin in Ethiopia in particular and; the emergence of an alternative on-farm PGRFA movement and its influence on policies relating to IPR and access.

4.1 | From Vavilov to self-awareness as a biodiverse country

Since the first foreign plant explorers arrived in Ethiopia in the 16th century, many historians and archeologists have identified Ethiopia as one of the Neolithic centers of crop domestication (Engels & Hawkes, 1991). Evidence drawn from archeology, biogeography, genetics, linguistics, cultural anthropology, and other contemporary social science studies of seed use confirm ancient cultivation of crops originating in Ethiopia (Boardman, 1999; D'Andrea, Lyons, Haile, & Butler, 1999; Diamond, 1999; Ehret, 1979; Finneran, 2007; Harlan, 1969; Harris, 1967; Harrower, McCorriston, & D'Andrea, 2010; Lyons & D'andrea, 2003; McCann, 1995; Munson, Harlan, De Wet, & Stemler, 1980; Simoons, 1965; Zohary, Hopf, & Weiss, 2012). Ethiopia's place on the global crop diversity "treasure map" was solidified by the contributions of Russian plant breeder N. I. Vavilov, who collected over 50,000 seed samples of different crop species in 50 expeditions throughout Africa, the Americas, Asia, Europe, and Mediterranean area (Pistorius, 1997). He visited "Abyssinia" (current Ethiopia) in 1926 and encountered a uniquely high plant diversity and considered the country as one of the centers of origin and diversity for several food crops (Vavilov 1926). Domesticated crops for which Ethiopia is best known as a center of origin include anchote (*Coccinia abyssinica*), arabica coffee or buna (*Coffea arabica*), Enset (*Ensete ventricosum*), teff (*Eragrostis tef*), niger seed or noug (*Guizotia abyssinica*), and gesho (*Rhamnus prinoides*) (Altieri & Koohafkan, 2017, pp. 2–3; D'Andrea, 2008; Diriba, 2018, pp. 83–86; Edwards, 1991; Ehret, 1979).

Later, other scholars revisited Vavilov's concept of center of origin and they confirmed that Ethiopia is the center of origin for the above crops while being the center of diversity for crops that originated elsewhere (Harlan, 1971, 1998; Hawkes, 1998). The latter include barley, emmer wheat, sorghum, finger millet, faba bean, linseed, sesame, safflower, chickpea, lentil, cowpea, flaxseeds, grass pea, and fenugreek (Abdi, 2011; Engels & Hawkes, 1991; Frankel, Brown, & Burdon, 1995, p. 58–59; Harlan, 1969, 1975b, p. 36; Ladizinsky, 2012; von Wettberg et al., 2018; WCMC, 1992; Zohary, 1970). For barley and emmer wheat, the diversity in Ethiopia was considered to be

higher than in their centers of origin (Engels, 1991; Harlan, 1971). Likewise, Ethiopia shelters important gene pools of crop wild relatives for many species, including cereals, pulses, oilseeds, vegetables, tubers, fruits, spices, stimulants, and fibers species (EBI, 2015, pp.16–21; Edwards, 1991; von Wettberg et al., 2018). Although very few cereals originated in Africa, half of the continent's contribution to global cereal crop species diversity (i.e., large-seeded grass) comes from Ethiopia (Diamond, 1999, p. 126; McCann, 2011).

Western visitors often described the genetic diversity of crops in Ethiopia as enormous, unique, unusual, incredible, and amazing treasures of nature (Harlan, 1969; Hummer, 2015; Nabhan, 2009, pp. 93–112). Today, this romantic image of Ethiopia's genetic resources makes an introductory paragraph in official statements, news articles (The Economist, 1998), scholarly literature (Knowles, 1969; Samberg, Shennan, & Zavaleta, 2013), political ideology books (Ahmed, 2019, p. 209), and country reports to the secretariats of the CBD and ITPGRFA (EBI, 2015; IBC, 2012a). This has created curiosity for many crop diversity enthusiasts and commercial actors. For instance, Harlan (1969) cites a narrative paragraph from the description given by N. I. Vavilov after his expedition to Ethiopia:

> *On the whole terrestrial globe, the Abyssinian Centre is distinguished by its diversity of forms of hulled barley, violet-grained wheat, original races of peas, peculiar races of oats and by a series of cultivated endemic plants (…) Ethiopia is primarily a land of field crops (…) which exist in amazing diversity of varieties.*

Visitors' often sentimental expressions about Ethiopia's crop diversity mirror what Tibebu (1996) asserts as a Western image of Ethiopia's isolation, where varied geography[26] is cited to explain why Ethiopia is an unconquered land of millennial independence and civilization (Milkias & Metaferia, 2005). Specifically, Ethiopia's endowment of rich genetic diversity is frequently related with the early civilization of its people, which resided in several isolated places and started crop domestication (Crummey, 1983; D'Andrea, 2008; Jaenen, 1958; Velissariou, 1954; WCMC, 1992).

Outsiders' testimonials of the uniqueness of Ethiopia's plant diversity and the country's ancient history and independence (Milkias & Metaferia, 2005; Rubenson, 1978; Tibebu, 1996) often establish the background for Ethiopians' own discussions and scientific writings related to PGRFA. Indeed, these testimonials have been key for the country's genetic resource scientists, technocrats, and politicians to become aware of the global importance of their country's germplasm (Dubale & Teketay, 2000; Engels & Hawkes, 1991; Gebrekidan, 1973; Harlan, 1969). For instance, Ethiopians commonly express pride over their seed heritage by citing the example of how the yellow dwarf virus resistant barley from Ethiopia was crossed with a Californian cultivar and saved Californian farmers $160 million per year (Hammer & Teklu, 2008; Montenegro de Wit, 2016; Nabhan, 2009).

This self-awareness as a biodiversity-rich country is a quotidian sentiment among Ethiopians that affects their perception in terms of policies and practices on PGRFA. Dr. Melaku Worede, a renowned geneticist and plant breeder, expressed how this awareness influenced his career in his acceptance speech at the Right Livelihood Award ceremony (Worede, 1989):

> *I started to actively work on PGRs some 23 years ago, the motivation to do so goes back to my Freshman Year in College, some 32 years ago. It started when a visiting Professor, from Oklahoma University, USA, to whom, during delivery of a speech he was giving on Agriculture, I asked why the big, well-developed countries are not giving us their superior varieties of crops so that we produce more in Ethiopia? He answered by telling a story of a crew that was sailing on a sea, out of water supply. In desperate need for water, the crew kept on calling for help with the radio. Being advised to drop the bucket right where they were, the crew was surprised to know what they were sailing on was fresh water – and the answer given to*

[26]Geographical diversity such as inaccessible terrain, rocky plateau, rolling plains, impenetrable high and rugged mountain fortress, deep gorges, valleys, and surrounding deserts.

> *my question was, drop your bucket right where you are. I always kept this important advice in mind in subsequent years as I conducted research, taught genetics and plant breeding and as the director of the national genebank. The Award bestowed upon me is a tremendous support and encouragement to my country and myself (…) with a view to provide in sustainable way useful germplasm to breeding programmes both in Ethiopia and the world community at large.*

In this narrative, we see how an American professor's comment about Ethiopia's immense crop genetic diversity kindled Worede's own self-awareness about the global importance of Ethiopia's genetic resources, an insight that he taught to other Ethiopians, something that many other technocrats and policy experts continue to do to this day.

In 2010, Mr. Sileshi Getahun, state minister of Ethiopia's MoA said the following in his speech at the global consultation meeting on farmers' rights in Addis Ababa (Andersen & Winge, 2010):

> *Ethiopia was named one of the 12 centers of crop diversity in the world by N.I. Vavilov, and the communal use of PGRFA has contributed to the existing diversity of farmers' varieties (…) farmers play a central role in the conservation, sustainable use and diversification of crop varieties. Selection and utilization have been part of the culture for generations, and farmers' varieties have been important sources of material for breeding. But farmers have not benefitted from the commercialization of these resources (…) the government sees the protection of the country's genetic resources is important. Towards this end the government has enacted the Environmental Policy, the National Policy on Biodiversity Conservation and Research, the Plant Breeders' rights and Community Rights to equitably participate in benefit-sharing in its laws and policies.*

In 2013, in an interview with the secretariat of ITPGRFA he said (FAO, 2013a):

> *Many countries are benefiting from barley and other crops from Ethiopia. In the same way, Ethiopia and other African countries are strongly dependent upon crops such as maize and sugarcane that originated from other continents. For our mutual benefit it is, therefore, necessary that we cooperate as good and equal partners in a way that builds trust to manage PGRFA in a sustainable manner.*

Such self-awareness of PGRFA endowment, sovereign ownership over these resources and the principle of sovereign equality of countries is central for Ethiopian actors. These perceptions in turn shape national policies, strategies, and laws as well as Ethiopia's engagement with its international partners. Today, several Ethiopian policies and laws related to seeds and genetic resources are different from other African countries. Very few seed companies operate in seed distribution due to lack of a liberalized seed market policy in Ethiopia (Alemu, 2011b; MoA, 2019b; Scoones & Thompson, 2011). The government has chosen a policy that promotes pluralistic seed systems aiming at implementing farmers' rights and on-farm management of crop diversity (Alemu, 2016; Otieno et al., 2017). Ethiopian negotiators have influenced early regional and international negotiations in favor of national control over own genetic resources, promoting farmers', and community rights (Chasek, McGraw, & Prather, 1996; de Fontaubert, Ivers, Megateli, & Prather, 1997; Fry, Ivers, Megateli, & Prather, 1998; Gebre Egziabher et al., 2011). Thus, for Ethiopians the issue of PGRFA, especially fair and equitable utilization, has always been important in international discussions. Technocrats and policy makers strive for ensuring sovereign ownership rights, and some of them openly confronted great powers in international negotiations (Gebre Egziabher, 2000; GRAIN, 2001). This position has also resulted in changes concerning conservation strategies in Ethiopia. In the next section, we examine how the ex situ conservation focus from the 1960s to early 1980s was associated with a "commons" ownership notion.

4.2 | Countering genetic erosion and supporting conventional plant breeding: The arrival of ex situ conservation

Inspired by Vavilov's work, many expeditions were conducted in Ethiopia to collect local varieties with the intention to find suitable genetic defenses against plant diseases and other desirable quality characteristics in the center of origin and diversity. For instance, a network of scientists in Western Europe (especially the United Kingdom), United States, Australia, and the Soviet Union (USSR) introduced genetic diversity from Ethiopia for their national plant breeding and genetic study in the 1940s and 1950s. According to Sidorov (1960), drought-resistant forms of wheat, barley, finger millet, pearl millet, and sorghum from Ethiopia were recommended for introduction as breeding material in the USSR. In addition, niger seed was introduced as an oil crop in southern USSR based on a study conducted on crop plants of Ethiopia. At the time, an organized group of scientists such as the European Society for Research and Plant Breeding from Europe and scientists from the United States took initiative to establish national plant introduction stations. These stations became not only centers for germplasm exchange in countries of the Global North, but also the basis for building modern genebanks later in the 1960s and 1970s (Pistorius, 1997).

Plant breeding on, and genetic studies of, Ethiopian germplasm was encouraging, in that genes conferring resistance to several plant diseases and many desirable quality characters of economic importance were discovered (Asfaw, 1999; Borrell, 2012; Charrier, 1980; Frankel, 1977; Gebre-Mariam, 1986; Harlan, 1976, 1977; Jørgensen, 1976, 1977; Mekbib, 1986; Mengistu & Gebrekidan, 1980; Negassa, 1985; Qualset, 1975; van der Graaff, 1981). For instance, Harlan (1976) documented genes regulating high lysine and protein contents in Ethiopian barley and sorghum. A comprehensive list of such early research results on several crops from Ethiopia is found in Negassa (1985).

While genetic gains were made from Ethiopian germplasm to develop improved varieties, scientists also recognized the risk of displacement of local genetic diversity by a few improved varieties, and thus predicted the inevitable consequence of genetic erosion as early as 1936. Harlan and Martini (1936, p. 317) wrote: "when new barleys replace those grown by the farmers of Ethiopia or Tibet, the world will have lost something irreplaceable." Starting in the 1960s, the wider adoption of modern varieties and mono-cropping with new hybrid strains was seen as the biggest threat to genetic diversity and received recognition from the Food and Agriculture Organization of the United Nations (FAO; Fenzi & Bonneuil, 2016; Scarascia-Mugnozza et al., 2002). Alluding to Vavilov's work on the world's centers of origin and genetic diversity, many scientists, including those involved in early exploration and germplasm collection in Ethiopia, expressed the dangers of genetic erosion. At the time, these scientists saw displacement of local varieties by new uniform varieties on an international scale as the biggest threat for global crop diversity (Chedd, 1970; Fowler & Mooney, 1990; Frankel, 1970; Harlan, 1972, 1975a; Miller, 1973; Montenegro de Wit, 2016; Wade, 1974). This concern dominated the 1960s and 1970s discussions among PGR scientists (mainly breeders and geneticists) and they constantly called for the collection and ex situ conservation of significant gene pools in centers of origin and diversity (Fenzi & Bonneuil, 2016). During this period (also today), Ethiopia was seen as the most important center of genetic diversity for durum wheat and barley due to genetic erosion happening in other parts of the world (Edwards, 1991).

This awareness at the international level led to a meeting in Beltsville, Maryland in 1972, where an ad hoc Technical Advisory Committee (TAC) of the CGIAR presented a global plan of action for collection, evaluation, and conservation of PGRs in line with an earlier proposal made by FAO. The TAC also recommended the establishment of a global network of Plant Genetic Resources Centers that would equally involve countries in the Global South and North (Bommer, 1991). Ethiopia was one of the priority countries selected by the TAC to establish such a center for collection, evaluation, and conservation of PGRs in East Africa and adjacent regions. The proposal to support establishment of the PGRC/E—now EBI—was accepted by German bilateral aid in 1976 and an agreement was signed between the Ethiopian Institute of Agricultural Research (EIAR) for the government of Ethiopia and the German Agency for Technical Cooperation (GTZ) for the government of Germany (Engels, 1984). In addition to

collection, evaluation and conservation, the agreement included a provision for the exchange of germplasm with other institutions in and outside Ethiopia for plant breeding and genetic studies. The export of Ethiopian germplasm was further facilitated through collaboration with the International Board for Plant Genetic Resources (IBPGR).[27]

It is important to note that the purpose of ex situ conservation during the establishment of EBI and the decade that followed was to serve the breeding, delivery, and adoption of modern varieties through conventional plant breeding programs and formal seed systems (PGRC/E, 1986). EBI was mainly providing germplasm to the EIAR and breeders abroad, especially in the CGIAR centers. The 10-year anniversary report of the PGRC/E (1986) states that:

> *Specific, or pointed, collecting missions have been conducted in various regions of the country and, based on recognized breeding demands, have dealt primarily with the major cereals, oil crops and pulses. EBI conducted such missions jointly with plant breeders representing various national and international universities and agricultural institutions. The multiplication of the collected germplasm is carried out on the respective breeding stations in close cooperation with the concerned breeder.*

This shows that the respective breeding stations and breeders determined priority crops and the conservation approach which followed, which was exclusively ex situ. Ex situ conservation became even more important to Ethiopia when the adoption of improved varieties (especially bread wheat) resulted in drastic displacement of local varieties (e.g., durum wheat) during the first attempt to bring Green Revolution to Ethiopia (Cohen, 1975; Demissie & Habtemariam, 1991). Similarly, at this time, EBI hinted about its plan to establish in situ conservation sites or "nature reserves" for coffee, forage, and forest species (PGRC/E, 1986) due to high deforestation and recalcitrance of their seeds to long-term storage (Frankel et al., 1995, p. 166). EBI established a coffee field genebank (field ex situ) the following decade and started a similar conservation plan for on-farm management of field crops in the late 1980s. In the next section, we examine how in situ started in Ethiopia and how this is associated with a shift from a commons approach toward the present "hyperownership" approach in Ethiopian PGRFA access governance.

4.3 | The emergence of an in situ approach: Competing pathways to PGR management

The emergence of in situ/on-farm management approach had a direct link to a severe drought that occurred in Ethiopia in the mid-1980s. PGR scientists and technocrats at EBI thought they were not doing enough to respond to the devastating drought and famine (Asfaw, 1999; Westengen, Hunduma, & Skarbø, 2017, p. 15; Worede, Tesemma, & Feyissa, 1999). This coincided with growing concerns within the international scientific community about the remoteness of genebanks and ex situ collections from farmers and dynamic farming systems, and increasing advocacy for in situ conservation (Altieri & Merrick, 1987). PGRFA scientists and technocrats within Ethiopia were self-critical of their own ex situ conservation strategy, which was unable to strengthen farmers' seed systems by injecting germplasm from the genebank (Fowler & Mooney, 1990, p. 206; Worede, Tesemma, & Feyissa, 2000). Thus, in the late 1980s, PGRFA scientists at EBI and their Canadian NGO partners, the Rural Advancement Fund International (RAFI) and Unitarian Service Committee of Canada (USC-Canada, called SeedChange since October 2019) started an in situ and on-farm management initiative "conservation through use" (WCMC, 1992, pp. 547–548; Worede, 1992). This happened three decades after the same alternative was turned down by FAO in favor of ex situ conservation, despite its promotion by prominent scientists such as Erna Bennett (Fenzi & Bonneuil,

[27]IBPGR (later renamed as IPGRI and now Bioversity) was an international scientific organization created in 1974 under the aegis of the CGIAR centers to establish national PGR programs and advance the global conservation and use of PGR for the benefit of present and future generations. CGIAR itself was established in 1971 from a growing network of International Agricultural Research Centers.

2016; Pistorius, 1997). Recalling how the PGR conservation pathway turned to accommodate in situ/on-farm, the then-director of EBI, Dr. Melaku Worede said:

> *The drought and famine that struck Ethiopia during the mid-1980s was a disaster, especially in the north-eastern (Welo) and northern (Tigray) parts of the country. Very few farmers did dig and hide their seeds underground before they migrated to the central, southern and western parts of the country. Many of the farmers were forced to either consume or sell their seeds in exchange for other commodities. When enough rain came two years later, and the people moved back to their homestead, they had nothing to plant. They had to depend on the grain and seed aid. That was another crisis, as the relief seeds planted did not fit the local agro-ecological conditions and resulted in crop loss. Then we asked ourselves: what are we doing if we cannot help our farmers during such a disaster? (…) we should do something. Since EBI was answerable to EIAR, we informed them. However, they told us that seed multiplication and distribution was not within EBI's mandate, and the Ethiopian Seed Corporation [now Ethiopian Seed Enterprise] was the one responsible. We refused and started Seed of Survival (SoS) program in 1989 with the financial support of USC-Canada, where we introduced great diversity of sorghum and maize from our collections at the genebank into farmers' seed system in Welo and Tigray (…) durum wheat and chickpea in the east central part of the country i.e. in east Shoa.*

The story told by Melaku illustrates the direct relevance of genebanks to strengthen farmers' seed systems and EBI's refocus on local management and the use of PGRFA. The aim of EBI became not only ex situ conservation to support formal plant breeding, but also the dynamic combination of ex situ conservation and on-farm management that utilizes farmers' practices and their social institutions. EBI's on-farm management project was not an easy operation indeed. Researchers and the management at the EIAR did not like that the in situ/on-farm initiative promoted the use of landraces among subsistence farmers. EIAR insisted that the main task of EBI should be ex situ conservation and making germplasm available for formal breeding, and that the promotion of varieties—and specifically modern varieties—was the mandate of EIAR, and not EBI's. Moreover, EBI scientists started advocating for in situ conservation and on-farm management together with civil society organizations at the international level, which we discuss below. This angered EIAR's management due to their research interest and collaboration with CGIAR centers, which at the time were supported mainly by ex situ conservation activities.[28]

Due to this conflict, EIAR, who had oversight over EBI, reduced the budget allocation to the genebank. However, EBI used external funding from USC-Canada to continue the SoS program, which reached out to 30,000 farmers (Chossudovsky, 2000) until it was closed down by the government in 1998. At the time, the genebank staff felt that the closing of the SoS program was due to the conflict with EIAR management.[29] But the in situ/on-farm initiative did not stop. A similar program supported by the Global Environment Facility started in 1994, and continued the program activities (IBC, 2007; UNDP, 1994), as did an Ethiopian NGO called Ethio-Organic Seed Action (EOSA) that was established by former EBI staff in 2003. EOSA has sustained the SoS program with the support of USC-Canada and the Development Fund of Norway until now. Other bilateral organizations (NORAD, GTZ, and CGN) and multilateral funders (FAO, UNDP, Bioversity International, and UNESCO) also supported in situ conservation and on-farm management of PGRs in Ethiopia (see Figure 2). These in situ conservation initiatives have been positive in terms of deploying varieties from the genebank to different farming systems (IBC, 2007; Worede, 1998). Although somewhat limited to specific localities, the in situ conservation and on-farm management of PGRs has become a common approach in Ethiopia due to continuous promotion by EBI and its international partners.

[28]Personal interview with former official of the EBI (Addis Ababa, February 23, 2018).

[29]Personal interview with a technical staff of a nongovernmental organization, Ethio-Organic Seed Action (Addis Ababa, January 31, 2018).

The approach also expanded to other countries in Africa, Asia, and Latin America where USC-Canada started supporting community-based food and seed security programs through deploying ex situ material and supporting in situ conservation (Worede, 1998). Ethiopia became a resource center to host trainees and share experiences in on-farm management through several international training workshops organized by USC-Canada in the 1990s for practitioners from about 30 countries (Dalle & Walsh, 2015). Renowned proponents of on-farm management of PGRs such as Melaku Worede of Ethiopia and Pat Mooney of Canada promoted the SoS program internationally, which later expanded to other countries and attracted several other donors in support of in situ/on-farm management of PGRs and farmers' seed systems as an alternative to formal seed system (Stegemann, 1996; Vernooy, Shrestha, & Sthapit, 2015).

This shows a gradual shift from a purely ex situ conservation development path to one which includes the on-farm management of genetic diversity to strengthen farmers' seed systems, both within Ethiopia and internationally. At a national level, EBI has played a key role and holds a sense of ownership over the in situ movement. This has motivated Ethiopian PGR scientists to promote in situ conservation and on-farm management of PGRFA, and has raised the relevance of EBI in the national seed policy dialogue and seed system development strategies (MoA and ATA, 2013; Worede, 1992; Worede et al., 2000). This has been one important factor that has influenced Ethiopia's position on IPR, in particular the concern to balance breeders' and farmers' rights. The shift from purely ex situ toward inclusion of a complementary in situ/on farm management approach is also an important part of the explanation for the implementation of an access governance regime that is liberal for national users, but restrictive for international users.

4.4 | Germplasm exchange: The international cooperation-distrust paradox

As we have seen from the history of ex situ conservation and as is apparent from the genebank holdings in Figure 1, for a long time Ethiopia shared its genetic resources openly and freely. Until the late 1980s, international plant explorers, tourists, diplomats, business people, and scientists who wanted to collect and take germplasm with them were free to do so. The national genebank continued this practice formally in the 1970s and 1980s. The following statement from EBI's 10-year anniversary report (PGRC/E, 1986) shows that germplasm transfer was based on a simple request, free and without any formal agreement:

> *Ethiopia adheres to the principle of free exchange of germplasm in accordance with its national policy. Germplasm is dispatched to or exchanged with foreign countries if a mutual interest in such an exchange exists. Germplasm requests should be forwarded to the Director of EBI with a detailed explanation of what is required. The coordination of germplasm distribution on the national level is also the responsibility of this unit.*

In terms of benefits, Ethiopia got direct support for basic infrastructure and human resource development at the national genebank from international collaborators.[30] In addition, Ethiopia benefited from the introduction of new germplasm materials such as rice (Alemu et al., 2018) and collaborative plant breeding efforts between CGIAR and EIAR, which helped to build national capacity in agricultural research (e.g., Gebre-Mariam, 1991; Wegary et al., 2011; Worku et al., 2002).

Concerns about the free exchange of germplasm were first recognized after the signing of the agreement between GTZ and EIAR for the establishment of PGRC/E (now EBI) in 1976. The agreement included a provision about the collection and exchange of germplasm with other institutions in and outside Ethiopia for plant breeding

[30]Personal interview with a former official of the EBI (Addis Ababa, February 23, 2018).

and genetic studies (Engels, 1984). At the time, massive transport of germplasm out of the country was controversial among genebank staff. This is because it was felt that there was not enough information where the exported germplasm was going, how it was used and for what purpose. Some people at EBI started to question and express suspicion about what benefits Ethiopia could gain from germplasm export:

> *We were excited about the establishment of the national genebank and the beginning of well-organized collection and conservation activities. The German expats proposed extensive collection of priority crops during the first phase of our agreement. The germplasm collection continued while the construction of the genebank was underway. Copies of each collected sample were sent to Germany and the remaining copies were stored in jute sacks in a temporary office at Arat Kilo in the main office building of the social security. The retained copies were all damaged due to improper storage conditions. At the time, no one questioned the massive export of germplasm to Germany. We were not aware, and we did not ask why we sent germplasm massively and how it was used. It should have been possible to have a sort of benefit sharing arrangement from use of Ethiopian germplasm, not only from Germany but also from other western countries who had access to our germplasm. The awareness about its use for developing commercial crops in Germany and elsewhere came much later when Ethiopians started to travel, see and hear success stories linked to materials acquired from Ethiopia. The question that many people asked was, why distribute Ethiopian germplasm from Germany to all rich countries, while the other countries benefiting from the germplasm were not supporting Ethiopian efforts. We needed much more support at the time.*[31]

In addition to this massive export of germplasm, another factor that heightened awareness about benefit sharing was the connection between genebank scientists and civil society actors during the development of the in situ PGR approach (see Table 2 for a precis on change of actors' perceptions and PGRFA governance in Ethiopia). This can be seen in the context of international debates that emerged in the 1970s and 1980s about IBPGR's political neutrality as coordinator of germplasm collection and exchange between countries (Fowler & Mooney, 1990; Lacy, 1995; Louafi, Bazile, & Noyer, 2013; Silva, 1997). At the time, IBPGR and CGIAR were supported through the World Bank by the government of the United States and the Ford and Rockefeller Foundations, and questions were raised about how germplasm collected by IBPGR was being used (Fenzi & Bonneuil, 2016; Louafi et al., 2013). Later in the 1980s, when the in situ approach was emerging in Ethiopia, some of these international critics were in contact with Ethiopian genebank scientists. These contacts played a significant role in creating awareness about commercial actors' interests in Ethiopian PGRs and their strategy to secure IPRs on commercial products. For instance, Pat Mooney, a Canadian activist who helped establish the SoS program with EBI, has been central in influencing the worldview of many delegates from the Global South (including Ethiopians). This was especially evident during the early renegotiation of the voluntary International Undertaking on Plant Genetic Resources for Food and Agriculture in the 1980s that led to the adoption of the legally binding instrument, the ITPGRFA in 2001 (Oberthür & Rosendal, 2014). Mooney (2011) states:

> *We were able to identify exactly how much germplasm of which crops every country in the world had either donated or received (…) overwhelmingly the South was a massive contributor of free germplasm, and that the North was actively using the germplasm to develop new varieties protected by IPR (…) I was able to go to literally every delegation in Africa, Asia and Latin America and hand them a note (…) showed them how much germplasm [their] country had donated and how much it had received—including a list of the countries to which their germplasm had gone.*

[31]Personal interview with former official of the EBI (Addis Ababa, February 23, 2018).

TABLE 2 Historical overview of change in actors' perceptions and PGRFA governance in Ethiopia.

	Plant explorers' discovery of "landraces" or "peasant seeds" and introduction of crops (16th century–1926)	Unfolding awareness as a biodiverse nation and representation on the global crop diversity "treasure map" (1926–1955)	Creating regional/national PGR center for conservation of raw material for breeding as natural commons and to manage genetic erosion (1955–1992)	From natural commons and free access to sovereign ownership a and control paradigm or private goods and restricted access (Since 1993)
Narrative frames	*Image of Ethiopia as isolated and inaccessible*: inaccessible terrain, rocky plateau, impenetrable mountain fortress, valleys, and surrounding deserts made it possible to hide its unique plants from rest of the world for a long time	*World's center of origin and diversity*: N. I. Vavilov found Ethiopia to be endowed with uniquely high plant genetic diversity for several food crops	*FAO policy on conservation*: one of the global environmental problems, that is, genetic erosion, can only be countered by establishing regional/national plant genetic resource centers, first in centers of origin	UN-CBD and UN-FAO concept of PGRs as the result of natural selection processes and the careful selection and inventive developments of farmers over millennia
	Archeological and historical studies: place Ethiopia within Neolithic cultures with agriculture antiquities; show that Ethiopia's unique indigenous peasant seeds are the result of selection of better-adapted indigenous plants and domestication	*Important pool of genes*: amazing diversity of varieties that have immense importance to the world for plant disease resistance, stress tolerance, and yield increase *Primitive Agriculture needs modernization*: Ethiopia's peasants need modern varieties	*Increasing distrust to FAO policy on crop diversity management*: South (e.g., Ethiopia) as the diversity provider and North as the manager and developer of genetic resources is exploitation	Sovereign right of Ethiopia to have control over and exploit its own genetic resources
			In situ *conservation and on-farm management*: deployment of ex situ collection for farmers as seed relief and for drought tolerance	Fair and equitable sharing of benefits from the use of Ethiopia's genetic resources and traditional knowledge
				Ethiopia can increase access to its PGRs to collect revenue for farmers and local communities
Institutional goal	Enhancing exploration and identification of plant diversity	Exploring for new varieties and crops	Multiplying and distributing ex situ collections to drought-affected areas to complement production of high-yielding and uniform varieties	Developing biodiversity policies for conservation and research
	Studying culinary diversity, ethnolinguistic uses and food processing technologies	Collecting and extracting pool of genes as raw material for crop adaptation and improvement	Rescue collection of local crop diversity from drought-affected	Developing effective national law and regulation for ABS to promote the

(Continues)

TABLE 2 (Continued)

	Plant explorers' discovery of "landraces" or "peasant seeds" and introduction of crops (16th century–1926)	Unfolding awareness as a biodiverse nation and representation on the global crop diversity "treasure map" (1926–1955)	Creating regional/national PGR center for conservation of raw material for breeding as natural commons and to manage genetic erosion (1955–1992)	From natural commons and free access to sovereign ownership a and control paradigm or private goods and restricted access (Since 1993)
			areas and in areas of high varietal displacement	use of biodiversity for economic development
	Extracting genes for adaptation and use	Introducing new varieties for use by peasants for higher yield, better disease resistance, and other stress factors	Reducing massive export of germplasm to limit misappropriation as well as engaging in international negotiations for farmers' rights, fair access and equitable benefit sharing agreements	Strengthening in situ conservation and on-farm management for sustainable agriculture and food security
	Introducing new crops from other parts of the world for increased production			Developing effective Sui Generis system for PVP, that is, PBR law and balance with FRs
National and global commons status	Common heritage of humankind	Common heritage of humankind	PGRs as public good for new variety development	Participatory agenda for PGR management
	Free access to the pool of genes	Free access to pool of genes	Balance between IPR and farmers' rights by creating awareness at national level and by putting pressure at international level as part of countries from the Global South and with the help of NGOs (e.g., RAFI)	Ethiopia exercises sovereign right over its PGRs through regulating access
	Balanced two-way exchange of PGRs	Massive germplasm export to other countries and introduction of new plant varieties to Ethiopia		Farmers and local communities as custodians of agrobiodiversity and associated traditional knowledge are rewarded
Actors	Foreign professionals: botanical explorers, archeologists and other travelers	Professional actors: state institutions, foreign explorers, plant collection expeditions and breeders	EBI cooperation with Germany and IBPGR/FAO/CGIAR on ex situ management	EIAR, CGIAR, GCDT on ex situ collection, management and use
	Local leaders of ancient kingdom	Peasants volunteering to give samples of their seeds and adapting newly introduced varieties	National agricultural research institutions' cooperation with CGIAR for developing new plant varieties	EBI, multilateral institutions (IPGRI/Bioversity International, GEF, Benefit Sharing Fund of ITPGRFA), NGOs (EOSA, MELCA, REST, USC-Canada, and Norwegian

(Continues)

TABLE 2 (Continued)

	Plant explorers' discovery of "landraces" or "peasant seeds" and introduction of crops (16th century–1926)	Unfolding awareness as a biodiverse nation and representation on the global crop diversity "treasure map" (1926–1955)	Creating regional/national PGR center for conservation of raw material for breeding as natural commons and to manage genetic erosion (1955–1992)	From natural commons and free access to sovereign ownership a and control paradigm or private goods and restricted access (Since 1993)
				Development Fund) on in situ/on-farm
			EBI cooperation with farmers and USC-Canada to promote Farmers' Rights and on-farm management of PGRs (SoS program)	Farmers, community seed bank groups, local community
				Commercial actors for PGR trade
System	Exploration and documentation	Documentation and reporting exploration results	Ex situ conservation	Ex situ conservation
		Collection, introduction, experimentation and adaptation at national plant introduction stations and ex-situ conservation	On-farm management	In situ conservation
			Advocacy and negotiation for farmers' rights, fair access and equitable benefit sharing	On-farm community management: PVS, CSB and restoration

Abbreviations: ABS, access and benefit sharing; CBD, convention on biological diversity; CGIAR, Consultative Group on International Agricultural Research; CSB, community seed bank; EBI, Ethiopian Biodiversity Institute; EIAR, Ethiopian Institute of Agricultural Research; EOSA, Ethio-Organic Seed Action; FAO, Food and Agriculture Organization; FR, farmer's right; GEF, Global Environment Facility; IBPGR, International Board for Plant Genetic Resources; IPR, Intellectual Property Right; ITPGRFA, International Treaty on Plant Genetic Resources for Food and Agriculture; NGO, nongovernmental organizations; PGR, plant genetic resource; PVP, plant variety protection; PVS, participatory variety selection; RAFI, Rural Advancement Fund International; USC-Canada, Unitarian Service Committee of Canada.

[a]The ownership approach refers to the right of farmers or communities to be rewarded individually or collectively for plant genetic resources obtained from their fields and used in commercial varieties and/or protected by intellectual property rights.

The Ethiopian genebank scientists were convinced that allowing access to germplasm that would then be used by commercial actors for capital accumulation was wrong.[32] This created a growing awareness about the need for fair and equitable benefit sharing, both at the national level, and—through the lessons learned from the in situ/on farm movement—for Ethiopian farmers. Although CBD and ITPGRFA later created mechanisms to regulate ABS, as described earlier, negative experiences in which such agreements were not respected (e.g., the *teff* patent), have acted to solidify earlier suspicions into a feeling of distrust, as the following informant explains:

> *The negotiated intentions of the Treaty's MLS and the implementation have not been compatible. Initially the focus was on how to manage and use CGIAR genebank holdings and how developing countries can benefit from these stocks of germplasm. Nevertheless, it is still serving those who benefited most from before. On top of that, the West is interested to expand Annex I crops of the MLS before we have a functioning benefit sharing arrangement. It also undermines the Nagoya Protocol by making it irrelevant for PGRFA. This has degraded our trust towards actors in developed countries. The motive does not seem to be fair and mutual benefits, because it mainly benefits the rich countries. This is wrong both technically and politically.*[33]

From this statement we see that Ethiopia's shift in PGRFA governance is due to a growing distrust. This distrust explains Ethiopia's inclination toward an hyperownership approach while formally signing on to "new commons" governance under the MLS of ITPGRFA. It is also linked to the apparent paradox of Ethiopia's access regulation that is liberal toward national users and restrictive toward international users. Our historical institutional analysis displays these linkages and shows how actors' perceptions, institutional goals and status of commons governance have changed over time (see Table 2).

Our analysis shows that the restrictive nature of Ethiopia's current access policies and legislations partly can be explained by the first design problem of the MLS identified by Halewood et al. (2013a); a lack of clearly defined boundaries and monitoring of rules and use. The fact that institutions managing international crop and forage collections under the Treaty's framework (e.g., CGIAR genebanks) and some member states (e.g., European countries) voluntarily provide material to nonparties has frustrated countries like Ethiopia. Furthermore, the MLS is not capable of enforcing rules to ensure reciprocal obligation of all participants to ensure contributions from nonmembers or "free riders" for PGRFA conservation work in provider countries.

Our study also points to the influence of the second design issue identified by Halewood et al. (2013a); the blurred boundary between bilateralism and multilateralism in the MLS in which users are allowed to realize proprietary benefits (through IPRs) while providers' benefits are supposed to be multilaterally distributed. Through the multilateral system, PGRFA users make a direct payment to the benefit sharing fund that is administered by the Governing Body and the Secretariat of the Treaty; countries can only access these funds by competing in calls for proposals for projects on PGRFA conservation. This is problematic because to date, only a limited number of voluntary payments (Rosendal & Andresen, 2016)—and one mandatory payment tied to accessed MLS materials (FAO, 2018)—have been made into the fund. As a result, calls for proposals have been very competitive and provider countries have no assurance of accessing financial benefits through the MLS. The fact that the Treaty's multilateralism breaks the direct link between PGRFA provider countries and users in terms of monetary benefit sharing can partly explain why some countries like Ethiopia prefer the bilateral MTA of the Nagoya protocol to the multilateral SMTA of the ITPGRFA.

Apart from the design issues, Ethiopia's restrictive practice on access to the country's PGRFA has also been triggered by the failure of the ABS agreements linked to the Dutch *teff* patent (Andersen & Winge, 2012). Between 2003, when the patent was first filed, and 2006, when Ethiopia issued its own Access Law, the country barely used

[32]Personal interview with a former staff of EBI (Addis Ababa, January 31, 2018).

[33]Personal interview with a government official of the Ministry of Environment, Forest and Climate Change (Addis Ababa, January 15, 2018).

any form of material transfer. Looking at the historical events and processes that have shaped Ethiopian actors' perceptions and governance of access to PGRFA (see Table 2), we find that the failure of international institutions to resolve tensions between IPR and ABS agreements is the major underlying reason for access restriction at the national level. The current suspicion and distrust may continue to prevail until a tension (perceived and real) between the ABS regimes under ITPGRFA and CBD is resolved, and larger monetary benefit sharing from the MLS of the Treaty is realized and acknowledged by the parties.

5 | CONCLUSIONS

Our analysis of the historical development of access to and management of PGRFA in Ethiopia has shown that the country has taken a different route to the governance of PGRFA compared to most other countries in the Global South. The country has issued comprehensive policies and legislations within the existing ABS and IPR frameworks to ensure national control over their genetic resources, promote farmers' and community rights, and encourage in situ conservation and on-farm management of PGRFA. Ethiopia's policies and legislations lean toward an hyperownership approach, which aims to maximize benefit sharing from international users through the use of bilateral access agreements, as opposed to the "new commons" approach.

With regard to historical factors, our findings are consistent with Nabhan's (2009) assertion that Vavilov inspired Ethiopian scientists and policy makers to conserve and have control over their seed heritage more than in any other country where he conducted his expeditions. Vavilov and other plant explorers inspired awareness of Ethiopia as a biodiverse nation clearly situated on the global crop diversity "treasure map." This heightened awareness among Ethiopians of the global significance of their genetic resources is an ideational factor that has affected policies and practices on PGRFA governance. At the same time, there can be no doubt about the material importance and value of genetic resources for Ethiopia's agriculture and economy. Furthermore, the fact that EBI began in the late 1980s to work on on-farm management of PGRFA to strengthen farmers' seed systems and has further sought to balance farmers' and breeders' rights in their national policies and legislations, reflects the central role that PGRFA play in ensuring national food security and economic growth.

Earlier studies have found that restrictive practices on access to PGRFA emerged following the adoption in 1992 of CBD, which recognizes sovereign rights to PGRFA (Falcon & Fowler, 2002; Halewood, 2013; Roa-Rodríguez & Dooren, 2008). Although Ethiopia began introducing legislation to restrict access to genetic resources following CBD (from 1993), our historical analysis of Ethiopia's PGRFA governance shows that the shift toward an hyperownership approach began as early as the late 1970s. This was due to growing concern over IPR restrictions on the use rights of smallholder farmers to protected plant varieties, and the lack of financial benefits through benefit sharing agreements from commercialization of PGRFA. Our study also shows that Ethiopia's positioning on these two issues was reinforced through alliances forged with civil society in the 1970s and 1980s, as part of the growing international movement against IPRs and for on-farm management of PGRFA. Thus, rather than being a cause for restrictive policies, the adoption of CBD in 1992 formalized existing concerns within Ethiopia over IPRs, benefit sharing, and farmers' rights by recognizing sovereign rights to PGRFA.

Most studies to date examine the effects of ABS or IPR legislations on access to PGRFA separately (Bjørnstad & Westengen, 2019). Our study analyzed both legislations simultaneously, which provides a better understanding of national PGRFA governance and its implication for different users. The Ethiopian ABS legislation, that is liberal toward national PGRFA users and restrictive toward international users, is directly linked to the country's Plant Breeders' Law. It provides farmers an easy access to ex situ collections and the right to freely use protected plant varieties for noncommercial purpose. At the same time, it requires commercial actors to disclose the origin of genetic material for their IPR applications for ease of traceability and enforcing benefit sharing obligations. This has been an attempt by Ethiopian government to use its national PGRFA legislation to address what they perceive as unresolved conflicts between IPRs and ABS agreements in international policies. The Governing Body of ITPGRFA

has continuously requested Contracting Parties to submit measures/practices and lessons learned on the implementation of farmers' rights and MLS since its first meeting in 2006 (FAO, 2019). In this regard, we find the Ethiopian policy approach to balancing IPRs and farmers' rights to be an important input for the ongoing negotiations on the interrelation between IPR institutions (UPOV and WIPO) and international treaties concerning genetic resources (the CBD and ITPGRFA).

Ethiopia's current access regime must be seen in connection with, and not in isolation from, international IPR regimes, as well as the historical, economic, political, and cultural role of PGRFA in the country. To establish the necessary trust, and arrive at mutually acceptable and beneficial governance arrangements in international policy fora, it is not sufficient with empirical evidence of the concrete benefits of PGRFA exchange, it is also important to understand the historical and political context of different national governance regimes.

In terms of theory and methods, the commons conceptualization by Halewood et al. (2013b) helps to understand PGRFA governance by focusing on the frameworks of international agreements, specifically by looking at access regimes practiced by countries before and after the CBD. This framework has also been useful to identify design problems related to the functioning of international agreements, for example, the MLS of ITPGRFA. However, a historical approach as we have used here is another useful method that can elucidate the factors contributing to specific PGRFA governance situations. Research on PGRFA governance at the national level thus requires us to look beyond the frameworks of the CBD and other international agreements, to consider the particular historical, political, and institutional factors within each country.

ACKNOWLEDGMENTS

This paper is based on research project conducted in completion of the PhD degree by the first author, under supervision of the second author. We appreciate the generous participation of actors involved in PGRFA work in Ethiopia for interviews. Teshome wishes to thank the Research Council of Norway (RCN) for the financial assistance that enabled his fieldwork in Ethiopia from October 2017 to March 2018, and the International Maize and Wheat Improvement Center (CIMMYT) in Addis Ababa for facilitating his fieldwork during the period.

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How to cite this article: Mulesa TH, Westengen OT. Against the grain? A historical institutional analysis of access governance of plant genetic resources for food and agriculture in Ethiopia. *J World Intellect Prop*. 2020;23:82–120. https://doi.org/10.1111/jwip.12142

Article 2: Pluralistic Seed System Development: A Path to Seed Security?

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Article

Pluralistic Seed System Development: A Path to Seed Security?

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Abstract: Seed security is central to crop production for smallholder farmers in developing countries, but it remains understudied in relation to long-term seed sector development. Here, we compare seed systems in two districts of Central Ethiopia characterized by subsistence-oriented teff cultivation and commercially oriented wheat production and relate this to the country's pluralistic seed system development strategy (PSSDS). Our analysis is based on quantitative and qualitative information from a household survey and focus group discussions with farmers, as well as document review and key informant interviews with actors that make up the seed sector in the study sites. Farmers in both districts used a range of seed sources but primarily obtained their seeds from informal sources. Evidence of seed insecurity was found in both districts, as apparent from discrepancies between what the seed farmers say they prefer and those they actually use, limited availability of improved varieties and especially certified seeds of these, challenges with seed quality from some sources, and differentiated access to preferred seed and information according to sex, age and wealth. We find that the interventions prioritized in the PSSDS address most of the seed security challenges and seed system dysfunctions identified, but implementation lags, particularly for the informal seed system, which is largely neglected by government programs. The intermediate system shows promise, but while some improvements have been made in the formal system, vested political, organizational, and economic interests within key institutions represent major obstacles that must be overcome to achieve truly integrative and inclusive seed sector development.

Keywords: seed security; access to seeds; seed availability; seed quality; varietal suitability; seed policy; smallholder farmers; Ethiopia

Citation: Mulesa, T.H.; Dalle, S.P.; Makate, C.; Haug, R.; Westengen, O.T. Pluralistic Seed System Development: A Path to Seed Security? *Agronomy* **2021**, *11*, 372. https://doi.org/10.3390/agronomy11020372

Academic Editor: Niels P. Louwaars and Bram de Jonge

Received: 12 January 2021
Accepted: 14 February 2021
Published: 20 February 2021

1. Introduction

Access to good seeds is fundamental for smallholder farmers' crop production and resilience in the face of environmental change and disasters. National seed policies and programs in developing countries have predominantly focused on the formal seed supply system, but despite decades of efforts to spur a Green Revolution in Sub Saharan Africa, farmers' use of seeds from the formal seed system remains limited [1]. In 2017, Ethiopia was the first country to officially adopt a Pluralistic Seed System Development Strategy (PSSDS) as an alternative to the dominant linear approach, i.e., formal seed system development [2,3]. The strategy is pluralistic in that it proposes support for three major seed systems operating in the country (informal, formal and intermediate) and promotes complementarity between value-chain components of each seed system. In this study of the Ethiopian seed sector, we analyze farmers' seed security and discuss the relevance and implementation of the new policy in terms of addressing farmers' challenges with access to enough quality seeds of preferred crops and varieties.

Farmers' access to seed is increasingly theorized in terms of two closely related concepts: seed systems and seed security [4,5]. The seed system concept has deep roots,

and various fields from crop science to agricultural anthropology and economics have contributed to the current understanding of seed systems as the activities, institutions, and actors involved in the development, distribution, and use of seeds [6–12]. This literature has highlighted that farmers in developing countries source most of their seeds outside the formal system, which develops and approves improved varieties, and regulates seed quality assurance and certification. Consequently, a branch of this literature suggests that efforts to support farmers' access to seeds should recognize the complementarity of formal and informal seed systems and thus advocates a pluralistic approach to seed sector development by promoting complementarity of activities between value-chain components of each seed system [5,13–17]. The Ethiopian PSSDS is arguably among the first national seed policies to take this perspective on board.

Seed security is a more recent concept originating in the literature on emergency seed aid in the wake of natural and human-made disasters [4,18–20]. The Food and Agriculture Organization of the United Nations (FAO) defines seed security as "ready access by rural households, particularly farmers and farming communities, to adequate quantities of quality seeds and planting materials of crop varieties, adapted to their agroecological conditions and socioeconomic needs, at planting time, under normal and abnormal weather conditions" [21]. The conceptual frameworks for seed security initially were based on three basic dimensions: *availability, access, and quality* (including seed quality and variety quality) [22]. Recently, FAO has added the two dimensions *varietal suitability* (varietal traits responding to farmers' preferences, previously included under the "quality" parameter) and *resilience* (stability of seed system in the context of shocks) to their framework [19,23]. Several frameworks and tools have been developed by researchers and practitioners concerned with understanding barriers and options for strengthening farmers' seed security [19,23–26]. The application of such frameworks has arguably led to relief efforts better tailored to specific local contexts [27]. For research more generally, the seed security concept (and related frameworks) provides a lens through which the performance of each seed system can be assessed. In this sense, seed security can be understood as a livelihood concept, representing the outcome of seed systems from the farmers' perspective [20,28]. Analysis of the roles and interactions between different actors in the seed sector is key to understanding seed security [27]. However, few studies analyze the complex interplay of policy, institutional, socio-economic, technical, and household-level factors that underly seed security challenges. Research linking the performance of seed systems to seed security outcomes, while considering the range of seed systems and channels farmers use, is therefore needed to deepen our understanding of the context-specific conditions and vulnerabilities that affect seed security, as well as to inform policy formulation [29].

Post-disaster seed security studies have shown that pre-existing "chronic stresses" are often at the root of most seed security problems [30]. While, in theory, the seed security concept is as applicable to understand the performance of seed systems in both normal seasons and those affected by disasters [23,25], there are few examples of seed security assessments from non-emergency contexts [20]. Studies analyzing the functioning of seed systems in developing countries under normal conditions [6,31–34] rarely empirically assess their effect on seed security [35]. Rather, most of the research on seed use in non-emergency contexts has solely focused on barriers to and determinants of adoption of improved varieties from the formal system [36–42]. This econometric literature commonly shows that women are less likely to adopt improved varieties than men [37] due to lack of access to key resources such as land, cash, credit, labor, and extension services [43,44] as well as challenges related to gender roles within households and communities [44,45]. Furthermore, a common finding is that the likelihood of adopting improved varieties increases with wealth [38,46,47], while the effect of age varies [48]. This adoption literature provides valuable assessments of supply and demand in the formal seed system, but its perspective does not suffice for assessing factors influencing seed use outside the formal system. From a seed security perspective this is a major gap as the formal system only covers a small share of farmers' seed use. In this article, we aim to address this gap by

exploring the relationship between farmers' seed security and the functioning of the seed systems they use under normal conditions in the central highlands of Ethiopia.

Ethiopia is a crop diversity hotspot, and a large body of literature exists both on the nature and geography of this diversity and the seed systems farmers use [32,34,49–51]. A few seed security assessments have been conducted to guide seed-related interventions [52,53], but the academic literature has made limited use of the seed security framework to analyze Ethiopian seed systems. The importance of crop diversity and local seed system is recognized in Ethiopia's national policy and law [54–56], and, as stated above, in 2017, Ethiopia became the first country to officially adopt a pluralistic seed system development strategy (PSSDS) as policy. Ethiopia's unique PSSDS, with provisions to support both formal and informal, as well as an emerging "intermediate" seed system, makes it a very interesting case to examine how the different seed systems function and their impacts on farmers' seed security.

In this context, we analyze farmers' seed use and preferences (demand-side) and the role of supply side institutions and actors, to understand how different elements of the seed systems affect farmers' seed security (i.e., varietal preferences, seed quality, and the availability and access of seeds from different sources). Specifically, we address the following research questions: (1) How does farmers' seed security differ between commercially and subsistence-oriented production systems; (2) How do wealth status, gender, and age affect farmers' access to preferred seeds from different seed systems; and (3) To what extent does Ethiopia's pluralistic approach hold potential to improve farmers' seed security and how is this conditioned by institutional, political and economic interests?

We address these questions using a comparative case study of two districts in the central highlands of Ethiopia with similar agroecological contexts but contrasting degree of seed system formalization and commercialization. The selected districts represent the range of conditions that smallholder farmers in Ethiopia face and provide a good basis for understanding how different elements of the informal, formal, and intermediate seed systems impact seed security.

The paper is organized as follows. First, we provide an overview of Ethiopia's PSSDS, as well as our methodology, study sites, and the crops and seed sector actors engaged in each district. We then present a comparative analysis of the dimensions of seed security in the two districts as experienced by smallholder farmers on the ground, considering household differences in access to preferred seeds. Thereafter, we map key seed sector actors in the study areas and analyze their roles and performances in seed supply and seed system governance to understand to what extent the priorities set out in Ethiopia's PSSDS address the seed security challenges identified in the previous section. In addition, we analyze the political, organizational, and economic factors that affect the implementation of the PSSDS, as revealed by our empirical findings on the performance of different actors. To conclude, we draw key lessons from this study on what it takes to achieve a pluralistic seed system development.

2. Ethiopia's Pluralistic Seed System Development Strategy

For decades, the Ethiopian government followed a linear model of formal seed sector development policy focusing on the development of improved high-yielding varieties and the distribution of certified seeds to farmers to increase national food security [35,57–61]. This approach started to be questioned in policy debates in the 1990s [62,63]. By the mid-2000s, the government policy began to shift, leading to the development of the first version of the PSSDS in 2013 [3]. This process was supported by the Integrated Seed System Development program (ISSD), initiated in Ethiopia in 2009, and informed by critical evaluations of the country's policies and programs [33,64] and experiences from community-based seed production projects within Ethiopia [65–70]. The ISSD program is part of the "Bilateral Ethiopian Netherlands Effort for Food, Income and Trade Partnership (BENEFIT Partnership) supported by the Dutch Government through the Embassy of the Kingdom of the Netherlands in Addis Ababa since 2009. The program is operationalized

by the Centre for Development Innovation of Wageningen University & Research Centre and the Royal Tropical Institute (KIT), the Netherlands. It is implemented in the context of the African Seed and Biotechnology Programme of the African Union Commission (African Union 2008) through its local partners in Ethiopia, Mozambique, Nigeria and Uganda. With Ethiopia's PSSDS, the previous policy focus of replacing the informal seed system with the formal seed system changed to supporting the diverse seed systems farmers use, exploiting both market and non-market channels for increasing seed security. This includes policy recognition of the existence of three different seed systems—informal, formal, and intermediate—which all have different performances in terms of seed security for different crops [2,3].

The informal seed system involves farmers' seed selection, multiplication, storage, use, and distribution through social seed networks and local markets. It dominates in terms of delivering large quantities of seeds of a diversity of crop varieties [28,31,59,71,72]. This includes both traditional varieties and improved varieties that have been released by the formal system in the past and integrated into the local seed system, so-called "obsolete" improved varieties [32]. The formal seed system involves public and private sector institutions and a linear series of activities along the seed value chain, including germplasm conservation in genebanks, plant variety development, variety release and registration, quality seed production, and distribution [58]. It plays a crucial role in delivering certified seeds of improved varieties of certain crops, including maize and wheat [73–75]. The formal system is still at an early stage of growth and is dominated by public institutions [1]. Additionally, an emerging intermediate seed system is growing in Ethiopia. This system involves market-oriented farmer groups who produce and market non-certified seeds of both improved varieties and farmer-preferred local varieties [65,76–78]. These community-based seed groups include Local Seed Businesses or Seed Producer Cooperatives (SPC) who produce quality declared seeds (QDS) of improved varieties. QDS is a simplified certification scheme developed by FAO in which seed-producing farmers are responsible for seed quality, while the government plays a monitoring role [79]. In Ethiopia, the QDS scheme requires seed producers to employ robust internal quality assurance and declare the quality of their seed based on limited quality control established by the regulatory authorities (Regional Bureaus of Agriculture), e.g., inspection of 10% of the total seed produced instead of undergoing the full inspection and quality testing procedures. This has intended to reduce the burden on seed regulatory authorities and hasten community-based production and marketing [55]. In addition, the intermediate seed system includes non-profit community-based seed producers such as community seed bank (CSB) groups [80] who produce higher quality seed than typically produced by the informal system, even if it is not certified nor fully regulated under existing regulations [3].

The PSSDS was fully adopted by the Ministry of Agriculture in 2017 [2], and based on this strategy, the government subsequently revised the national seed policy [54]. The government has also developed/amended a series of laws and regulations [2] including: (1) A Plant Variety Protection or a Plant Breeders Rights law to encourage the development of commercial plant varieties [56]; (2) A national seed law and regulation for commercial seed production and distribution of certified seeds [81,82]; (3) A QDS scheme and community based seed (CBS) production directive for multiplication and distribution of non-certified seeds of either improved or local varieties within the local community or nearby communities [55]; and (4) several other service and governance related directives concerning seed marketing. These service and governance related directives include the Council of Ministers Regulation to Determine the Rate of Fee for Seed Competency and Related Services Proclamation No. 361/2015, the Directive for Issuance and Administration of Certificate of Competency Proclamation No. 02/2010 and the Directive for tracking rejected seed field and lot Proclamation No. 03/2010.. The informal seed system is left unregulated, but interventions were identified to strengthen the system, emphasizing on the key seed security features [2,3]. We return to the PSSDS provisions in Section 6 of this paper when we discuss its match with farmers' seed security needs.

3. Methods

This study is based on fieldwork conducted from October 2017 to February 2018 in a total of eight gandas in Gindabarat and Heexosa districts (four gandas per district). *Ganda* is the smallest administrative unit in Oromia National Regional State of the Federal Democratic Republic of Ethiopia. This administrative unit is called "kebele" in other parts of the country. Methods included a household survey and focus group discussions (FGDs) with small-holder farmers, key informant interviews with seed sector actors in the respective gandas/districts, and document analysis.

In order to assess actors' roles and performances in seed supply and seed system governance, we used the CGIAR Roots, Tubers, and Bananas program's "multi-stakeholder framework intervention in RTB seed systems" [26]. This is an actor-oriented approach, in which the roles of seed sector actors are analyzed in relation to different seed security parameters.

For this study, the analysis focused on the following actors: local government and extension services, regulatory bodies/seed laboratories, national/regional agricultural research, international research, local traders, public seed enterprises, agrodealers, SPCs and farmers' unions, Non-governmental organization (NGOs) and development agencies, private sector grain processors and smallholder farmers. Information on seed supply and seed system governance was collected from these actors using FGDs with 80 smallholder farmers (see details below) and semi-structured interviews with 50 key informants. A checklist for the FGDs and key informant interviews was developed covering the following topics: seed use and management, seed availability, access, quality, and varietal suitability, farmers' resilience to shocks, technological and institutional innovation, historical policy and institutional changes, and actors perceptions and roles in the seed sector. Questions were tailored for specific actors and elicited information on both the current situation and changes over time, where appropriate. All FGDs and key informant interviews were recorded, transcribed, and analyzed using the RTB matrix (Table A1).

The demand side of farmers' seed security was assessed using quantitative data from the household survey, complemented with qualitative information from the FGDs. The household survey was administered to a stratified random sample of 223 household heads in Gindabarat and 209 in Heexosa. The sampling frame was established from a list of household heads, and stratified by wealth category (poor, medium, rich), age and gender, based on information provided by the ganda administration. Households were then randomly selected from each stratum. In cases where the randomly selected household was not available, another household from the same stratum was interviewed. Focusing on the 2017/2018 main growing season (June to September), the survey elicited quantitative information on the types of seeds and seed sources farmers used. It also produced quantitative information on household characteristics, agricultural assets, labor, and other biophysical factors. The survey instrument drew on tools developed for seed security assessment [19,23,25] and for seed sector and seed value chain analysis [83,84] to assess varietal suitability, seed availability, seed access, and seed quality. Statistical analysis was conducted using STATA version 15 [85].

The FGDs were conducted with men and women household heads in all eight survey gandas (16 FGDs). Participants were purposively selected from the stratified random sample used for the household survey. Separate FGDs were held with women and men, with representation from all wealth and age groups. In the case of female heads of household (FHH), these were mainly widows and divorcees, a few of whom were women in polygamous relationships who essentially functioned as FHHs. In total, over 80 farmers contributed to the qualitative empirical data in this study.

4. Study Area, Crops, and Actors

The study was conducted in Heexosa district in Arsi Zone and Gindabarat district in West Shewa Zone of Ethiopia's Oromia Regional State (Figure 1, Table 1).

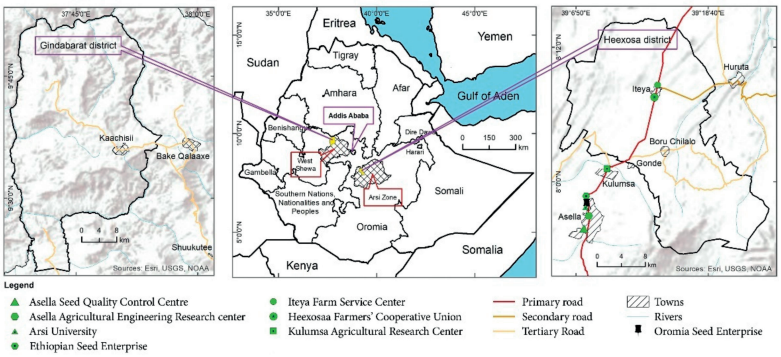

Figure 1. Map of Ethiopia, Gindabarat and Heexosa districts.

The study districts were selected to represent contrasting degrees of seed system formalization and commercialization, considering both institutional and physical infrastructure (Figure 1), but with otherwise similar conditions in terms of landholding size, agroecological and demographic characteristics (Table 1). Gindabarat is remote, being isolated geographically by lowland gorges and rivers which separate it from all but one neighboring district, and physically, due to a poor road network. Gindabarat lacks research and proper institutional services that facilitate access to agricultural technologies, including fertilizer and improved seeds. Heexosa, on the other hand, is centrally located in terms of access to primary and feeder roads and linkages with institutions providing inputs, credit, and marketing services. In the late 1960s, Arsi zone was selected as one of the areas in Southeastern Ethiopia for the first green revolution project that focused on bread wheat cultivation, and already by 1972, about 150 landowners in Arsi were operating more than 250 tractors and 50 combines on approximately 30,000 hectares of land [86]. Nowadays, 97% of farmers in Heexosa use combine harvesters, as opposed to threshing their wheat crop manually [87].

The difference in formal seed system development in the two districts is reflected in what crops farmers cultivate. The Ethiopian staple grain teff (*Eragrostis tef*) is the key crop in Gindabarat, while in Heexosa, nearly all farmers produce bread wheat (*Triticum aestivum*) (hereafter wheat). In both districts, FGD participants identified a high infraspecific diversity of the dominant crop by their vernacular/cultivar/breed names (27 teff varieties in Gindabarat and 25 wheat varieties in Heexosa), with individual households growing on average three to four varieties of their key crop in the 2017/18 growing season.

In Gindabarat, farmers mainly planted local varieties of teff (68% of seed sown), although one improved variety of teff (Quncho) is popular. For wheat, old improved varieties that have been integrated into the local seed system (obsolete varieties) were the dominant (57% of seeds), while the remaining varieties are recycled seeds of improved varieties recently supplied through the Primary Multipurpose Cooperatives (PMCs) in Gindabarat. In Heexosa, farmers relied primarily on improved varieties of both wheat and teff (89% and 64% of seed, respectively) (Figure 2). "Local" wheat varieties in Heexosa are mostly obsolete improved varieties that were recycled for more than five years. In order to distinguish between obsolete and improved varieties, we used a five-year cut-off point based on recommendation from wheat breeders at the International Maize and Wheat Improvement Center (CIMMYT) in Addis Ababa and Kulumsa Agricultural Research Center. Thus, we considered improved varieties to be those that farmers recycle up to five years, while local varieties were improved seeds recycled for more than five years and traditional varieties.

Table 1. Key demographic and agroecological characteristics of Gindabarat and Heexosa districts.

Characteristics	Districts	
	Gindabarat	Heexosa
Total population	104,595 [a]	124,219 [a]
Population (persons/per km)^2	124 [a]	188 [a]
Rural Population	90% [a]	85% [a]
Total land/Crop land (ha)	119,879/65,491 [b]	93, 700/49,498 [c]
Major crops cereal and pulse crops in order of total production	Teff, maize, sorghum, wheat, faba bean, barley and field peas [d]	Wheat, barley, maize, faba bean, teff, sorghum and field peas [d]
Elevation (masl)	1501–2607 [e]	1500–4170 [f]
Topography	Plateau, hilly and sometimes steep slopes [e]	Mostly flat terrain [f]
Climate	Highland (temperate) and midland (moist sub-tropical) accounting for 40% and 60% of the area, respectively [e]	Highland (temperate), midland (moist sub-tropical) and midland (dry sub-tropical) accounting for 17%, 61% and 22% of the area, respectively [f]
Mean maximum and minimum annual temperatures (°C)	10–25 [e]	14–27 [h]
Mean farm size (ha)	2.15 [g]	2.31 [h]
Households with 0/1/2/ > 2 oxen (%)	7/6/49/37, respectively [h]	8/27/44/21, respectively [h]
Annual minimum and maximum rainfall at district town (mm)	1377.9 to 2214.2 [i]	800–1300 [f]
Rainfall onset	Low variability with 12.1% coefficient of variation. Receive most rainfall during long rainy season (June to September) [i]	Low variability except in dry mid-land areas. Receive most rainfall during long rainy season (June to September) and some during short rainy season (February to May) [f]

[a] CSA [88]; [b] Amenu et al. [89]; [c] Yiemene [90]; [d] CSA [91] [e] Mulesa and Mulubiran [92,93]; [f] Amade and BFED [94,95]; [g] Beressa [96]; [h] Respective District agriculture bureaus; [i] Nurgi [97].

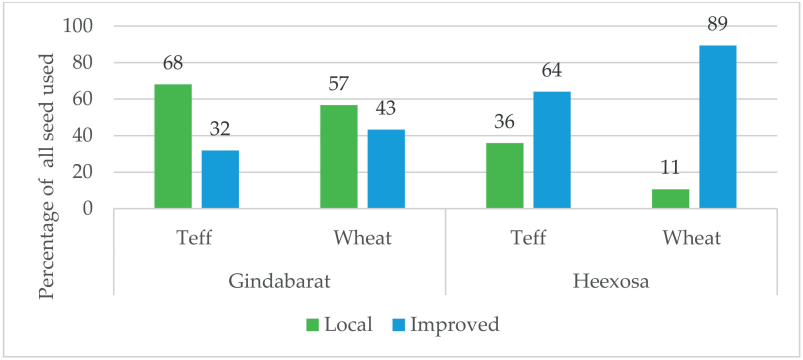

Figure 2. The use of teff and wheat varieties by farmers (% of all seeds used) in Gindabarat (n = 222 teff growers sowing 11,428.00 kgs of seeds on 297.36 hectares of land and n = 28 wheat growers sowing 676 kgs of seeds on 6.03 hectares of land) and Heexosa (n = 207 wheat growers sowing 85,149.00 kgs of seeds on 342.15 hectares of land and n = 60 teff growers sowing 1756.00 kgs of seeds on 27.64 hectares of land) districts during 2017/2018 growing season. Improved seeds category includes certified seeds and recycled seeds up to five seasons.

A range of institutions are involved in the development, production, and dissemination of seeds in the two areas. There are some significant differences between the two

districts, both in terms of the actors present and their level of engagement, reflecting the different degrees of formalization and commercialization of the seed sector (Table 2). In both districts, farmers are the backbone of the seed sector, with the district bureaus of agriculture, traders, NGOs, and CSB groups having lesser but similar levels of engagement. Many actors engaged in the formal seed system are only present in Heexosa. These include agriculture research, commercial seed producers, regulatory bodies, processors, and distributors for quality declared and certified seeds. National agriculture research centers, farmers' unions, and their member PMCs play a much more important role in Heexosa than in Gindabarat (Table 2, Table A1).

Table 2. Actors engaged in seed supply and seed sector governance in the study districts. Our assessment of the actors' contribution to smallholder farmers' seed security is indicated as high (***), moderate (**) or low (*). Actors that are not operating in the districts or are not engaged in seed supply and seed sector governance are denoted with (–). See Aix A (Table A1) for details.

Actors	Gindabarat	Heexosa
1. Smallholder farmers/households	***	***
2. National agricultural research centers	*	***
3. International research centers (e.g., CIMMYT)	–	***
4. Seed producer cooperatives	–	***
5. Regional agricultural research institutes	–	**
6. Regulatory bodies/seed quality control and certification laboratories	–	**
7. Agro-dealers/retail sales outlets	–	*
8. Private sector grain processors	–	*
9. Commercial private farms	–	*
10. Public seed enterprises	–	**
11. District bureau of agriculture	**	**
12. Grain/seed traders (include farmers)	**	**
13. Farmers' Union and primary multi-purpose cooperatives	*	**
14. Non-Governmental Organizations	*	**
15. Community seed bank groups	*	*
16. Afoosha ‡	*	–

‡ Afoosha is an indigenous social institution established to provide financial and other types of support when a family member dies in most communities in Ethiopia. In Gindabarat, we found that Afoosha groups have established grain reserve in most peasant associations to support poor families affected by calamities by providing food grains, which is increasingly used by those affected as seeds

5. Assessing Demand-Side Seed Security

5.1. Varietal Suitability

Varietal suitability refers to whether crop varieties have traits that meet farmers' specific needs and preferences, such as yield, storability, marketability, tolerance to environmental stresses, pests and diseases, and culinary and cultural needs [19,29,32,98]. In terms of seed security, problems of varietal suitability are generally associated with chronic conditions, such as the buildup of pests and diseases, genetic erosion, and lack of access to extension/research services [99–101]. In addition, the distribution of varieties that are poorly adapted or fail to meet farmers' preferences is a common problem in seed relief and agricultural extension efforts [11,15,30,102].

To understand farmers' varietal preferences, we asked survey respondents to list all varieties of their key crop they grew and rate each according to a set of criteria. The criteria were: agroecological adaptation (tolerance to drought and frost, and resistance to plant diseases), socio-economic importance (household food security, yield, fodder value,

grain market value and cost of agrochemical inputs), and culinary and cultural uses (taste). This was triangulated with qualitative information on varietal preferences collected in the FGDs, which in all cases was found to be consistent. In both districts, respondents preferred at least one improved variety of their key crop, but the overall importance of improved compared to local varieties was higher in Heexosa (Table 3). In Gindabarat, 42% of respondents preferred the improved variety Quncho, released in 2006, but the remaining preferred teff varieties were all local. In contrast, most of the wheat varieties preferred by respondents in Heexosa were improved varieties released during the past decade, except Kubsa, which was released in 1995.

Table 3. Widely grown and preferred varieties of teff by proportion of respondents in Gindabarat (n = 222) and Heexosa (n = 207) and by area coverage.

	Variety Name (Year Released)	Variety Type	Proportion of Respondents	Total Area Sown (ha)
Teff in Gindabarat	Quncho (2006)	Improved	42%	81.8
	Daaboo	Local	30%	29.9
	Adii-qola-gurraachaa	Local	22%	47.2
	Adii-qola-adii	Local	22%	52.6
	Minaaree	Local	13%	22.1
	Maanyaa	Local	11%	21.0
Wheat in Heexosa	Ogolcho (2012)	Improved	59%	125.4
	Kubsa (1995)	Improved	55%	91.5
	Hidase (2012)	Improved	52%	75.5
	Kingbird (2015)	Improved	18%	31.4
	Kakaba (2010)	Improved	13%	18.9

Farmers' varietal preferences were shaped by a combination of agroecological, socio-economic, and cultural factors. For example, in Gindabarat, Maanyaa and Quncho are both white-seeded varieties that fetch a high market price due to urban consumers' preference for lighter *buddeena*. *Buddeena* (Oromo) or *enjera* (Amharic) is a fermented flat bread that is a staple food in many parts of Ethiopia. Quncho is high yielding with good straw palatability for cattle and equines but is only adapted to midland agroecology. FGD participants explained that Quncho has good vegetative growth in the highlands at the expense of seed-bearing panicles and fails to yield enough grain/seed. In contrast, Maanya is low yielding but is widely adapted. Daaboo is a brown-seeded variety with lower market value but is well adapted to both highland and midland agroecological areas of Gindabarat. According to FGD participants, Daaboo is higher-yielding than all white-seeded varieties and has good taste and nutritional quality, as expressed by the following local proverb in the Oromo language: "*Daaboo dhiiga dhiiraa, dhiirrii qoomaf, dubartiin duugdaf si nyaattii*", meaning "Daaboo, you are part of men's blood, men eat you for physical strength; women eat you to regain back strength [after labor/delivery]".

When explaining the challenges they faced in terms of varietal suitability, FGD participants in Gindabarat mentioned the loss of local varieties due to their susceptibility to new plant diseases (e.g., wheat rust) and climatic variability (e.g., late onset of rain) as well as the absence of new, improved varieties that are adapted to these challenges. Aside from Quncho and the obsolete wheat varieties, improved varieties are totally lacking in the district. FGD participants described the chronic varietal insecurity in several food crops as follows:

> *In the past, we had many traditional varieties of teff, wheat, barley, sorghum, maize, peas, and faba bean. Most people have now abandoned many traditional varieties, especially*

> *sorghum and wheat. Unfortunately, we do not get disease-resistant or well-adapted improved seeds from the government. So, we shifted to teff and maize. We also have a bad experience with the few varieties of teff and sorghum that we received from the agriculture bureau in the past. Almost all failed to perform well on our soil. A few years ago, a new sorghum variety did not flower at all. It failed. We are now cautious about using new varieties because the risk is high if it fails after investing all our resources (labor, seeds, fertilizer, and land) into its cultivation. The two most important improved varieties that have benefited us so far are Quncho and hybrid maize varieties.*

Elderly FGD participants stated that chronic varietal insecurity in wheat represented a huge production loss for farmers in Gindabarat compared to three to four decades ago when wheat was widely grown. Even as recently as 2006, the proportion of households growing wheat and number of wheat varieties was much higher than at the time of the present study (31% vs. 13% households and 14 vs. 6 varieties) [92].

In Heexosa, farmers generally preferred improved wheat varieties released in the last decade due to their yield and relative wheat rust resistance, although many respondents also selected wheat varieties based on other factors such as market value, taste, frost tolerance, and straw palatability for livestock. The most striking example is Kubsa, which continues to be planted in Heexosa for its high yield and good taste, despite being susceptible to wheat rust and requiring frequent application of pesticides. That said, FGD participants explained that the virulence of the Ug99 stem rust was a major concern and strongly emphasized the need for continuous varietal replacement:

> *Our biggest concern is the recent increase in wheat rust [i.e., Ug99]. There were plant diseases in the past too. Now it is worse. We see a link between climatic variation, such as the late onset of rain, and wheat rust. When we observe rust on maize in June following a late rain, we know that it will be devastating for wheat in the autumn. In the past 10 years, if it had not been for pesticide, we would not have produced even for our own consumption. Thanks to pesticides, we now produce a surplus for the market. The day Kulumsa Agricultural Research Center is unable to develop rust-resistant varieties for us, and agrodealers stop the supply of pesticides, agriculture will collapse in our district. We cannot go back to traditional varieties for better resistance and higher yield. Most traditional wheat varieties lodge if we apply fertilizer because they grow tall and have thin stems. What we need from the research is a continuous supply of new, improved varieties that are resistant to plant diseases and high yielding in order to sustain our production.*

In both districts, newly established CSBs have re-introduced preferred local varieties from genebank collections and well-established CSB in similar agroecological areas. Although the FGD participants in Heexosa felt that traditional varieties did not perform well for high yield, some farmers expressed interest in gaining access to durum wheat varieties with important cultural values and appreciated the reintroduction of lost durum varieties in the face of high genetic erosion (75–100% loss) in the central highlands [103–105].

5.2. Seed Availability

Seed availability is adequate when farmers can source enough seed at the right time to meet their needs from available sources [19]. In post-disaster contexts, seed security studies typically find that even when farmers' own seed saving is reduced, seed continues to be available from other sources, especially local markets [52,106,107]. Exceptions to this are often linked to disease outbreaks, especially for vegetative crops, or disruptions in the functioning of social networks, markets/road networks, or the formal seed system (for certified seeds) [30,108,109]. Understanding seed availability thus starts with gauging the relative importance of different seed sources. Our survey shows that farmers in both districts overwhelmingly rely on farm-saved seeds, both for their major crop and secondary crop (Figure 3). Social networks are the second largest source for the dominant crop in both districts, but in Heexosa, where farmers rely more strongly on improved varieties, the public seed sector is almost on par with social networks.

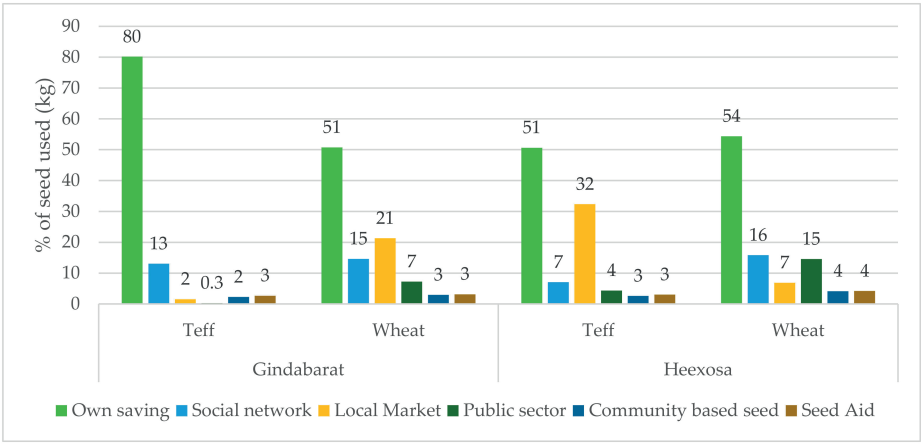

Figure 3. All seed sources as percentage of all seed used for teff and wheat in Gindabarat and Heexosa districts in 2017/2018 planting season, respondent households (n = 223 teff growers and n = 28 wheat growers in Gindabarat, and n = 209 wheat growers and n = 60 teff growers in Heexosa). The seeds sources included (1) own savings; (2) social network (exchange with relatives, neighbors and/or friends); (3) local markets; (4) public sector (parastatal seed enterprises, associated PMCs, agricultural research centers and district agriculture extension bureaus; (5) community-based seed groups (SPCs and CSBs); and (6) Seed Aid (emergency seed relief programmes in Heexosa and Afoosha self-help group in Gindabarat). Direct Seed Marketing (DSM) represented a negligible volume of seed in Heexosa, and was excluded from the figure.

The high reliance on own-saved seed is in line with other studies of cereal seed systems in normal conditions [32,110–112]. FGD participants in both districts indicated that they consider their own saved seed to be the most reliable seed source. Even for improved varieties of wheat in Heexosa and the one commercial variety of teff in Gindabarat (Quncho), farmers primarily use own-saved seed, relying on social networks and the public sector mainly for seed renewal purposes. This is consistent with a study of major wheat growing areas in Ethiopia, which showed that about 84% of the farmers depend on recycled seeds while only 14% used new seeds [113].

Some seed security studies show that local markets play a major role for many crops in post-disaster areas [71,114]. In our study, this is only true for the secondary crops in each district, for which local markets were the second largest source (approx. 20–30% of seed). The secondary crops are grown by a minority of households, and not necessarily every year; FGD participants explained that farmers often invest less effort in seed saving for these crops, relying instead on the local market.

Community-based and seed aid contributed less than 5% of the quantity of seeds in both districts (Figure 3). In Gindabarat, there were no SPCs, while in Heexosa recently established cooperatives produced non-certified seed, which they sold locally. This included 15% of certified seed they produced for the public sector, which they can lawfully retain, as well as "QDS seed", though in practice this was not quality controlled. There was also a CSB in one ganda of each district that produced seeds of traditional varieties that were not common in the district. In Heexosa, this focused on traditional wheat varieties (i.e., durum wheat) that were almost entirely lost due to displacement by improved bread wheat varieties over the past five decades [104].

In Gindabarat, seed supply by agrodealers or seed agents is absent. In Heexosa, we encountered a few direct seed marketing (DSM) agents supplying wheat seeds from the public seed enterprises, but only a few farmers (n = 5) in our survey bought seed from these agents. DSM was introduced in Ethiopia in 2011 to enable public and private seed producers to directly assess seed demand and supply adequate quantities of seed in convenient locations using either their own sales staff or hiring private agents [115,116].

According to FGD participants, the main seed security challenges relating to availability in the two districts was the lack of adequate and/or timely supply of certified seeds. In Heexosa, certified seeds produced by the public sector were insufficient or distributed late, whereas, in Gindabarat, certified seed use was limited to small quantities of Quncho (0.3% of seed) and wheat varieties (7% of seed) that PMCs receive from the Ambo Farmers' union and sell to farmers. The almost negligible contribution of the public sector to teff seed supply in Gindabarat is much lower than the national average of 10% [110], and FGD participants emphasized that the demand among farmers for certified seeds like Quncho is much higher than the supply.

Although the overall frequency of calamities is perceived to be low in both districts, FGD participants pointed out that drought, flood, and plant diseases (e.g., Ug99) have been increasing in recent years. As a result, FGD participants in Gindabarat expressed their desire for external support to establish a local grain/seed reserve suitable for long-term seed storage to ensure local seed availability during disasters. They discussed this in connection with Afoosha self-help groups that provide donations of grain/seed to poor households affected by socioeconomic and environmental disasters, as well as CSBs that provide low-interest seed loans. They explained that Afoosha is based on an indigenous long-term seed storage practice called *dilbii* (grain/seed reserve) in which rich farmers *Abba dilbii* ("owners of grain/seed reserve") who saved teff seeds/grain up to seven years in well maintained *gotooraa* gave seed/grain to poorer households for free or as credit. *Gotooraa* is the name in the Oromo language for medium and large sized cylindrical or rectangular granaries made from bamboo or sticks and built on a bed having four forked support poles. They are plastered with mud and dung and dried before use for grain/seed storage. *Dilbii* has disappeared due to successive land redistribution programs and increased poverty but has been reinvigorated by Afoosha in Gindabarat, where the practice is widespread. In Heexosa, FGD participants felt that increasing the SPCs' annual seed production and supply at the community level would be more appropriate than establishing a seed reserve due to the shorter storability of wheat seeds.

Finally, despite the efforts of the CSB in Heexosa, the availability of adaptable durum wheat varieties is still very limited in the district. This is also the case of improved durum wheat varieties that have been developed by the public sector [117] but are not multiplied or made available to farmers [113].

5.3. Seed Access

Seed access refers to farmers' ability to acquire seed, whether it be with cash or through exchange, loan, or social networks [19]. In addition, CGIAR [26] identifies seed access as depending on extension and seed dissemination/delivery channels (e.g., transportation and distance) and sufficient information/awareness about how and where to get quality seed, as well as information on prices. Problems with seed access tend to be among the most common challenges facing farmers in emergency contexts, due to acute problems such as loss of financial resources or assets and insecurity/inability to travel to markets, while also exacerbating chronic vulnerabilities experienced by specific socio-economic groups [30,102,118]. Insights from the adoption literature on factors associated with the use of improved varieties also provide a useful backdrop for assessing the access dimension of seed security.

Here we focus on access to seeds that were considered expensive by farmers: recycled Quncho seed that is obtained through exchange or purchase via social networks in Gindabarat and certified wheat seeds sourced from the public sector in Heexosa. Our survey results show that in Gindabarat, Quncho represented a higher share of total teff seed volume for male heads of household (MHH) compared to female, self-reported wealthier farmers compared to medium and poor, and for younger farmers compared to older farmers (Table 4). In Heexosa, there was relatively little difference between gender, wealth, or age groups in terms of the share of wheat seed volume represented by improved varieties (Table 4). However, more substantial differences among groups were observed in farmers'

use of certified vs. recycled seed for improved varieties (Table 5). Compared to wealthier farmers, poor farmers used less certified seed and recycled seed for longer, with 13% doing so beyond the maximum of five years recommended by research [119]. Interestingly, relatively *more women* (FHH) used certified seeds than men (42% vs. 27% of respondents), and no FHH recycled seeds for more than five years. As described below, there are several factors that explain these trends: purchasing power, access to information, and privileged positions within government rural development programs, and how they are differentiated according to gender, wealth status, and age.

Table 4. Percent seed volume represented by improved varieties for the major crop in Gindabarat (Quncho) and Heexosa (Wheat).

	Gindabarat	*n*	Heexosa	*n*
Gender				
MHH	33%	190	90%	172
FHH	25%	33	83%	37
Wealth status				
Poor	25%	30	83%	28
Medium	32%	182	92%	166
Rich	36%	11	71%	15
Age				
Young <45 years	40%	118	86%	117
Old ≥45 years	23%	105	93%	92

Table 5. Percent of farmers using certified and recycled wheat seed in Heexosa.

	Certified Seed (Changed Annually)	Recycled 2–5 yrs	Recycled >5 yrs	*n*
Gender				
MHH	27%	65%	8%	172
FHH	42%	58%	0%	37
Wealth status				
Poor	22%	65%	13%	28
Medium	30%	64%	6%	166
Rich	50%	50%	0%	15
Age				
Young <45 years	33%	59%	8%	117
Old ≥45 years	26%	69%	5%	92

High seed/grain price for both Quncho in Gindabarat and certified seed in Heexosa was identified by FGD participants as limiting factors for poor households. In Heexosa, this is one of the main reasons that poorer households recycle improved seed for longer. As described by the FGD participants, poor farmers do not have access to newly released wheat varieties for the first couple of years until enough recycled seed of the new variety is available in their communities through SPCs and social networks at more affordable prices:

> *In our districts, all gandas have at least one PMC. All of us are supposed to buy certified seeds and other inputs from the government enterprises at the PMC shops. The price of 100 kg of certified wheat seeds from the PMCs [1350 ETB] is almost twice the price of our grain produce [800 ETB]. [ETB: Ethiopian birr; 1USD = 40ETB]. Not all of*

> *us access because of the high price. (. . .) Renewal of seed or getting seeds of a new, improved variety is extremely challenging because there are not enough seeds. During the first few years, only model farmers and out-growers get the seeds of the newly arrived variety. These seeds are much more expensive than seeds of older varieties. (. . .) Timely access to seeds of a new variety is not possible. The positive thing, though, is that out-growers/model farmers sell at a lower price [1200 ETB] than the PMCs. For them, it is still profitable compared to the grain price.*

While high price is one limitation, this explanation also reveals that model farmers have preferential access to certified seed compared to other farmers. The FGD participants also underlined that poor farmers are rarely recruited as model farmers. Key informants explained that this is due to poor farmers' small landholdings and assets, which limit their ability to participate in seed multiplication and dissemination. They also pointed out that political allegiance was used by the district to select model farmers. This is consistent with Hailemichael and Haug [120]'s study of the extension system and advisory services in eight districts of Ethiopia, which argues that political allegiance is a major factor influencing the selection of model farmers, favoring wealthier farmers aligned with the government, and giving them privileged access to information, technology, and new skills, to the exclusion of other farmers. It is also consistent with political extension studies that view the model farmer approach to agricultural extension in Ethiopia as a historical continuation of the exploitative power relations between farmers and the regime [121–123].

The case of Quncho in Gindabarat shows that high grain/seed price is relevant not only for seed accessed through the formal seed system but can also play a role even for seed accessed through social networks. Due to Quncho's high market value, FGD participants explained that it is expensive to obtain Quncho seeds/grain using cash or in exchange against other crops/varieties of equivalent value. They described that this limits access for poor farmers, who have large families compared to their landholdings, and prefer to produce another teff variety, Daaboo, for household consumption. Thus, access and use of Quncho was more common among wealthier farmers.

Our finding that younger farmers also use more Quncho than older farmers was unexpected because farmers under the age of 45 years tend to lack adequate farmland and/or be considered poor because few of them participated in the last land redistribution in Ethiopia following the fall of the military government in 1991. It is therefore surprising that they are willing to pay the price for pure Quncho seed. According to FGD participants, this was because the younger farmers with limited landholdings preferred to grow Quncho for its market price and purchase cheaper grains such as maize and sorghum for home consumption. This strategy allows them to secure more food grain than growing Daaboo, but the *buddeena* made from these crops is considered inferior to that made from teff, and its consumption is considered a sign of poverty. A similar strategy of selling high-value improved wheat to purchase maize and sorghum was also described by younger participants of the FGDs in Heexosa. Thus, younger farmers were willing to sacrifice food quality for economic gain.

While limited purchasing power is a constraint to seed access for all resource-poor groups, our study reveals dynamics related to access to information that are specific to gender, with surprising contrasts between the two districts. In Gindabarat, FHHs self-reported more frequently as poor than their male counterparts (27% of FHHs vs. 11% MHHs), and this may be one reason that they also use less Quncho seed than MHHs. However, FGD participants also agreed that men were better represented in agriculture and rural development related meetings and trainings provided by local extension, which enabled them to get more knowledge about improved seeds than women. Timely and reliable information about farmers who have good quality surplus Quncho seed was also exchanged at these gatherings, giving men an advantage in sourcing Quncho seed. Women FGD participants mentioned that most of them were not members of PMCs and were not recruited as model farmers. They also spoke about a lack of time to attend agricultural extension meetings and trainings when they were invited. This result is

consistent with other studies that have found that 'non-model' and/or women's limited access to agricultural awareness creation platforms influences their access and use of agricultural technologies [123,124].

The situation for FHHs was markedly different in Heexosa, where women used more certified seed than men and recycled it within the recommended time frame (Table 5). Adoption studies show that the decline in wheat productivity can be improved by using new certified seeds compared to older recycled seeds [125,126] and that frequent seed renewal by smallholder commercial farmers shows their productive behavior [112]. Knowledge on the use of agricultural technology is created mainly through access to information [127], and this is a strong indicator of women's empowerment [128]. Interestingly, female FGD participants explained that compared to men, FHHs in Heexosa had equal access to information and agricultural inputs, including certified seeds. FHHs also had similar wealth status (16% FHH vs. 13% MHH self-reporting as poor) and were well represented as model farmers. The women FGD participants highlighted unexpectedly positive empowerment of FHH, and their related access to improved agricultural technologies:

> *Unfortunately, all of us are on our own i.e., we are widows and divorcees. (. . .) We do everything that most men do in farming. In the past, women, including widows and divorcees, were not considered equal to men. Now, we have more freedom and voice. We equally participate in meetings, trainings, and access inputs as men. We express our ideas in public gatherings. In recent years, we are also privileged to sometimes get priority over men for inputs and trainings due to our active engagement, which authorities appreciate. We learnt new techniques and gained skills in agriculture. We have better savings; some of us have saved between 70,000 to 100,000 ETB. We have full control over our incomes and resources. We hire labor and rent land to expand our production. In fact, some of us are better than many male farmers.*

This is a striking account considering the patriarchal culture in Ethiopia as well as socioeconomic and political marginalization of women in all sectors, including agriculture [129,130]. Indeed, it seems to reflect an important change in agricultural technology use over time, as Tiruneh et al. [124] found that 20 years ago, FHHs in central Ethiopia used improved seed 50% less than their male counterparts. Although it requires further investigation, FHHs' high empowerment and access to agricultural inputs and positions was explained by key informants in terms of "effective" implementation of the government's decentralized extension program, citing among other things that the posting of female development agents in every ganda has been very useful for agricultural technology dissemination. In addition, they explained that the strong presence of externally supported development projects in the district has led to a significant push for a gender-sensitive approach to agricultural development. The long history of agricultural development interventions, combined with donor requirements for gender mainstreaming, therefore seems to have created opportunities at least for FHHs in Heexosa, in contrast to the situation in Gindabarat, where external agricultural development actors are largely absent.

It is important to note, however, that the FGD participants emphasized that married women did not benefit from the same kind of empowerment as FHH did. As they explained: "They are still under the control of their husbands. They do not go out and participate in meetings and trainings. They are powerless. There is a big difference between married women and us".

5.4. Seed Quality

Seed quality refers to the physical, genetic and physiological properties of the seed, including germination, vigor, varietal purity, and freedom from disease and impurities, and is crucial for farmers to establish robust plant stands and harvest higher yield [19,131,132]. Problems with seed quality are among the major challenges facing farmers in emergency contexts. This is mainly due to poor seed quality management practices among seed traders, NGOs, and other actors involved in seed relief [114,133], as well as chronic is-

sues that smallholder farmers experience with pests and diseases, seed handling and storage [134–136].

Here, we examine farmers' perception of the quality of seeds they obtain from different sources and the storage facilities they use. Focusing on seeds obtained during the 2017/2018 growing season, we asked respondents to rank the quality of the seeds used for each variety of their major crop (i.e., seed lot) as "good" and "not good" and triangulated this with qualitative assessment by farmers in FGDs. Farmers rated seed as "good" if they had no weeds, debris, varietal mixture, had good germination and were free of insect damage; and "not good" if most of these seed quality features were lacking. Our survey shows some marked variations in seed quality between seed sources and districts (Figure 4). In both districts, community-based seed (from SPCs and CSBs) was rated by farmers as the highest quality, with less than 10% of seed lots considered "not good". FGD participants in Heexosa explained that the SPC members pooled together knowledge and experience, and the trainings they received from experts from the public seed enterprises, research, and bureau of agriculture helped them to maintain good quality standards for the seeds they produced. In addition, CSB members spoke in the FGDs about how the CSB technical committee assessed quality based on information they gathered on preharvest handling and through visual inspection when members paid back their seed loans. We also observed a good storage facility that one SPC had built with external support. A study by Sisay et al. [77] supports farmers' assertions that organized seed producer farmers maintain higher quality standards than individual households. On average, 94% of all cereal seeds produced by farmers' groups for the Ethiopian Seed Enterprise in the 2009/2010 season were approved as certified seeds [137]. While these findings show that community-based seed has good quality, there are recent studies that report infrastructure challenges and poor seed handling practices among SPCs [138,139]. Moreover, these seed sources are marginal in terms of seed volume in our study areas (Figure 3).

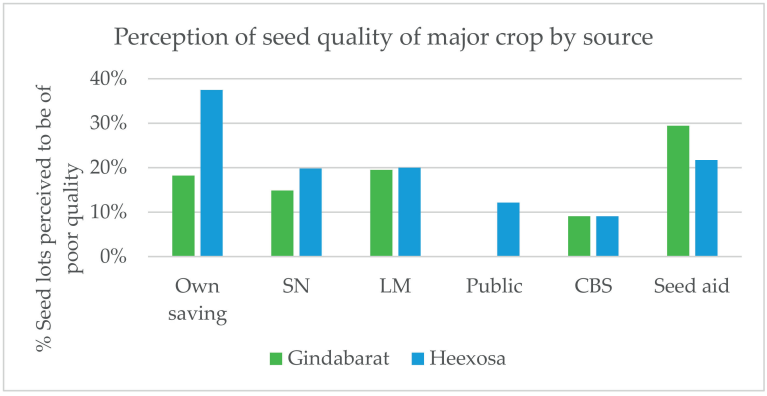

Figure 4. Percentage of respondents' rating of seed quality (germination/vigor, physical purity, varietal purity and seed transmitted diseases or sanitary conditions) for seeds they accessed from different sources (Own saving, SN = Social seed network, LM = Local market, CBS = Community-based seed producers, Seed Aid = emergency seed relief programmes in Heexosa and Afoosha self-help group in Gindabarat) during the 2017/2018 planting season (n = 605 teff seed lots in Gindabarat and n = 758 wheat seed lots in Heexosa). "Seed lot" is defined in this paper as the seed from a specific teff or wheat variety that was planted by a household in the 2017/2018 season. Only one farmer in Gindabarat rated the quality of seed from the public sector, so this was excluded.

In line with other studies [30], farmers reported quality problems with seed aid, particularly in Gindabarat (27% of seed lots), where the traditional Afoosha self-help system was the main source. The Afoosha grain reserve has relatively poor quality because it is established through contributions of food grain (rather than seed) from different

families, though many aid recipients use it for planting. In addition, the Afoosha do not typically have good seed storage facilities. In Heexosa, key informants explained that seed aid is provided by NGOs and international research institutions (i.e., CIMMYT), who source the seed primarily from SPCs and public enterprises, being one of the main customers of for these groups [138]. Afoosha are present in Heexosa but are not involved in seed/grain aid.

Own-saved seed is the major seed source in both districts, and therefore seed quality problems for this source are of particular importance. There were seed quality problems for own saved seed in both districts, but this was particularly high in Heexosa (37% of seed lots). FGD participants in both districts related seed quality problems mainly to the mixing of varieties between harvest and processing stage, as well as problems in seed storage. In Heexosa, FGDs explained that varietal impurities were caused by the use of communal combines, which were used to harvest plots of neighboring farmers with insufficient cleaning in between. Storage problems for wheat were chiefly caused by seed-borne fungi and granary weevils. In both districts, mixing of white and brown-seeded teff varieties was the major problem with varietal purity due to the commercial value associated with the seed color. Otherwise, mixtures between local varieties were not considered problematic. The main causes mentioned were heavy rains and run-off after planting that transports seeds and seedlings from one field to another, as well as poorly cleaned winnowing fields and seed storage. The main storage problem was high moisture levels in the seed storage caused by insufficient drying of seed after untimely rain during harvest and winnowing.

One reason that the quality of own-saved seed in Heexosa was perceived to have more problems than in Gindabarat could be differences in the inherent storability of the crops. Due to its small seed size and resistance to insect pests, teff has good viability for up to five years if stored following a proper drying [140,141], while wheat can typically not be stored for more than two seasons due to infestation by granary weevils and/or fungal diseases [32]. In addition, we found significant differences in seed storage practices (Table 6). In both districts, survey respondents stored seeds inside their homes, but in Heexosa, woven polypropylene bags were used to store 90% of seed lots, with chemical insecticide applied to increase storability. In contrast, in Gindabarat *gotooraa* played a much more important role than in Heexosa. Gotooraa is perceived to have a better aeration, and only 16% of teff seed lots stored in *gotooraa* were reported as "not good" in Gindabarat, compared to more than twice as many (37%) wheat seed lots stored in polypropylene bags in Heexosa. In Heexosa, FGD participants explained that *gotooraa* has been abandoned as households have increasingly adopted an urbanized way of life and thus do not have enough space inside their homes to build a bulky *gotooraa*. Furthermore, increased grain theft discouraged farmers from building *gotooraa* outside their homes, except in predominantly Muslim gandas where theft is uncommon. A decade ago, 66% of farmers were using the facility in northwest and central Ethiopia [32]. At the same time, farmers have not yet adopted hermetic bags that are effective for seed storage [142] due to lack of awareness and high price [143,144].

Table 6. Table Storage facilities most used per district. Data is presented as the % of seed lots produced from own-saved seed. "Seed lot" is defined in this paper as the seed from a specific teff or wheat variety that was planted by a household in the 2017/2018 season.

Storage Facility	Heexosa (Wheat)	Gindabarat (Teff)	Total
Woven polypropylene bags	89.5%	41.5%	64.2%
Gotooraa	0.5%	33.0%	17.7%
Woven polypropylene bag with inner liner	3.3%	13.4%	8.6%
Jute	0.5%	6.5%	3.7%
Other ‡	6.3%	5.6%	5.9%

‡ Plastic bag, metal/plastic drum, earthen/clay pot, gourds, loose in a room and community storage facility such as CSBs.

In Heexosa, the quality of seed lots sourced from the public sector seeds was high, with only 12% of lots reported as "not good", nearly on par with the community-based seed (Figure 4). In Gindabarat, only one farmer rated the quality of seed from the public sector, so this was excluded from the analysis. Nonetheless, our qualitative information gives a different picture. FGD participants in both districts asserted that the quality of their own-saved seed was equal to or sometimes even better than certified seed. This is consistent with studies in Syria and Ethiopia, which found that about 90% of farmers are satisfied with the quality of own saved seeds for cereal crops [32,98,145]. Moreover, male FGD participants in Heexosa spoke with utter disappointment about the certified seeds they accessed:

> *We want to tell you that the seeds we buy from PMCs have no good quality. They mix seeds from the present season with unsold seeds carried over from the previous season, seeds produced in different agroecologies, as well as seeds of different crop species/varieties, and sell to us. Sometimes, we found barley in a package of wheat seeds that we bought. The wheat seeds we purchased from them did not perform uniformly when we sowed in the field. They were like our fingers [a farmer shows different length of his fingers]. They did not have equal height, awn types, and panicle size.*

6. The Potential of the Ethiopian Seed System Development Strategy to Meet Demands

The results and analyses presented above testify to the widespread seed insecurity in both the commercially oriented wheat-centered seed system in Heexosa and in the subsistence-oriented teff-centered seed system in Gindabarat. In this section, we ask to what extent does Ethiopia's shift from a linear model of seed sector development to a pluralistic approach holds potential to improve farmers' seed security? We address this question by analyzing the relevance of the PSSDS' priority interventions (for each seed system and their cross-linkages) in relation to our empirical findings on seed security (above), and examine how the underlying functioning of the seed systems, as revealed by our analysis of seed sector actors' roles and performances (Table A1), pose constraints and opportunities for the PSSDS' implementation.

6.1. Informal Seed System

The informal seed system provides most of the seed volume for the major crop in each district, mainly from own-saved seeds and social networks, with the local market being more important for the secondary crops. The PSSDS includes several priority interventions to strengthen the informal system (Table A2), including:

- Improving access to locally adapted varieties by strengthening coordination between farmers, research centers, and genebanks for re-introduction of lost varieties, selection of locally adapted varieties, and by improving access to germplasm for participatory varietal selection and breeding;
- Increasing the diffusion of local varieties through innovative marketing networks (seed fairs, field days, open markets) and through investment in CSBs, including allocating gene funds from access and benefit–sharing agreements;
- Setting up a national system for seed provision during emergencies to improve emergency response, including the establishment of a national seed reserve, creating an independent institution to lead seed security assessments and interventions, and strengthening quality control measures for emergency seed;
- Improving awareness, skill, and infrastructure to improve farmers' production and management of good quality seed.
- *Cross-linkages—informal and formal:* engaging farmers, agricultural research, and regulatory authorities in participatory varietal development and release to ensure varietal suitability for farmers; supporting farmer-genebank linkages using the gene fund to compensate farmers' management of local genetic diversity.

These are all relevant to addressing key seed security issues identified in this study, such as the loss of traditional durum wheat varieties, interest in strengthening teff seed re-

serves (Gindabarat), and challenges in the perceived quality of some informal seed sources, such as Afoosha seed aid (Gindabarat) and own-saved seed (especially Heexosa). However, our study shows that interventions to improve the informal seed system have largely been left out from current government-seed related programs, with the only supports being made through NGO interventions backed by international donors, e.g., CSB projects financed by western NGOs and "crowdsourcing" to engage farmers in participatory testing and dissemination of open-pollinated local and improved varieties through the ISSD program (Table A1; [138]).

Our key informant interviews show that government- and NGO-led interventions in both districts have been riven with conflicts (Table A1). On the one hand, district agriculture bureaus promote the use of 'the full package' (improved varieties, chemical fertilizer, pesticides, and improved agronomic practices) as a means to achieve higher yield. We found that the district development agents were doing everything possible to convince farmers to adopt the package, as their salary and benefits are related to fulfilling the district's targets for adoption. This finding is consistent with studies of the Ethiopian agricultural extension system during the Sasakawa Global 2000 program in the 1990s [146,147]. On the other hand, NGOs focus on community-based seed production, emphasizing the superiority of traditional varieties for higher yield stability, low-cost input, better nutrition and adaptation, and encouraging farmers to diversify crop production. This has created confusion among farmers in areas where NGO projects were implemented. Our interviews with key informants suggest that the lack of coordination is partly due to a lack of awareness about the PSSDS and the mandates it prescribes among stakeholders at local level, which calls for attention by all actors.

This disjuncture at the local level mirrors a conflict at the national level that has existed for decades between the Ethiopian Institute for Agricultural Research and Ethiopian Biodiversity Institute concerning their respective mandates [63], and ideological differences regarding the use of Green Revolution technologies versus local varieties adapted to low input agriculture [148]. Since the 1990s, the Institute for Agricultural Research has asserted that the main task of the Biodiversity Institute should be limited to ex situ conservation and making germplasm available for formal breeding, arguing that development of high yielding varieties is critical for food security, whereas the Biodiversity Institute, who has supported community-based seed management initiatives together with allied civil society organizations, has insisted that promotion of diverse varieties, and specifically locally adapted landraces, is critical to strengthen farmers' seed systems in face of recurrent drought and genetic erosion. Both institutes participated in the development of PSSDS and advocated for their respective approaches, but thereafter have continued to implement their programs as before, without making adjustments for complementarity between value-chain components of each seed sector and integrating their activities, as set out in the PSSDS. The one exception is the ISSD program, in which diverse stakeholders have been involved in efforts to properly implement the cross-linkages identified in the PSSDS, e.g., linking farmers with agricultural research for crowdsourcing and participatory variety selection [149]. More generally, this lack of implementation of the PSSDS is due to the authoritarian nature of the Ethiopian state itself. In his study of seed policy in Ethiopia, Beko [150] finds that although the government often seeks stakeholders' input for policy making, this is mostly done to meet official procedure or as a formality. In practice, only policy provisions that are in line with the government's political objectives are implemented, with the aim to maintain control over farmers and secure political allegiance [74,151,152].

This lack of attention to the informal seed system in Ethiopia's agricultural development programs has major implications for seed security. For example, the finding that over a third of own-saved wheat seed lots used by farmers in Heexosa were rated as poor quality is concerning. Aside from some technical trainings and awareness creation provided to a limited number of farmers who participated in out-grower schemes, SPCs, and the CSB, there are nearly no interventions to help strengthen household-level seed handling and storage (Table A1). The combination of deteriorating traditional seed storage practices

and incomplete modernization—affecting the quality of the most important seed source used by farmers in Heexosa—deserves concerted investment at scale by government and NGOs alike.

The PSSDS provision to develop a national seed emergency system has yet to be implemented but responds to the desire for a reliable local teff seed reserve, expressed by the FGDs in Gindabarat. The seed security literature identifies direct seed distribution and market-based approaches such as vouchers and seed fairs as typical emergency seed aid interventions [30]. Our findings suggest that there is an opportunity for the development of a seed emergency system building on existing community institutions such as Afoosha and CSBs, as proposed by the FGDs. Given the working principles such as trustworthiness and altruism [153], Afoosha is a strong, cohesive force at the community level and has effectively reinvigorated the practice of *Abba dilbiis*. However, unlike *Abba dilbiis*, our findings indicate that seeds/grain from Afoosha are of low quality as the seeds are from grain reserve. This, therefore, requires technical and management solutions such as separating varieties, proper drying of seeds, having a proper warehouse and maintaining seed stores, recommended also for other seed aid actors [114,154]. Although Afoosha seed aid is widespread in Gindabarat, its scope at national level is not clear, which calls for further study. Seed reserves would be less appropriate for crops with short storability like wheat.

To finance efforts to strengthen the informal seed system, the PSSDS proposes to establish a fund derived from monetary benefits that the federal government expects to gain from international Access and Benefit-Sharing agreements under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) and the Nagoya Protocol of the Convention on Biological Diversity (CBD). Thus far, some projects for on-farm management of genetic resources have been funded by the Benefit Sharing Fund of the ITPGRFA [155,156] and the CBD have supported development of national policy and legal frameworks for the implementation of Nagoya Protocol [157]. However, monetary benefits have not been generated from the small number of bilateral access and benefit-sharing agreements established under Nagoya Protocol to date and such funds are likely to remain limited [63]. Investment to improve the informal sector should thus be based on other more reliable funding sources (e.g., over the regular agriculture budget).

6.2. Formal Seed System

Farmers in both study districts show a clear interest in improved varieties but rely mainly on informal channels to source seed. In Gindabarat, this is due to the near total absence of formal seed system actors in the district, whereas in Heexosa the system is well established but suffers from ineffective performance.

The PSSDS recognizes several bottlenecks in the formal seed system and proposes a comprehensive approach to "bring about a holistic transformation" of the system (Table A2). Some of the main interventions proposed are:

- Improving the development of adapted crop varieties by strengthening the coordination of federal and regional research centers, promoting participatory plant breeding, and establishing a body independent of research institutions to oversee variety registration, release, and protection;
- Increasing the volume of certified seed by addressing inefficiencies in the value chain (including improving the accuracy of seed demand estimation and delineating responsibilities for the production of each seed class) as well as by increasing the capacity and number of out-growers;
- Improving the timeliness of certified seed supply through DSM and by replacing government price setting with open pricing to reduce delays due to excessive bureaucracy;
- Strengthening access of resource-poor farmers, especially women, to certified seed through credit and savings schemes;
- Improving seed laboratories' capacity for seed quality inspection and testing by building their technical capacity, infrastructure, and equipment, as well as increasing the number and remuneration of technical staff.

- *Cross-linkages—formal and intermediate*: institutionalizing out-grower and agrodealer schemes by establishing contractual agreements between public seed enterprises and community-based seed producers (e.g., SPCs and PMCs) for certified seed production; improving community-based seed producers' access to basic and first generation certified seeds for production of QDS.

Our findings from Heexosa indicate that several investments have been made in the last decade that align with the strategy. This includes increases in the production of certified seed by strengthening the Oromia Seed Enterprise and expanding the number of out-growers organized in cooperatives and commercial cluster groups [138,139]. Contractual agreements have also been established between seed producer cooperatives and public seed enterprises for seed multiplication, although many breaches in these contracts have been reported, linked to price setting and capacity [158]. Since 2011, ISSD, together with Ministry of Agriculture and the Agricultural Transformation Agency, has also piloted DSM, which has now been scaled out to 313 districts nationally [149,159]. Key informants in Heexosa indicated that this has reduced delays in seed supply to farmers, and according to Alemu et al. [149], efficiency has been increased especially by reducing costly rates of seed carryover in store by as much as 85%. From the perspectives of development actors, the expansion of DSM is seen as partial liberalization of the seed sector, a step in the right direction to transform the formal seed system [116,159,160]. A regional seed laboratory has been established in Asella, taking over most of the responsibility for field inspections and certification from the national laboratory. The regional and federal agricultural research centers have been assigned specific responsibilities for variety development and adaptation research (Sinana on durum wheat and Kulumsa on bread wheat), albeit with some overlaps.

Despite these efforts, important barriers still exist that underly several of the seed security problems identified in our study. One key issue is the need for better-adapted improved varieties, reflected in the general lack of improved varieties of teff, as well as the need for better disease resistance in wheat. Although teff is the most frequently grown staple food and biggest cash crop in Ethiopia [161], it is generally considered an "orphan crop" receiving little attention from international research and the donor community [162,163]. At the time of our field research, there were 37 improved teff varieties listed on the national crop variety register [117] and one newly released brown seeded variety [164], but only five of them were adopted nationally for extensive cultivation, with two of these (Quncho and Tseday) accounting for 90% of all teff seed production [110,165]. The main reason that the other varieties are not distributed is the lack of farmers' preferred traits such as lodging and biotic/abiotic stress tolerance, non-shattering, and higher yield [162]. In Gindabarat, this challenge at the national level is compounded by the lack of local research on the adaptation of released varieties. The district agriculture bureau's interventions are limited to sporadic theoretical trainings for model farmers on the importance of agricultural technology packages, without corresponding investment in seed production and supply of improved varieties. By and large, most FGD participants viewed certified seed from the formal system as risky and government seed supply as something they cannot rely on. In effect, Gindabarat can be considered an "orphan district" in terms of the formal seed system.

There has been more investment in wheat and high potential districts such as Heexosa. Kulumsa Agricultural Research Center has released approximately 70 improved bread wheat and durum wheat varieties [166], but disease resistance—especially to Ug99—is a global challenge [99,167]. It is therefore not surprising that farmers in both districts expressed challenges with this. Nonetheless, as with teff, it is also the case that many released wheat varieties are sitting on the shelf. According to key informants and recent project reports [168], some of the new varieties that have very farmer preferred traits, e.g., the variety Kingbird with superior disease resistance [169], have been quickly adopted and spread through informal channels by model farmers who get the seed in adaptation trials. Yet, distribution through formal channels has lagged for many varieties due to bottlenecks in the regulatory system. As with teff, some key informants indicated that there

are improved wheat varieties that are not distributed due to the lack of farmer-preferred traits, pointing to the poor involvement of farmers in the breeding process. The lack of better-adapted varieties is therefore compounded by constraints in variety deployment (including variety promotion, seed production and dissemination), which is a major issue for many crops in most developing countries [170,171].

The PSSDS' plans to promote participatory plant breeding holds potential to improve the suitability of released varieties. Indeed, Quncho was developed through participatory plant breeding and multi-station variety selection on black soils, which helped to successfully incorporate farmers' criteria [172,173]. Furthermore, the provision to establish an independent body for registration and release and to increase the efficiency of the registration and release process. However, it is less clear to what extent these and other investments will be made in "orphan districts" like Gindabarat.

Another key problem is the shortage of certified seeds and delays in supply. Key informants from Kulumsa Agricultural Research Center (KARC) explained that this is partly due to lack of resources (funding, land, infrastructure, and technical capacity), which constrains the production and distribution of early generation seeds (EGS), and the low number and capacity of the federal and regional seed enterprises. In addition, the seed recovery rate from out-growers is generally low, as out-growers often retain more than the 15% share they are entitled to [111,112]. As a result, only limited quantities of popular varieties are produced. Perhaps even more critical are problems with seed demand estimations and quota allocations that are carried out under the oversight of the Ministry of Agriculture. In Heexosa, none of the district agricultural development agents we interviewed had confidence in the seed demand information they collected, citing mistrust in the information provided by farmers, the failure to collect current data due to the lack of transport, and high demands of other tasks, among others. This is consistent with Hailu et al. [174] who found that the poor performance of Ethiopia's agricultural extension system was explained by limited synergy and partnership among actors, poor motivation and competence among development agents, and insufficient resources for their mobility. In Gindabarat, key informants explained that the very limited amounts of certified Quncho seed that reach PMCs often do not correspond to seed demand estimates that the district development agents submitted. They blamed this on the top-down manner in which the formal seed supply system is governed, with minimal participation of local government.

To be more effective, seed demand estimation should be made directly by public seed enterprises and other private seed producers rather than by the Ministry of Agriculture. In this sense, DSM seems to be a viable alternative to improve the performance of the formal seed supply for self-pollinating cereal crops in Ethiopia. However, to do so will require the Ministry of Agriculture to relinquish direct control over parts of the seed supply system, focusing instead on coordination and regulation. Whether there is political will to do so is an open question, considering that seed supply in Ethiopia has to date been politically driven. For example, the government has used input provision as a way to control farmers and secure their political support [120,175,176]. To maintain their dominance of the seed sector, the government has also curtailed the role of private sector actors by using market disincentives such as price setting or limiting areas of operations for seed marketing [74,177]. In practice, the government has been skeptical towards the private sector, despite the many policy documents promising to strengthen their involvement [74].

One of the main goals of any formal seed system is to provide seeds of verified quality, yet FGDs in both districts pointed to quality problems with certified seed distributed by the PMCs. We identified two main reasons for this. The first is inadequate inspection of growers' fields, including the existence of rent-seeking and collusion in the regulatory services. Key informants from the regulatory authority admitted that quality control is seldom carried out per the required standards because of the limited number and competence of field inspectors, insufficient cars for fieldwork, and inadequate facilities to conduct germination tests. Although inspectors denied this, seed producer farmers claimed that inspectors made unfair decisions based on bribes and that there was a lack

of transparency around field inspection decisions, quality approval, and distribution of certification tags. For instance, key informants from a commercial out-grower group complained that the seed they jointly produced on 15 hectares of land was rejected because inspectors found a smut contaminant in just one of the fields. They also mentioned that regulatory staff secretly distributed certification tags to some producers who had not undergone seed quality procedures. Consistent with the PSSDS, recent reports point to the lack of an independent regulatory authority as the main reason for poor seed quality control and certification services in Ethiopia [138,178,179], a situation that Tripp and Louwaars [180] argue can open the door to rent-seeking and collusion. The second reason is the lack of strict quality control at later stages in the value chain, particularly the work carried out by the public enterprises to collect seed from out-growers and clean and package it for distribution. Key informants indicated that it is not uncommon to combine seed from different agroecologies, as well as with seed leftover from the previous year, which explains why farmers in both districts complained of quality problems. To mitigate for this, there should be control along all parts of the value chain so that farmers can trust the seed that they are buying.

In terms of access to certified seed, the PSSDS notes that the price of certified seed in Ethiopia is relatively low compared to neighboring countries and thus does not consider this to be a major issue, beyond strengthening credit and savings schemes for resource-poor farmers, especially FHHs. This is generally true for commercial farmers in Heexosa, who explained that the costs of other inputs such as fertilizer and especially pesticides (given the heavy use) are more expensive than seed. Nonetheless, they considered the price unfair, claiming that the production gain from certified seed did not justify the cost. Key informants from the district bureau and research institutions felt that farmers did not understand all the costs implied in certified seed production. However, given shortcomings in quality control and the availability of less expensive, high quality seed from the intermediate sector, this also raises questions about the cost efficiency of certified seed production.

For resource-poor farmers, improving their purchasing power through credit and savings is one strategy to increase access to certified seed, especially for young farmers who are interested in using full-package technologies. However, until greater quantities of certified seed are available, it is likely that wealthier model farmers and out-growers will continue to have privileged access, thus increasing supply is key. Furthermore, our findings point to access problems even for seed of high-value varieties like Quncho obtained through social networks. Strategies to improve seed access should therefore extend beyond certified seed and include "orphan districts" like Gindabarat.

The formal seed system and related extension services and agricultural programs have provided opportunities for access to information and led to the impressive empowerment of FHHs in Heexosa. These findings show that progress in gender-responsive extension [181] is possible, but more efforts are needed to create opportunities for women in MHHs and to expand supports in marginal districts with few agricultural development actors.

6.3. Intermediate Seed System

The intermediate seed system has emerged during the past decade in Ethiopia as a way to increase farmers' access to seed and build local economies through decentralized community-based seed production and distribution. The ambition is to promote the development of independent, self-sustaining seed enterprises that address local needs and demands, especially for self-pollinating crops and specific agroecologies that are not met by the formal system. Given that it is relatively new, the interventions proposed by the PSSDS focus primarily on developing community-based seed production and marketing, including:

- Providing technical, financial, and infrastructure support for community-based seed producers to increase their capacity for QDS production and develop viable local seed businesses;

- Linking community-based seed producers to multiple marketing strategies and distribution channels, e.g., DSM agents and local market to facilitate access by farmers;
- Increasing community-based seed producers' access to diverse crop varieties for multiplication by linking them through contractual agreements with research institutes, the national genebank, and well-established CSBs.
- *Cross-linkages—intermediate, formal and informal:* leveraging social seed networks to increase distribution and access by farmers of all types of seeds (informal, QDS and certified); exchanging knowledge and skill among seed sector actors; formalizing promotion of all varieties (local, open pollinated and hybrid) based on farmers' needs through bureau of agriculture/government agricultural extension in collaboration with farmers organizations, NGOs, genebank and agricultural research.

Our findings show that community-based seed produced by CSBs and SPCs have made contributions to seed security in terms of availability, affordability, and quality. The growth and expansion of SPCs have mainly been supported by ISSD program in collaboration with government institutions in the seed sector. Through its 10-year intervention in Ethiopia, ISSD has established or strengthened 270 SPCs and mainstreamed the SPC approach to seed production and distribution in 50 government and development institutions, including the Ethiopian Agricultural Transformation Agency and German Federal Enterprise for International Cooperation (GIZ). Nationally, these SPCs have produced and distributed 392 varieties of 35 crop species [149]. This shows a growing positive contribution of SPCs to the availability and access to good quality seeds of diverse crop varieties [77,182].

Although the overall contribution to wheat and teff seed supply in the study districts remains limited, the most significant impact of ISSD is probably in terms of institutional innovation, especially with regard to the intermediate system. The program has successfully encouraged the government to facilitate SPCs' access to input and service providers (e.g., credit, source seeds, technical and management training) and infrastructure development [138] as well as to develop/adjust relevant policies and regulations, including the PSSDS itself as well as the QDS directive [149].

That said, implementation still lags behind. In general, SPCs in Heexosa are still mainly operating as out-growers for the formal seed system, with the sale of the 15% they retain as their main contribution to the intermediate seed supply system. While this has increased farmers' access to more affordable seed of improved varieties the volumes are still low. Further investments in terms of technical, financial, and infrastructure support are required to build their capacity to become independent seed enterprises that can meet local seed demand. Moreover, there is no QDS certification provided to the SPCs in Heexosa, as seed laboratories have prioritized seed certification in the formal system over QDS certification due to capacity constraints. Key informants and recent reports [139,179] indicate that there are gaps in the technical capacity of the SPCs' internal quality control committees, which QDS could help to address. Nonetheless, our findings indicate that farmers in the study districts are satisfied with the quality of community-based seed from SPCs and CSBs, consistent with recent evaluations of SPC seed supply in Ethiopia [183,184].

The PSSDS includes CSBs as relevant actors for commercial production and distribution of local varieties. To date, CSBs in Ethiopia have played a more important role in terms of making a diversity of locally adapted varieties available to farmers through low-interest seed loans for members. We are not aware of any that have integrated commercial seed production and marketing into their operations, as has been done by CSBs in other countries like Nepal [185]. Given the CSBs' experience with local varieties such as durum wheat, they could play a role in QDS seed production and marketing of improved durum wheat varieties that are currently on the shelf. There are still relatively few (approximately 30) CSBs in Ethiopia [186], despite its promotion since the mid-1990s [187], thus the overall contribution to seed supply remains limited.

From the perspective of pluralistic seed systems, a diversity of seed sources provides smallholder farmers a greater choice of seeds and varieties [17,188,189]. SPCs and CSBs

are both contributing to increasing production and distribution of certified, QDS and local seed. Our findings also suggest that there may be an opportunity to scale out impacts of the intermediate sector, particularly in marginal areas, by linking CSBs and SPCs to existing community institutions like Afoosha, that have a strong local governance based on principles such as trustworthiness and altruism [153]. Overall, we find that the intermediate system represents a huge potential to foster linkages between formal and informal systems and increase the availability and access of diverse seeds and varieties to farmers. To meet this potential, government needs not only to invest in expanding existing programs and capacities, but also to resolve conflicts between conservation and agricultural research and development institutions.

7. Conclusions

This study contributes to the seed security and seed system literature by revealing some of the social, political, and institutional constraints and opportunities that underlie chronic seed insecurity among smallholder farmers in Ethiopia. While the seed security literature has focused on post-disaster settings, our findings from a "normal" growing season reveal evidence of seed insecurity in all four dimensions (varietal suitability, availability, access, and quality) for both the subsistence and commercially oriented production systems examined.

In broad terms, a number of seed security challenges are common to both subsistence and commercially oriented systems, such as seed quality issues relating to lack of varietal purity and storage of own-saved seeds and the need for new varieties to adapt to diseases. However, the nature and severity of the challenges differ particularly as they relate to the formal seed system. For example, although farmers in both districts suffer from insufficient availability and access to seed from the formal system, this is more marked in the subsistence-oriented district where crop improvement research and formal seed supply channels are nearly entirely absent. On the other hand, in the commercially oriented production system, there is a lack of availability of certified seeds and a lack of access to farmer preferred traditional varieties. Furthermore, our findings indicate that the heavy presence of seed sector actors in the commercially oriented district has led to differences in seed access between socio-economic groups. It seems the targeting of female headed households by the extension services have indeed increased this group's access to certified seeds. Another group with better access to certified seeds are wealthy farmers aligned with the government who are favored for positions as model farmers and out-growers. Our study further shows that high grain/seed price constrains access not only for seed from the formal seed system but also for high value seed/grain accessed through social networks. Overall, we conclude that farmers are navigating between an eroding traditional system and a dysfunctional formal system.

Our analysis of the PSSDS shows a good alignment between the policy's proposed priority interventions and farmers' seed security challenges. In large part, this is due to the pluralistic approach taken in the policy that puts farmers at the center of seed sector development by promoting complementarity between value-chain components of each seed system and integrating their activities, in contrast to the dominant linear model to seed sector development in developing countries. However, our field-based findings show that the operationalization of the policy lags behind, with investments in the informal seed system largely missing from government programs, whereas the main source of proposed funding for this system (i.e., access and benefit-sharing funds) is unlikely to materialize. Some improvements have been made in the formal system, and the overall integration of all seed systems for holistic seed sector development, however progress is hampered by vested political, organizational, and economic interests within key seed sector institutions, as well as insufficient resources and capacity. The intermediate "community-based" seed system shows promise, though limited in scale, and in the subsistence-oriented production system, restricted only to investments by NGOs. More generally, the implementation of

the PSSDS faces fundamental problems with key actors not adapting their mandates and programs to reflect the PSSDS' pluralistic approach.

Overall, our study suggests that pluralistic seed system development can provide a path to seed security in developing countries. This requires that well-designed policies like the PSSDS lead to investment at scale to strengthen the informal seed system and dysfunctions in the formal system, while investing in the intermediate system. However, for this to happen, historical, institutional, political, and social factors that underlie the current (dys)functioning of the seed sector need to be understood and tackled. Context specific research that examines this complex interplay of factors is crucial. Finally, the potential that the intermediate seed system shows call for more investment, but while some improvements have been made in the formal system, vested political, organizational, and economic interests within key institutions represent major obstacles that must be overcome to achieve truly integrative and inclusive seed sector development.

Author Contributions: Questionnaire preparation, T.H.M.; Tool pre-testing, T.H.M.; Conceptualization, T.H.M., O.T.W. and S.P.D.; Methodology, T.H.M. and O.T.W.; Data collection process, T.H.M.; Data cleaning and analysis, C.M. and T.H.M.; Draft preparation, T.H.M.; Draft review editing, O.T.W., S.P.D., R.H. and T.H.M.; Supervision, O.T.W.; Funding acquisition T.H.M. and O.T.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by RESEARCH COUNCIL OF NORWAY, grant number RCN 277452 and RCN 4850060008.

Institutional Review Board Statement: The study was conducted according to the guidelines for research ethics of the Norwegian University of Life Sciences and Norway's guidelines for research ethics in the social sciences, humanities, law, and theology. Based on these guidelines, we submitted a notification form to the Norwegian Center for Research Data (NSD) prior to commencing data collection and received approval from NSD (Harald Hårfagres gate 29, N-5007 Bergen, Norway) on 18.09.2017. The guidelines did not require an explicit ethics approval in Ethiopia. We informed the state, district and village authorities and they gave us permission to carry out the surveys, interviews, and discussions.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available from the corresponding author upon request. The data are not publicly available due to protection of privacy linked to research participants' personal data.

Acknowledgments: This paper is based on research project conducted in completion of the PhD degree by the first author, under supervision of the last two authors. We are very grateful to the Oromia Bureau of Agriculture and Natural Resources and the district Bureau of Agriculture and Natural Resources in Gindabarat and Heexosa for facilitating the household surveys and FGDs. We appreciate the generous participation of farmers, public, non-government and private seed sector actors involved in Ethiopian seed systems for discussions and interviews. We thank Tola Gemechu Ango (Stockholm University) for making the map and Habtamu Alem (Norwegian Institute of Bioeconomy Research) for valuable advice on data analysis. We also thank Åsmund Bjørnstad and Trygve Berg in Norwegian University of Life Sciences (NMBU) for providing important inputs to earlier versions of this paper. THM wishes to thank the NMBU for the scholarship to carry out this research and the Research Council of Norway (RCN) for financial support for his fieldwork under grant number (RCN 277452), and the International Maize and Wheat Improvement Center (CIMMYT) in Addis Ababa for hosting him and facilitating his fieldwork during the period. OTW, CM and RH are grateful for the financial support through the RCN funded project ACCESS (RCN 4850060008).

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

Appendix A

Table A1. Roles of seed sector actors in contributing (↑) and/or constraining (↓) smallholder farmers' seed security of the teff-centered and subsistence focused farming system in Gindabarat district, and the wheat-centered and commercially oriented farming system in Heexosa district. Roles that have not yet had the intended effect are denoted with ↔.

Actors (Gindabarat)	**Seed Security Features**				
	Varietal Suitability and/or Adaptability [1]	**Availability** [2]	**Access** [3]	**Quality** [4]	**Gender, Socioeconomic Status, and Age** [5]
Local government decision makers/experts *District bureau of agriculture*	↑ Bring pre-basic/basic seeds or early generation seeds (EGS) of improved varieties from agricultural research located in similar agroecology and conduct participatory variety trials together with farmers under different input packages and agronomic practices at FTC. ↑ Recognize and support participatory variety selection (PVS) of traditional varieties conducted by the community seed bank (CSB) group (see below) ↔ Requested support from regional government for variety testing and research on new technologies (not yet obtained)	↑ Assess farmers' seed demand and determine quantity of certified seeds required ↑ Provide external support (e.g., administrative and financial management) for formally organized farmers for seed production (see below) in collaboration with District Cooperative Promotion Bureau ↔ Requested support from regional government for seed production and distribution to increase supply of improved seeds (not yet obtained) ↓ Did not establish seed reserve for seed system resilience in cases of disaster. ↓Not aware about or did not request the Regional Bureau of Agriculture to provide certificate of competence for interested seed agents [8] and cooperatives for direct marketing of certified seeds to farmers and effective distribution	↑ Determine share of certified seeds for peasant associations, enforce government prices, and support Primary Multipurpose Cooperatives (PMCs) during seed distribution ↑ Conduct field demonstration of new varieties at Farmer Training Centers (FTC) to increase awareness among farmers ↓Despite weak evidence, the extension often promotes improved varieties as better yielding than traditional varieties ↔ Submitted requests for budget from regional government to build physical infrastructure (e.g., access road) to improve access to agricultural inputs and marketing outputs (not yet obtained)	↑ Collect data from farmers and report events of poor performance due to low seed quality of certified seeds to regional bureau of agriculture to enforce commercial guarantee [6] and settle disputes ↑ Recognize the seed quality criteria that most farmers use [7] ↑ Support trainings on quality seed production and storage for members of an NGO-supported community seed bank (CSB) group (see below) ↓ No trainings provided on seed production and storage provided for individual households ↓No technical training and infrastructure support for PMCs to increase their capacity to properly store seeds they receive from public seed enterprises	↓ Extension services, technology promotion, and agronomic trainings prioritize model farmers (often the majority are male household heads), which marginalize women and youth ↔ Established women/youth leagues/federations at the local and district level to increase participation in agriculture development issues, but the structure is mostly utilized for political governance of the district by the leading party
National/regional research *Holeta Agricultural Research Center (HARC) and Debre Zeit Agricultural Research Center (DZARC)*	↔ Send limited EGS samples of new varieties to the district agriculture bureau for use in participatory trials (see above), but most of them failed to adapt to the local environment [9] ↓ Do not conduct variety development and adaptation specific to the district agroecology	↓ Do not produce and distribute early generation seed in the district because commercial seed producers are not present	↓ Do not provide extension and training for DAs and lead farmers to increase awareness on varietal information and agronomic practices	↓ Germination failure of seeds for PVS trials, due to delays in shipments/long shelf life	

Table A1. *Cont.*

Actors (Gindabarat)	Seed Security Features				
	Varietal Suitability and/or Adaptability [1]	**Availability** [2]	**Access** [3]	**Quality** [4]	**Gender, Socioeconomic Status, and Age** [5]
Local traders/markets and seed agents/agrodealers *Traders of grain/seeds including farmers who sell at local markets*	↓ Vendors/traders combine grains from different agroecological areas (lack traceability of source); this sometimes causes crop failure for teff if planted in the wrong agroecology	↑ Bring diversity of grain from different areas to local marketplaces that farmers buy for food grain or seed ↓ Lack of local agrodealers hinders availability of improved seeds	↑ Seeds sold at local markets are easily accessed (close by and timely available) ↓ Wheat seed sold or lent by traders/venders is often expensive due to low availability	↓ Grain/seed sold at local markets generally rated by farmers as poor in terms of germination and purity	↑ Local markets provide poor farmers (e.g., landless youth) access to grain/seeds when they cannot save seeds or consume their saved seeds. This is a last resort, due to poor quality of seed.
Specialized seed producers and farmer organizations/groups *Community Seed Bank (CSB) group, Primary Multipurpose Cooperatives (PMC) and Afoosha* [10]	↑ The CSB group conducts PVS on pools of varieties from the local area, genebank, and other communities to identify varieties suitable for low input farms ↔ Occasionally, the PMCs distribute varieties that are not recommended for the specific local agroecology (e.g., hybrid maize for highland is sold to midland areas)	↑ One CSB group produces limited quantities of local wheat and teff seeds ↔ The PMCs obtain certified seeds from the Ambo Farmers Union, but these often arrive too late and in insufficient quantities ↑ Afoosha maintain grain reserves for local food and seed relief ↓ There are no organized seed producers for improved varieties	↑ The CSB group distributes seeds through a loan system with low interest repaid at harvest (10% in kind/seed) ↑ The PMCs sell certified seeds to users at government price ↑ Afoosha give free seeds to families affected by death or natural calamities	↑ Farmers have positive perception of local seeds produced and communally certified by CSB group ↓ Farmers complain about poor quality of certified seed distributed by PMCs (e.g., hybrid maize and Quncho seeds)	↑ CSB groups and Afoosha offer seeds to poor farmers and households affected by calamities (e.g., widows) ↑ Gender balance in the CSB group allows consideration of women's priorities in seed multiplication (e.g., local barley varieties that were introduced from other areas) ↓ Female household heads have limited access to certified seeds from PMCs that are dominated by men
Non-governmental Organizations/ Development agencies/Inter-governmental organizations *Movement for Ecological Learning and Community Action (MELCA-Ethiopia)* [11]	↑ MELCA trains men and women CSB members on PVS of local varieties to meet diverse environmental and socioeconomic needs	↑ MELCA brings seed/germplasm from the national genebank and other communities for multiplication to increase availability of traditional seeds	↑ MELCA supports seed loan system managed by CSB group (see above) ↓ MELCA's training crop diversification often promote traditional varieties as better varieties than improved varieties	↑ MELCA supports communal seed certification through CSB's seed committee ↑ MELCA supported construction of community seed bank facility for improved seed storage	↑ MELCA supports CSB groups in organizational capacity building including administration, seed, and financial management through balanced representation of different farmer categories (gender, age, and wealth categories)

Table A1. *Cont.*

Actors (Gindabarat)	Seed Security Features				
	Varietal Suitability and/or Adaptability [1]	**Availability** [2]	**Access** [3]	**Quality** [4]	**Gender, Socioeconomic Status, and Age** [5]
Smallholders *Own seed production and social networks*	↑ Farmers verify the varietal suitability of seed provided through social networks (neighbor certification) ↓ Farmers lack sources of new varieties to adapt to declining soil fertility and increasing rust for wheat production	↑ Most farmers produce and save own wheat and teff seeds ↑ Lead farmers save seeds from adaptation trials if they prefer a variety and multiply for their own use and exchange with other farmers ↓ Most landless and poor households do not save enough seeds to meet their needs	↑ Farmers loan (i.e., with interest), sell, or exchange seeds with friends, neighbors, or family ↑ Better-off individuals provide cash loans that are used for seed purchase ↓ The custom of seed gift is abandoned	↑ Farmers perceive quality of own seeds as good ↑ Farmers maintain varietal purity of high-yielding improved teff through appropriate selection and seed handling ↓ Occasionally untimely rain combined with lack of good storage facility cause damages in household seed stocks	↔ Social networks and moneylenders help landless and poor households to access seeds on credit, but interest rates are high, making repayment difficult. ↑ Younger farmers often access an improved teff variety through social networks to increase productivity on small landholdings ↓ Most lead farmers are men, limiting women's access to new varieties
Others not active in Gindabarat	The following seed sector actors are not active in Gindabarat: Regulatory bodies (Ambo seed quality control and certification laboratory of the Oromia Agricultural input regulatory authority); International research (e.g., CIMMYT, ISSD); Public/private seed sector (Ethiopian Seed Enterprise/ESE, Oromia Seed Enterprise/OSE and commercial private farms); and Private sector processors (e.g., private small-scale milling)				
Actors (Heexosa)	**Varietal Suitability and/or Adaptability**	**Availability**	**Access**	**Quality**	**Gender, Socio-Economic Status and Age**
Local government decision makers/experts *District bureau of agriculture*	↑ Conduct participatory variety adaptation trials of new varieties together with farmers under different input packages and agronomic practices at FTC ↑ Recognize and support PVS of traditional varieties in marginal areas (e.g., higher elevations)	↑ Support market-led seed supply to increase availability of certified seeds and locally produced quality declared seeds (QDS) ↓ Supported seed agents and cooperatives to get certificate of competence from the Regional Bureau of Agriculture for direct seed marketing of certified seeds to farmers and effective distribution ↑ Collect demand from farmers and determine quantity of required certified seeds ↑ Support CSB seed production to increase seed supply through farmer training ↓ Did not establish seed reserve for seed system resilience in cases of disaster	↑ Determine share of certified seeds for peasant associations, enforce government prices, and support PMCs during seed distribution ↑ Conduct field demonstration and seed fairs (field days) to increase awareness and information on new seed varieties and their characteristics ↓ Despite weak evidence, the extension often promotes improved varieties as superior varieties for yield and disease resistance and discourage use of traditional varieties	↑ Monitor farmers involved in the production of certified seeds and seeds for the CSB for implementation of good agronomic practices [12] ↑ Collect data from farmers and report events of poor performance due to low seed quality of certified seeds to regional bureau of agriculture to enforce commercial guarantee[13] and settle disputes	↔ Support women's participation in seed producer cooperatives and trainings, but limited to women household heads ↑ Encouraged and recruited women household heads as model farmers

Table A1. *Cont.*

Actors (Heexosa)	Varietal Suitability and/or Adaptability	Availability	Access	Quality	Gender, Socio-Economic Status and Age
Regulatory bodies *Asella seed quality control and certification laboratory of the Oromia Agricultural input regulatory authority*		↓ Strict certification and rejection of seeds produced by contract cluster groups and individual farmers reduced availability of certified seeds to some extent, but limited sales inspection allowed seed sellers to supply rejected seeds though sometimes adulterated		↓ Inadequate human resources to conduct field inspection at all seed production stages and limited laboratory facilities and testing protocols to conduct quality tests of all seeds from producers' plots contributing to ineffective seed certification ↑ Provide training for organized producers on quality seed production and management	↑ Provide technical training on seed production, processing, and storage for internal seed quality control committee of seed producers, including female members
National/regional research *Kulumsa agricultural research center (KARC) and Asella Agricultural Engineering Research Center (AAERC)*	↑ Since its establishment, KARC has produced about 70 wheat varieties [2] with different merits and conducted adaptation trials in collaboration with agriculture bureau at FTCs and on farmers' plots to ensure suitability to farmers' environmental and socioeconomic conditions ↓ Disease-resistant wheat varieties are generally lacking, and production is impossible without pesticides ↓ Variety replacement rate is low due to slow release of new varieties and low seed multiplication of released varieties	↑ KARC produces EGS and makes these available for public seed enterprises, unions, and SPCs ↓ However, not enough quantity EGS are produced and made available for the multiplication of successive generations of seeds (e.g., certified seeds) by seed producers	↑ KARC supports field demonstration and extension to increase awareness of farmers and development agents on varietal information and good agronomic practices ↓ Lack of strong unit in agricultural research is the cause for weak coordination for sustainable EGS access and supply and loose responsibility of EGS multiplication	↑ KARC conducts internal quality control of its EGS before distribution for adaptation trial and multiplication ↓ Poor quality of EGS is sometimes delivered due to limited human resources, equipment, and infrastructure ↑ AAERC provides training in pre-harvest, harvest, and post-harvest technologies (e.g., cleaning combines to avoid varietal mixture)	↑ KARC involves some female household heads in variety testing and adaptation trials
International research *CIMMYT*	↑ CIMMYT brings advanced lines of wheat seed samples from other countries for the testing and identification of adaptable variety ↑ Together with KARC, CIMMYT develops disease-resistant wheat varieties ↓ CIMMYT does not work on teff	↑ CIMMYT provides support to KARC for the multiplication of large quantity of EGS	↑ CIMMYT organizes exposure visits for farmers, development agents, and entrepreneurs to increase awareness about new varieties	↑ CIMMYT ensures the seed samples it imports are free from quarantine pests	↑ CIMMYT provides training of trainers and researchers on gender issues for mainstreaming in crop improvement research

Table A1. *Cont.*

Actors (Heexosa)	Varietal Suitability and/or Adaptability	Availability	Access	Quality	Gender, Socio-Economic Status and Age
Local traders/markets *Traders of grain/seeds including farmers who sell at local markets*	↑ Recycled wheat variety from midland areas is perceived by farmers to have better yield and disease resistance in highland agroecological conditions and vice versa	↑ Bring large quantities of grain/recycled or traditional seeds from all agroecological areas and make these available at local markets	↑ Grain/seed sold by traders/vendors is easily accessible (nearby) ↓ Seed sold or lent by traders/vendors is expensive (especially teff)	↓ Seed purchased from traders/venders is not quality controlled and generally perceived by farmers as having poor quality	↑ Local markets provide poor farmers access to grain/seeds when they cannot save seeds or consume their saved seeds. This is a last resort, due to poor quality of seed.
Public/private seed sector *Ethiopian Seed Enterprise/ESE, Oromia Seed Enterprise/OSE and Seed agent/agrodealers*	↓ Sometimes, wrong varieties are distributed in wrong agroecological areas	↔ The seed enterprises produce and supply most of certified seeds via government-controlled distribution channels, but quantities are insufficient (especially teff) and distribution is often delayed ↔ The seed enterprises also produce and supply EGS to other seed producers, but quantities are insufficient ↑ Recent increase in number of seed agents improved availability of certified seeds in wider coverage of agro-ecologies ↑ Prioritize seed supply to severely seed insecure areas when disaster hits	↓ High price discourages farmers from using certified seeds ↑ Recent contract-based direct seed marketing (DSM) through seed agents has increased timely supply within easy reach, but the agents sometimes increase the price against the agreement and make it unaffordable for the poor ↓ The involvement of the private sector that sells seed is generally limited ↓ EOSAs often promote traditional varieties as better varieties than improved varieties	↔ Supply certified seeds but sometimes quality fails to meet the required standards, especially for carryover seeds ↑ Train contract cluster groups and members of seed producer cooperatives in quality seed production and management as well as agronomic practices in wheat production ↓ Seed agents lack good storage facility for temporary stocking until they sell seeds or return leftover seeds, which sometimes affect quality	
Specialized seed producers and farmer organizations/groups *Seed Producer Cooperatives (SPCs), Community Seed Bank (CSB) groups and Individual out-growers*	↑ SPCs produce seeds of many preferred and adapted crops and varieties (e.g., self-pollinated, high-yielding, and marketable cereals and legumes) that were not easily available through the public seed enterprises in the past ↑ CSB groups conduct PVS and produce seeds of locally preferred varieties for low-input farms (especially in high-elevation areas) ↑ SPCs and CSBs are in the center of the farmers' village and know their customers in terms of varietal suitability to the agroecology and availability and affordable price	↑ SPCs and individual out-growers produce large quantities of seeds locally or within easy reach ↔ PMCs receive seeds from Heexosa Farmers Union but in insufficient quantities ↓ No organized group of farmers produce teff seeds	↑ Seed producer farmers/out-growers can keep enough seeds (up to 15%) for own use ↑ Seed price is lower than the prices of public/private companies ↑ SPCs are in the center of the farmers' village and set seed prices that their customers can afford ↑ CSB gives seed loan that is paid with low interest (10% in kind/seed)	↑ Farmers have positive perception of seeds produced by SPCs and communally certified by internal seed quality control Committee of SPCs and CSB ↓ SPCs lack a seed cleaner machine, mini seed laboratory equipment such as moisture testers, and germination Petri dishes for seed quality checks ↓ Experts see farmers' confidence in their long agriculture experience as a guarantee for their capacity to control seed quality, instead of using skilled personnel and establishing laboratory facility, as the cause for sporadic poor seed quality produced by SPCs	↑ Cooperatives support to farmers in provision of basic seed, training, and supervision through linking farmers with research institutions and input, and service providers emphasize women participation ↓ However, the number of women members in SPCs is very low

Table A1. *Cont.*

Actors (Heexosa)	Varietal Suitability and/or Adaptability	Availability	Access	Quality	Gender, Socio-Economic Status and Age
Non-governmental Organizations/ Development agencies/Inter-governmental organizations *USAID, FAO, Hunde Oromia and Ethio-organic seed action (EOSA) and ISSD Programme*	↑ EOSA brings seed/germplasm from other communities and the national genebank and conducts PVS of local and improved varieties to meet diverse environmental and socioeconomic needs in marginal areas ↑ ISSD introduced an innovative approach called crowdsourcing and participatory variety selection that aims to outsource multiple improved and farmers' preferred varieties of different crops to many volunteer farmers who are willing to grow and share the selected variety in their locality	↑ FAO, USAID, and Hunde provide seed aid when disaster hits and support seed multiplication ↑ EOSA supports CSB group to multiply traditional seeds/varieties selected through PVS ↑ ISSD provides financial and technical support to agricultural research (mainly regional) and OSE in contract-based multiplication of a large quantity of EGS ↑ ISSD provides financial, technical, and administrative support to increase the number and capacity of SPCs and seed agents for the production and distribution of large quantities of self-pollinating crop varieties that are neglected by public seed enterprises and private companies	↑ USAID, FAO, and Hunde provide vouchers to assist resource-poor households to access seeds according to their needs ↑ EOSA supports the CSB group in administering seed loans (see above) ↑ ISSD supports linkage between SPCs and financial institutions for credit as well as EGS sourcing institutions to increase SPC's access to pre-basic and basic seeds ↑ ISSD promotes small seed pack sizes based on the average land size that smallholders cultivate for each crop to increase access to required quantities of seeds at affordable prices	↑ FAO, USAID, and Hunde distribute certified, and quality declared seeds ↑ EOSA supports communal seed certification through seed farmer committee ↑ EOSA trains CSB members on crop diversification, good quality seed production, and storage ↑ ISSD supports training of SPC members on clustering, isolation, field management, and roughing to remove off types as well as seed value addition (cleaning, grading, treating, packaging, and labeling) to increase quality through technical training, exchange visits, resource mobilization, and linking them with service providers (e.g., credit institution for purchase of processing machines and seed labs for coaching)	↑ EOSA also trains farmers in organizational governance and women participation to ensure sustainability ↑ ISSD promotes gender-sensitive crop and varietal preference for deployment in its crowdsourcing and PVS activities
Private sector processors *Heexosa Multipurpose Union and private small-scale milling factories*	↓ Sometimes, the Union distributes certain varieties to areas for which there is no demand ↓ Sometimes, the Union distributes seeds to the wrong agroecologies	↑ The Union procures certified seeds from SPCs, ESE, OSE, and private seed companies for distribution through its PMCs ↓ PMCs do not participate in seed demand assessment and depend on unrealistic data collected by extension agents and wrong quota allocation, which restricts seed supply/availability	↑ The Union collects seeds and transports to selling points ↑ The Union and private small-scale milling factory purchases grains for milling at a reasonable price from primary cooperatives, allowing farmers to get income to purchase seeds for the upcoming planting season	↓ Sometimes, the Union distributes untraceable poor-quality seeds (including carryover seeds without laboratory seed tests) due to lack of accountability and transparency in the conventional seed distribution system	↑ The Union trains cooperative members including women and youth on business management ↑ Provides benefit for male and female household heads through agro-commodities procurement

Table A1. *Cont.*

Actors (Heexosa)	Varietal Suitability and/or Adaptability	Availability	Access	Quality	Gender, Socio-Economic Status and Age
Smallholder farmers *Own seed production and social networks*	↑ Own produced seed of recycled/traditional varieties is comparable in productivity compared with certified seeds ↓ Farmers lack new disease-resistant wheat varieties ↓ Low productivity/high labor demand of teff varieties causes most farmers to abandon its cultivation	↑ Most farmers produce and save own seeds ↑ Farmers save seeds from adaptation trials organized by district bureau of agriculture or CIMMYT for own use ↓ Some poor and landless households do not save enough seeds to meet their needs ↓ As secondary crop, few farmers grow teff, and its seed is not available in many villages	↑ Seeds sold by trusted farmers (e.g., neighbors) are close and affordable ↑ Farmers loan (i.e., with interest), sell, or exchange seeds with friends, neighbors, or family or provide cash loans for seed purchase ↑ Rich farmers often access new seeds, and they multiply and sell their produce as seeds to other farmers ↓ The custom of seed gift is absent	↑ Farmers perceive quality of own seeds, and those purchased/exchanged from fellow farmers, as good (known quality, neighbor certification) ↑ Most farmers use pesticides and recommended polypropylene bags to store wheat seed for one season	Farmers see high seed insecurity among landless and poor households in lowland areas Farmers who do not save their own seeds mostly depend on local exchange or purchase recycled improved seeds locally

[1] Varietal traits meet farmers' preferences including adaptation to local environment and production conditions, market demand, culinary and cultural needs, livestock feed, construction, and soil fertilization. [2] Physical existence of desired seeds in enough quantity in a reasonable proximity (spatial availability) for critical sowing periods (temporal availability). [3] Means to acquire seeds such as cash, credit, social network, and transportation with affordability and awareness/information. [4] Seed is healthy (free from disease/pest), has good physical qualities (not broken/cracked/shriveled), has good genetic and physiological qualities (good germination, optimum moisture content, genetic purity, and vigor), free from weeds and poses preferred color/size/shape/taste. [5] Impacts on seed security by gender, socioeconomic status, and age (cross-cutting). [6] Commercial guarantee: obtained from purchased seed usually bought locally from known seed dealer and oral, commercial, and often legal assurance is given. [7] Known quality: obtained from on-farm saved seed; 'neighbor certification': obtained from seed saved by family members and neighbors on trust. [8] A seed agent is an individual or institutions who sell seed to farmers on behalf of seed producer/s. They should acquire certificate of competence (CoC) from the government based on the requirements in the 2018 COC directive No.2/2010. The seeds are sold at a fixed producer price and commission is based on the amount sold. [9] In the last decade, only three teff varieties (Quncho, Kora and Guduru) and two wheat varieties (Digelu and Hidase) have been adapted to the environment and are liked by farmers. [10] Afoosha is an indigenous local social institution established in most communities in Ethiopia to provide financial and other types of support when a family member dies. In Gindabarat, we found that Afoosha groups have established grain reserves in most peasant associations to support poor families affected by calamities; these reserves are increasingly used as seed by those affected. [11] MELCA-Ethiopia is a local NGO supported by the Development Fund of Norway. [12] Soil use and fertility management (e.g., fertilizer application), crop rotation, row planting, recommended distance between plots per species, and crop protection. [13] Commercial guarantee: obtained from purchased seed usually bought locally from known seed dealer, and oral, commercial, and often legal assurance is given.

Table A2. Analysis of the Ethiopian pluralistic seed system development strategy [3] for improving the functioning of seed systems and smallholder farmers' seed security. The table illustrates the policy interventions identified and recommended for implementation based on analysis of issues and constraints that form systematic bottlenecks across the seed value chain in all the three seed systems (informal, formal and intermediate). The interventions presented here cover all levels of seed system governance with relevance to the availability, access, quality and varietal suitability of seeds that are required to meet farmers' needs.

Seed System	Seed Security Features			
	Varietal Suitability [1]	**Availability** [2]	**Access** [3]	**Quality** [4]
Informal	• Improve linkage between farmers and agricultural research (e.g., institutionalize PVS/PPB in crop improvement, identify and train seed selectors, and involve them in multiple stage of conventional variety breeding) especially by ensuring participation of women who can provide feedback on characteristics beyond yield, e.g., health-related issues and traits for food preparation • Strengthen pre-breeding component of the national genebank and promote increased access to germplasm for PVS, PPB and conventional breeding programs of the national agricultural research centres.	• Promote application of appropriate agronomic practices (recommended seed and fertilizer rate, pest and weed management, crop rotation, intercropping, etc.) to enhance yield and quantity of seeds produced by farmers • Support ex situ and in situ linkages to strengthen management of local genetic diversity through CSBs and strengthen their capacity to multiply seeds of diverse local varieties and reduce risk of genetic erosion • Set up an efficient *National Seed Emergency System* to effectively respond to natural/manmade disasters and increase seed security, e.g., develop a national strategy for seed reserve and emergency assistance (setting aside adequate local seed reserve), set up an independent institution for seed security assessment, planning and implementing seed assistance activities.	• Strengthen CSBs' capacity to facilitate farmers' access to seed by providing revolving funds and designing a system where CSBs receive financing from Ethiopia's access and benefit sharing agreements • Set aside an independent fund (revolving fund) that is specifically dedicated for emergency seed aid and coordinating seed aid actors' interventions to increase access to seeds by affected farmers • Strengthen and promote innovative local seed marketing networks for efficient seed diffusion (e.g., promote field days, community seed fairs, open markets and CSBs)	• Strengthen the technical and infrastructural capacity of CSBs for improved seed storage • Develop a special seed quality control system for emergency seeds, i.e., quality/quarantine checks for insect, pests, plant diseases and noxious weeds • Strengthen farmers' awareness in proper seed management methods and improve access to affordable implements, e.g., use improve seed processing techniques (harvesting at maturity, keep physical and varietal purity and use post-harvest technologies) and effective seed storage techniques (e.g., proper drying and use of hermetic bags) • Disseminate best practices in seed/varietal selection and maintenance for the informal system, e.g., developing manuals on proper seed/varietal selection (including farmers' criteria and scientific techniques for local varieties) and recycling practices or quality maintenance techniques (e.g., varietal purity for improved varieties) and well as using demonstration plots at Farmer Training Centers for raising awareness on varietal traits and agronomic practices for good quality seed production

Table A2. *Cont.*

Seed System	Seed Security Features			
	Varietal Suitability [1]	**Availability** [2]	**Access** [3]	**Quality** [4]
Formal	• Strengthen linkage between federal and regional research centers and increase their financial viability to embrace participatory variety development to incorporate traits beyond yield, involving especially women • Establish a federal regulatory authority independent from variety development entities; build its capacity (e.g., finance, human resource) for varietal evaluation, release, registration and plant variety protection through development or amendment of laws, regulations and directives; support technical capacity building and implementation of national seed proclamations and regulations at regional level	• Support training of staff/certified agents in seed demand estimation and local market assessment to improve planning of early generation seed (EGS) and certified seed production • Delineate and enforce roles and responsibilities among actors to avoid overlap and increase production (e.g., designate production of breeder seeds to research institutes; pre-basic and basic seeds to ESE; certified seeds of self-pollinating food crops to ESE and regional public seed enterprises; certified seeds of commercially attractive crops such as hybrid maize and vegetable seeds to international and national private seed companies) • Expand certified seed production using contractual out-grower scheme between public/private seed companies and SPCs/cluster groups; build capacity of out-growers and provide incentives (subsidized production inputs, credit, seed cleaning/processing services, transportation, land, improved business planning, marketing, and operations management)	• Promote direct seed marketing (not involving the bureau of agriculture and PMCs) to overcome delays that occur in the government's centralized conventional seed supply system and increase timely access by farmers • Implement open pricing mechanism for seed producers of public varieties and eliminate government price-setting by the Ministry of Agriculture and corresponding bureaus at regional levels to hasten timely access to quality seeds • Provide financial services to farmers to increase input affordability, with emphasis on female-headed households (with target to increase their access to agricultural credit from 5.4% baseline to 30% of female-headed households.	• Establish more robust transportation, logistics, and seed storage systems, and better financial and technical support for seed distributing agents to avoid seed adulteration or mixture with grain/infested by pest/physically damaged during storage and transportation • Ensure accreditation of seed laboratories and issue certificate of competence for multiregional enterprise at federal level based on set of criteria for quality seed production and supply • Build capacity of seed laboratories (e.g., training of technical lab and field staff, equip lab facilities, vehicle access, sufficient budget) for proper coordination and planning of controls with seed producers, e.g., field inspection, seed quality testing, decision on rejections/approval of seed fields and seed lots • Build capacity of agricultural research to ensure maintenance of breeder seeds

Table A2. *Cont.*

Seed System	Seed Security Features			
	Varietal Suitability [1]	**Availability** [2]	**Access** [3]	**Quality** [4]
Intermediate	• Focus CBSP seed production on less profitable crops such as local and improved varieties of self-pollinating crops (developed through conventional plant breeding, participatory variety selection and participatory plant breeding) with superior traits to fulfill seed production needs unmet by the formal system • Increase CBSPs' access to diverse crop varieties for multiplication by effectively linking them through contractual agreements with research institutes, the national genebank, and established CSBs	• Establish a revolving fund and/or provide credit guarantee to lending institutions to increase access to finance for CBSPs for capital and production investment as well as building technical and infrastructure capacity that will eventually contribute to expansion of Quality Declared Seed (QDS) production • Improve operational efficiency and sustainability of existing CBSPs to transition them into independent business entities that produce large volumes of QDS, i.e., by providing them targeted and continuous training, strengthen their logistic and storage capacity, promote proper clustering of plots and fair pricing mechanisms for out-growers to maximize seed recovery rate • Promote direct contractual linkage between CBSPs and public seed enterprises instead of quota scheme through bureau of agriculture to increase access to EGS, thus increasing production of QDS • Increase women's participation in SPCs, provide skill development support for women in seed production and infrastructure to increase their capacity for seed production.	• Link CBSPs to multiple marketing strategies and distribution channels (direct seed marketing agents, local market, etc.) to facilitate access by farmers	• Replace conventional quality standards that are too stringent for CBSPs with QDS regulatory system to ensure basic seed quality • Build internal capacity of CBSPs for quality seed production through agronomic training, infrastructure development and quality input supply (e.g., EGS)

[1] Varietal traits meet farmers' preferences including adaptation to local environment and production conditions, market demand, culinary and cultural needs, livestock feed, construction and soil fertilization. [2] Physical existence of desired seeds in enough quantity in a reasonable proximity (spatial availability) for critical sowing periods (temporal availability). [3] Means to acquire seeds such as cash, credit, social network and transportation with affordability and awareness/information. [4] Seed is healthy (free from disease/pest), has good physical qualities (not broken/cracked/shriveled), has good genetic and physiological qualities (good germination, optimum moisture content, genetic purity and vigor), free from weeds and poses preferred color/size/shape/taste.

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Article 3: Politics of seed in Ethiopia's agricultural transformation: pathways to seed system development

frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 10 November 2021
doi: 10.3389/fsufs.2021.742001

Politics of Seed in Ethiopia's Agricultural Transformation: Pathways to Seed System Development

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Seed system development in the developing world, especially in Africa, has become a political space. This article analyzes current Ethiopian seed politics in light of the historical dynamics of national and international seed system politics and developments. Drawing on multiple power analysis approaches and employing the lens of "international seed regimes," the article characterizes the historical pattern of seed regimes in Ethiopia. While colonial territories underwent three historical seed regime patterns—the first colonial seed regime, the second post-WWII public seed regime, and the third post-1980s corporate-based neoliberal seed regime, Ethiopia has only experienced one of these. Until the 1950s, when the first US government's development assistance program—the Point 4 Program—enabled the second government-led seed regime to emerge, the farmers' seed systems remained the only seed innovation and supply system. The first colonial seed regime never took hold as the country remained uncolonized, and the government has hitherto resisted the third corporate-based neoliberal seed regime. In the current conjuncture in the contemporary Ethiopian seed regime, four different approaches to pluralistic seed system development are competing: (1) government-led formalization, (2) private-led formalization, (3) farmer-based localization, and (4) community-based integrative seed system developments. The Pluralistic Seed System Development Strategy (PSSDS) from 2013 is a uniquely diverse approach to seed system development internationally; however, it has yet to realize its equity and sustainability potential. This study shows that the agricultural modernization dependency and government-led formal seed systems development have sidelined opportunities to tap into the strength of other alternatives identified in the PSSDS. In conclusion, an integrative and inclusive seed sector is possible if the government takes leadership and removes the current political, organizational, and economic barriers for developing a truly pluralistic seed system.

Keywords: seed politics, seed regime, power analysis, pluralistic seed systems, 4D pathways approach, Ethiopia

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Edited by:
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Specialty section:
This article was submitted to Climate-Smart Food Systems, a section of the journal Frontiers in Sustainable Food Systems

Received: *15 July 2021*
Accepted: *07 October 2021*
Published: *10 November 2021*

Citation:
Mulesa TH (2021) Politics of Seed in Ethiopia's Agricultural Transformation: Pathways to Seed System Development. Front. Sustain. Food Syst. 5:742001. doi: 10.3389/fsufs.2021.742001

INTRODUCTION

Calls for zero hunger, poverty eradication, and adaptation to climate change have increased the focus on seeds and seed system development in sub-Saharan Africa. The focus has been explicitly geared toward developing and supplying good quality seeds of improved varieties among smallholder farmers aiming at agricultural production and productivity increase, nutritional enhancement, system resilience, and income generation (Otieno et al., 2017; Ariga et al., 2019). To contribute to these goals, donor countries, multilateral institutions, foundations, and non-governmental organizations (NGOs) have supported several policies and programs[1] (Odame and Muange, 2011; Joughin, 2014; Borman et al., 2020; FAO, 2020). However, while most actors' policy and program interventions share the goal of increasing seed security among smallholder farmers, the strategies differ substantially and sometimes conflict (Scoones and Thompson, 2011; Westengen, 2017). These policy and program interventions also come with pressure from diverse actors who want their interests to be met with appropriate measures. Simultaneously, a country's political regime's governance and economic system want policies to align with its interests and priorities, making it difficult for policymakers and legislatures (Tansey, 2011; Mockshell and Birner, 2015). Moreover, actors' diverse interests and strategies contribute to the lack of coherent policies, programs, and practices to create a robust seed system development and enhance seed security (de Boef et al., 2010; Amanor, 2011).

This article is about seed system politics and development in Ethiopia. It aims to describe and analyze Ethiopia's seed system development trajectories under three different governance regimes and focuses on its current pluralistic seed system development strategy (PSSDS). It examines why and how the formal seed system has been prioritized over other alternatives (farmers' and community-based seed systems) by government policies and programs since the beginning of Ethiopia's agricultural modernization in the 1950s. It shows how the agricultural modernization agenda (Geels, 2004) ignores opportunities to tap into the strength of the farmers' seed systems (Mulesa et al., 2021), even after its official recognition by government policy in 2013 (MoA and ATA, 2017), and the experience of decades of an ineffective formal seed system (Ariga et al., 2019). The article further illustrates how developing countries' growing seed systems development debate generates challenges for policymakers and governments using the Ethiopian case. The discussions have put policymakers under financial and donor pressure to develop coherent national seed policies while at the same time serving the national governance regime's overall agricultural development plans.

[1]Some of the recent programs and policies related to seed sector development in Africa include: African Seed and Biotechnology Program (ASBP), Integrated Seed Sector Development (ISSD) program in Africa, Alliance for a Green Revolution (GR) in Africa's Program for Africa's Seed Systems (AGRA/PASS), World Bank's Seed Sector Development projects, COMESA Seed Harmonization Implementation Program (COMSHIP), ASARECA's Seed Policies and Regulations harmonization in East African Community, SADC Seed Laws harmonization program and ECOWAS's Harmonization of Seed Trade Laws in West Africa.

A seed system refers to physical, organizational, and institutional components, their actions and interactions that determine seed conservation, improvement, supply, and use (Cromwell, 1992; Scoones and Thompson, 2011), and includes formal, informal, and emerging "intermediate" seed systems (Mulesa et al., 2021). Farmers' seed systems involve farmers' seed selection, production, storage, and dissemination (Almekinders and Louwaars, 2002). The formal seed system comprises public and private sector institutions and a linear series of activities along the seed value chain, including germplasm conservation in genebanks, plant variety development, variety release and registration, quality seed production, and distribution (Louwaars et al., 2013). The intermediate seed system has recently emerged from market-oriented farmer groups that produce and market non-certified seeds of improved varieties and farmer-preferred local varieties. These are community-based seed producer groups, including community seed banks that produce good quality uncertified seeds (MoA and ATA, 2017) and seed producer cooperatives (SPCs), who produce quality declared seeds of improved varieties (Kansiime and Mastenbroek, 2016; Sisay et al., 2017). Quality declared seed is a simplified certification scheme in which seed-producing farmers are responsible for seed quality while the government plays a monitoring role (FAO, 2006).

Until the advent of the first Green Revolution (GR), the age-old practice of seed saving, selection and exchange, and farmers' knowledge associated with seed use and seed sourcing were the single most important seed systems farmers used in Ethiopia. The 1960s and 1970s transfer of the technology paradigm during the first GR in Africa promoted formal seed systems to boost agricultural production and productivity (Groosman et al., 1991; Tansey, 2011; Byerlee, 2020). Since then, developing countries, including Ethiopia, have used the linear model of formal seed systems as a blueprint solution for seed sector development. This approach assumed that the farmers' seed systems would be replaced by the government-led formal seed system, gradually moving toward privatization and liberalizing the seed market with the public sector's withdrawal (Louwaars and de Boef, 2012; Louwaars et al., 2013). Despite these assumptions, the farmers' seed systems remain the leading supplier of large quantities of seeds of diverse crops and varieties in developing countries (Coomes et al., 2015; McGuire and Sperling, 2016). Over the years, critical voices have risen in response to the linear formal seed system's poor performance. Its perceived and actual consequences for seed security and seed governance issues are today a debated topic. Emanating from these debates are alternative development visions and pathways suggested by different actors. These alternative development visions include formalization vs. localization of seed systems, high-yielding improved varieties vs. locally adapted farmers' varieties, private-led vs. government-led certified seed supply, community-based vs. private-led seed production and marketing, and farmers' rights vs. plant breeders' rights.

This article's point of departure is that the seed is political. All areas of contestation (environmental, social, economic, political, and system resilience) around seeds involve asymmetric power (Tansey, 2011; Sumberg et al., 2019). For instance, studies

show that intellectual property rights (IPRs) over seeds and seed regulations have resulted in seed market concentration in the hands of few multinational seed companies. Consequently, the socio-cultural connections between people and plants have mobilized resistance against IPRs and seed market concentration (Lyon et al., 2021; Tschersich, 2021). In this case, power asymmetry relates to access to and control over seeds. Moreover, studies suggest that particular historical factors shape national seed policies within each country (Westengen et al., 2019; Mulesa and Westengen, 2020). Therefore, contestation of seed system development pathways is ongoing in Africa as the production and regulation of seeds limit farmers' political and economic participation and weaken state political interests under the current "New Green Revolution" (Scoones and Thompson, 2011; Mayet, 2015).

Analyzing Ethiopia's historical seed sector development brings valuable knowledge to the seed systems literature. European countries never colonized Ethiopia, unlike many other countries in Africa. For this reason, its institutional foundation is independent of colonial influences. Ethiopia's long history of independence means that national autonomy is practiced in policy formulation (Keller, 1991). It has also undergone different governance regimes with different agricultural modernization approaches since the establishment of its Ministry of Agriculture (MoA) in 1907 (Diriba, 2018) and especially after its re-establishment following the second Italo-Ethiopian war (1936–41) in 1943 (Belay, 2003). Ethiopia's governance and economic systems changed from authoritarian monarchy rule/dominant feudal society (Cohen, 1974a) to military government/dominant socialist enterprises (Cohen and Isaksson, 1988) to an authoritarian developmental state/"free market" economy (Clapham, 2018). These governance regimes had different political effects on agricultural development that have affected the seed sector development pathways. Moreover, Ethiopia experienced extreme disasters such as drought, war, and consequent famine during the socialist regime, which created debate among technocrats about the role of formal and farmers' seed systems since the 1980s. Exploring seed sector development by considering these political and economic regime changes and environmental shocks provides unique perspectives to better understand how historical settings impact the dynamics of current seed system policy processes and practices.

In recent years, Ethiopia has gone "against the grain," deviating from the linear approach to formal seed system development by favoring a PSSDS as the country's overarching seed policy (MoA and ATA, 2017; Mulesa et al., 2021). The government of Ethiopia was the first country to officially adopt a PSSDS in 2017 as an alternative to the dominant linear formal seed system development to comprehensively transform its seed sector. The PSSDS proposes support for three major seed systems operating in the country (informal, formal, and intermediate) and promotes complementarity between the value chain components of each seed system. It assumes that the public, private, community, and NGO stakeholders take particular roles in dissimilar seed value chains and integrate activities along the seed value chain between the three seed systems. This article is a follow-up of an in-depth study that examined farmers' seed security as functions of seed systems in two districts of Central Ethiopia characterized by subsistence-oriented teff cultivation and commercially oriented wheat production and relates this to the country's PSSDS (Mulesa et al., 2021). Mulesa et al. (2021) find that the interventions prioritized in the PSSDS can address the widespread seed insecurity and seed system dysfunctions identified in the study districts. However, the implementation lags, particularly for the informal seed system, which is neglected by government programs despite its role in supplying large quantities of seeds and most of the crops and varieties farmers use. The study suggested further research that examines the complex interplay of factors to understand why the Ethiopian government has not fully implemented the PSSDS. Therefore, this article analyzes the effects of actors' seed politics on the opportunities and challenges in creating more equitable and sustainable seed systems in the new PSSDS—as a unique contribution to seed system literature. I draw on Leach et al.'s (2020) power analysis which combines plural approaches for studying food politics and development. The power analysis is used to understand the dynamics of Ethiopia's seed sector development process over the past seven decades, starting from the emergence of formal seed systems in the mid-1950s. The approach is used to analyze a continuous and dynamic process of institutional transformation co-shaped by a complex interaction of the regime's political and economic orientation, global seed-related frames and funding, and local environmental risks and explores how different pathways have emerged. To do this, I examine the history of the seed sector's evolution under agricultural policies of three different governance regimes: imperial, socialist military, and authoritarian developmentalist. The analysis helps to understand how the government prioritized some seed sector policies while excluding other policies under these political regimes and the policy directions, benefits, costs, and risks involved in these processes. Specifically, the article addresses the following research questions: (1) How have seed sector development policies been formulated and implemented, (2) How have different actors' interests influenced seed policy formulation and implementation, and (3) What are the socio-political and ecological outcomes of the current seed system policies and practices in the country?

ANALYTICAL FRAMEWORK

To understand seed system politics and development in Ethiopia, I draw on the analytical approach of Leach et al. (2020), combining plural approaches/concepts underpinned by broader theoretical traditions in power analysis. From Leach et al.'s (2020) list of approaches to power analysis in food politics and development, my analysis of Ethiopia's seed sector policy development and implementation is informed by approaches of food regimes (Harriet and Philip, 1989), food institutions (Clapp, 2012), food contentions and movements (Borras et al., 2008; Patel, 2009), food innovation systems (Scoones and Thompson, 2009; IPES-Food, 2016) and food discourses (Sumberg et al., 2012). I treat these approaches as nested or use their possible

pairwise combinations to study seed system politics and development in Ethiopia.

First, I identify the *seed regime* pattern linked to historical and political changes over the past seven decades of agricultural modernization in Ethiopia. The seed regime typology proposed by Lyon et al. (2021) is an adaptation of the food regime framework (Harriet and Philip, 1989; Jakobsen, 2021). In Leach et al.'s (2020) power analysis, the strength of an actor, and consequently its capacity to control exists in historically shaped political, social, and value regimes, including relations between states and capital and their supporting ideologies. In Ethiopia, the seed system development has changed from a farmer-managed seed system to a government-led formal seed system to a pluralistic approach. The seed regime approach can reveal how these changes occurred, who has gained and who has lost, implicating various power relations between diverse actors. As part of this analysis, historicizing institutional development allows to examine how the prior history of conflict or cooperation, the incentives for actors to participate, power and resource imbalances, governance and institutional design, shared narratives, interests, and politics have shaped the Ethiopian seed system development (McCann, 2005; Mulesa and Westengen, 2020).

Lyon et al. (2021) identify three seed regimes based on Kuyek's (2007) adaptation of Harriet and Philip's (1989) food regimes. The chronicles of these different seed regimes can vary from country to country, and not all countries have gone through the three seed regimes. The first seed regime is a relatively stable set of relationships, norms, and regulations that organized the increasing commodification and enclosure of seed during the early colonial period. Lyon et al. (2021) exemplify the first seed regime by describing the disruption of agricultural practices and foodways during the early colonial period when European settlers introduced few cash and commodity crops for the export market in North America. This regime constitutes colonial dispossession and displacement of indigenous people and their crop diversity. Post-WWII, the breeding, delivery, and adoption of new plant varieties by public institutions were the key features of the second seed regime. The third corporate-based neoliberal seed regime is related to the advent of transgenics in the 1980s (James and Krattiger, 1996) that enabled agrochemical firms to research and develop transgenic plants (Lyon et al., 2021) and prevent other actors from commercial production and marketing of their product using technological and legal control means (Tansey, 2011). Such technical and legal control of seeds was not new as this has been the practice since the 1930s in North America when hybrid cultivars emerged. However, IPRs protection[2] of new cultivars became a global phenomenon with the advent of biotechnology applications to agriculture during the past five decades (Kloppenburg, 2004; Lyon et al., 2021). The IPR protection has given more power to the private sector in the seed industry to make independent decisions on what to invest in and the type of technology they can promote (Kuyek, 2007; Clapp, 2021). Government intervention is limited to facilitation, i.e., providing incentives and removing impediments for private sector investment. The overview of the history of seed sector development in Ethiopia shows a unique national pattern of seed regimes. As mentioned, Ethiopia never became a colony in the classical sense. Therefore, the first colonial seed regime never really took hold in Ethiopia. But post-WWII, we see a distinct patterning of seed regimes that follow other essential patterns in Ethiopian history. My analysis operates with three regimes at both levels, i.e., three governance regimes (imperial, socialist, and developmental government regimes), and uses three seed regime patterns (the first, second, and third seed regimes). However, the seed regimes do not follow the political regimes in a one-to-one fashion.

I use the *food institution* approach to Leach et al.'s (2020) power analysis, which conceptualizes the actor's strength and capacity to control events as embedded in and to operate through multilevel formal and informal institutional arrangements, or the "rules of the game" (North, 1990). This kind of power contributes to the change in the food/seed system *via* norm and rule changes. Such norm and rule changes can occur in particular institutions or shifts in different institutions' relative power and influence (Tansey, 2011; Leach et al., 2020). The food institution approach provides a more nuanced picture of seed system development linked to smallholder agricultural commercialization. For instance, the food institution concept helps analyze Ethiopia's seed system development policy related to seed sector liberalization and privatization, funding requirements, and the government's political and economic orientation or national interests. In addition to incentives for the private sector, such liberalization can include the actual implementation of IPR laws and regional seed trade regulations. The food institution is associated with the *food/seed contentions* and movements approach, which involve power and agency that resist institutional changes through grassroots social mobilization and collective action, countering dominant force and interests (Demeulenaere and Piersante, 2020). This article applies the seed contention and movements approach to reveal how several years of joint project implementation and documentation work among NGOs (local and international) and a national institution influenced the government to recognize farmers' seed systems in Ethiopia.

While not restricting specific themes and contexts, I use the approaches of *food innovation* systems to analyze actors'

[2]IPR protection of new cultivars started when the government of the United States (US) introduced Plant Patent Act in 1930, which allowed patenting of asexually reproducing plant cultivars (except tubers). In 1970, the US introduced the Plant Variety Protection (PVP) Act to protect new varieties of sexually reproducing crops. In Europe, the Netherlands (1942) and Germany (1953) were the first countries to introduce the PVP Act. The harmonization of the PVP Act started in 1957 through the facilitation of the Government of France. Later the European governments adopted the international system of protection of new plant varieties under the auspices of the International Union for the Protection of New Varieties of Plants (UPOV) Convention in 1961 (Correa, 2015). Since 1961, the UPOV Act was amended a couple of times (1972, 1978, and 1991). National PVP Acts have been primarily developed based on the UPOV system to support the 1995 Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement of the World Trade Organization (WTO). Patents on plant traits (not varieties) emerged together with transgenics. In the Global South, stringent IPR protection (UPOV 1991 and plant patents) on seeds expanded since the adoption of TRIPS (Tripp et al., 2007).

narratives, beliefs, values, practices, and rules for analyzing multiple trajectories of seed system development. Specifically, food/seed innovation systems emphasize socio-technical and ecological systems and their dynamic and complex interactions that involve different actors or institutions that challenge path dependencies or "lock-ins." The food innovation system approach can also explain the path dependency of promoting the dominant seed system development model as an intertwining political interest of the state. Finally, power and agency are located more firmly in ideas, rather than people, institutions, or systems in *food discourses* that can help understand the narratives, interests, politics, and actions of actors or narrative coalitions in seed system development. Overall, Leach et al. (2020) argue that the combination of different conceptualizations and power sites helps understand change and transformation owing to their relevance to a diversity of actors and relationships and various scales—at the local, national, and global level.

Concluding the historical pathway analysis, I engage the "4D pathways approach" questions proposed by Leach et al. (2020) as an integrative analytical lens for assessing agri-food system political outcomes. Critical questions about the overall *direction* and *diversity* of technical and institutional innovation pathways, their *distributional* consequences, and the extent of *democratic* inclusion in decisions about the turning point in Ethiopia's seed policy reveal that the agricultural modernization dependency ignores opportunities to tap into the strength of the farmers' seed systems, even after their official recognition by the PSSDS in 2013 and after decades of an ineffective formal seed system.

METHODS

This study is a follow-up to a thorough investigation of the performances of different seed systems in two districts in the central highlands of Ethiopia, as mentioned in the introduction section. In order to address the above analytical questions and the main research questions, I gathered additional data using qualitative interviews with key actors in the seed sector during fieldwork in Ethiopia from December 2017 to March 2018. I interviewed 26 representative experts and researchers from various public and private institutions in agricultural and environmental governance. The actors include individual representatives from public seed enterprises ($N = 5$), private seed companies ($N = 2$), decision making and regulatory bodies ($N = 6$), NGOs ($N = 5$), agro-dealers ($N = 4$), and extension service providers ($N = 4$). The interview with each interviewee lasted between one and a half hours to 2 h. Issues related to the genetic resource governance of plants and the supply and use of commercial seeds in Ethiopia are filled with asymmetric power relations, contestation, and seed struggle (Alemu, 2011; Mulesa and Westengen, 2020). With this in mind, I purposively selected the interviewees from actors with different politics and values, framings, and perspectives regarding agro-ecological, social, cultural, and economic factors. In addition to key informant interviews, the qualitative analysis utilizes participant observations in two national seed policy meetings. The first meeting was a 1-day "Workshop on Assessment and Identification of Constraints to Private Seed Sector Development in Ethiopia" in February 2018. It gathered 40 representatives of key private and public seed sector actors. The second meeting was a 1-day "National Seed Policy Consultation Workshop" that gathered 63 representatives of seed sector actors from federal and regional institutions, farmers, NGOs, and the private sector in March 2018. I produced minutes from both meetings that documented actors' interests, politics, vision, activities in the seed system development from the presentations and discussions. I used this information to examine actors' approaches to Ethiopia's seed system development. In addition, the qualitative analysis of literature and documents uses a large volume of peer-reviewed articles, research reports, policy and strategy documents in Amharic and English, and gray literature such as minutes from a high-level policy meeting. Information gathered from key informant interviews was triangulated with the document analysis to validate and supplement evidence to increase the validity of the findings.

EARLY POLICY CHANGES: FROM FARMERS' CUSTOMARY SEED SYSTEMS TO GOVERNMENT-LED FORMAL SEED SYSTEM (THE EARLY 1900s TO 1974)

Bypassed Colonial Seed Regime

The current diversity of seed systems in Ethiopia is the result of five to seven millennia of wild plant species domestication by indigenous people (Vavilov, 1992), selection and diversification of the domesticated species (Harlan, 1969), and seed exchange over a wide geographical range (Murdock, 1960; Harlan and de Wet, 1976). This age-old practice of seed selection, saving and exchange, and farmers' knowledge associated with seed use and seed sourcing (McGuire, 2007) are the foundations of the farmers' seed systems in Ethiopia (Thijssen et al., 2008). However, the diversification of farmers' seed source and management started to change in colonial countries of the developing world in the early 1900s. Europeans introduced new agricultural technologies (e.g., improved seeds) and technical agronomic practices to promote cash and commodity crops (Bonneuil, 2000; Austin, 2009). The colonial promotion of cash and commodity crops (e.g., coffee, cotton, and tea) brought a new set of relationships, norms, and control, which pushed out most indigenous crops such as sorghum and millet through agricultural extension and marketing (Tansey, 2011; Bezner Kerr, 2013). Scholars have seen the contours of a distinct colonial food/seed regime within this historical context (Kuyek, 2007; Lyon et al., 2021). For instance, the radical dispossession of indigenous crops in colonial Africa marks the first seed regime. Until their independence, imported crops displaced over 2000 native grains, fruits, vegetables, and root crop species in colonial Africa (National Research Council, 1996). National and international agricultural initiatives have also neglected these crop species, and these countries have been unable to repossess most of their food culture (Highfield, 2017, p. 3).

Unlike colonial African countries, Ethiopia did not go through the first seed regime. The imperial governments

and Ethiopian people resisted Italian occupation and stayed uncolonized (Rubenson, 1961), and farmers continued to depend on their indigenous seeds and Neolithic agricultural innovations (Westphal, 1975; Diriba, 2018). The only exception was the introduction of agricultural technologies during their first Italian colonization attempt in the late nineteenth century and WWII, which discontinued owing to the first (1893–1896) and second (1935–41) Italo-Ethiopian war (McCann, 1995, 2011). Thus, farmers' seed systems remained the only supplier of seeds in Ethiopia until post-WWII. Ethiopia's seed regime change started with the second public seed research and development when the Imperial Ethiopian Government (IEG) introduced modern agricultural technologies. These included a mix of cash and commodity crops such as cotton and tobacco and the GR food crops (e.g., wheat and maize) discussed below.

The Beginning of the Second Seed Regime During the Imperial Period in the 1950s

Post-WWII, the advance in plant breeding in developed countries brought different technologies (e.g., new varieties) and seed management practices and created formal institutions to govern breeding, delivery, and adoption of new plant varieties (Timothy et al., 1988; Fernandez-Cornejo, 2004). These new technologies and seed regulation practices through formal institutions were transferred to colonial countries in Africa in the 1920s except in Ethiopia (Rusike, 1995; Rusike and Donovan, 1996). In Ethiopia, this was delayed until the mid-1950s (Simane, 2008), when the IEG established physical, organizational, and institutional infrastructure for agricultural research and extension. The IEG received financial support from the first United States (US) government development cooperation in the Global South and other multilateral donors for building institutional and physical infrastructure to achieve its ambition of a monetized economy (Elliott, 1957; McVety, 2012). In his inaugural speech in 1949, the incumbent President of the US, Harry S. Truman, announced his government's readiness to support agricultural modernization to fight hunger and poverty in developing countries (Truman, 1949). Scholars argue that Truman's speech marks the origin of modernization theory in development studies (Westengen and Banik, 2016). Following Truman's announcement, the US government established a development assistance program, widely known as the Point 4 Program[3], referring to President Truman's fourth point in his list of foreign policy objectives. At the time, Ethiopia was in a deep agricultural and food crisis after the second Italo-Ethiopian war (Diriba, 2018), and Emperor Haile Selassie sought US support while subscribing to their anti-communist stand (Velissariou, 1954; McVety, 2008). The US development partners used this as a reason to select Ethiopia in Africa's horn as a testing ground for Point 4 Program implementation (1952–1957) and to induce social and economic change through technology and capital transfer, assuming that this would eventually steer Ethiopia away from communism (McVety, 2012). The US government provided an average of USD 2,466,700 per year for economic and military assistance to the IEG between 1952 and 1957 (Elliott, 1957; McVety, 2012).

The Point 4 Program supported extensive infrastructure development, including establishing higher learning agricultural institutions, public and agriculture schools, community/agricultural clubs, and creating agriculture extension groups and training professionals. Besides, the IEG received financial and technical assistance from the United Nations Development Program and the Food and Agriculture Organization of the United Nations (FAO) to build the technical and institutional capacity for its agricultural research, extension, and technology dissemination. With this assistance, the IEG established the Ethiopian Institute of Agricultural Research (EIAR) and a seed unit at the MoA in 1966 (Stommes and Sisaye, 1979a; Bishaw and Louwaars, 2012). The physical and institutional infrastructure building laid a foundation for the IEG's agricultural modernization projects through public agricultural research and GR technology extension, which marks the main features of the second seed regime in Ethiopia. Ethiopia attempted to implement the first GR projects with this institutional base as part of the IEG's three successive five-year agricultural development plans from 1957 to 1973 (Cohen, 1975; Stommes and Sisaye, 1979a,b). Considering the seed regime pattern in Ethiopia, the second public seed regime found fertile ground owing to the emperor's shared anti-communism platform with the US administration. Ethiopia's seed policy moved from almost non-participation in the first colonial seed regime to becoming the "pioneer" of the second public seed regime in the horn of Africa. In addition to the 15 years of agricultural development plans, the IEG also prioritized commercialization concession contracts for foreign companies and established state commercial farms to produce export crops such as coffee, sugarcane, cotton, tobacco, fruits, and vegetables. For this purpose, the government appropriated land for investors, which displaced pastoralists, agro-pastoralists, and peasants from their grazing- and farmlands and their indigenous seeds. By examining the situation using the food institutions approach, we see the institutional and political factors were the leading causes of social exclusion and increased vulnerabilities. For instance, pastoralists and peasants became laborers and survived on a "contribution" rather than a wage payment. At the expense of this exploitation, the companies who exported agricultural products and the industrialists in Europe who exported machinery and technology were winners. In contrast, the IEG, whose benefit from taxes and dividends was lower than commodity import expenses, and laborers who squandered their local livelihoods, were losers (Bondestam, 1974).

[3]President Harry Truman announced four major courses of action for achieving global peace and freedom post-WWII. Truman said, we will continue to (1) support the United Nations and related agencies, (2) American programs for world economic recovery, including reducing the barriers to world trade and increasing its volume, (3) strengthen freedom-loving nations against the dangers of aggression, i.e., in the form of collective defense arrangement within the terms of the United Nations Charter, and (4) embark on a bold new program for making the benefits of American scientific advances and industrial progress available for the improvement and growth of underdeveloped areas because more than half the people of the world are living in conditions approaching misery, their food is inadequate, and their economic life is primitive and stagnant.

Later during the 1960s and early 1970s, the IEG's agricultural development plan emphasized the implementation of big GR projects. The biggest of all was the Chillalo Agricultural Development Unit in Ethiopia's southeastern highland supported by the Swedish International Development Cooperation Agency, which aimed to replicate a "successful" GR experience from the Comilla district of Bangladesh in 1957 (Karim, 1985). The agency's support focused on increasing bread wheat production and productivity using improved seeds, chemical fertilizer, and pesticides. The IEG later scaled out the GR projects to other regions in Ethiopia and crops (e.g., maize) with the financial and technical support from other donors such as the World Bank, United States Agency for International Development (USAID), and France's government (Cohen, 1974b; Stommes and Sisaye, 1979a). The IEG's first GR projects prompted seed system formalization. However, with its emphasis on donor-supported government agricultural research and extension for higher yields and productivity, the IEG's second seed regime of the GR projects created winners and losers among participants. Specifically, the political economy of the donor-supported and IEG-centered GR projects created inequality between landlords and tenants through its exploitative land tenure system, especially in the southern provinces of Ethiopia.

In the nineteenth and twentieth centuries, the "land hunger" of the imperial regime led to the expansion and consolidation of the southern regions by confiscating land from southerners and granting it to the regime's supporters from the north and center (Brietzke, 1976; Clapham, 2019). The imperial regime created solid political bondage with the few landlords and absentee landlords[4], who acquired large tracts of fertile land. When they lost their land, most local tillers and pastoralists became peasants and tenant sharecroppers for the landlords. They paid one-third or one-half of their annual produce, depending on the fertility/productivity of the land they plowed. With the donor-supported GR projects, peasant sharecroppers became more vulnerable instead of benefiting from commercial wheat and maize production. For instance, corrupt local and provincial government officials and their associates neglected donor policy provisions to only supply subsidized inputs to peasants holding <20 hectares of land. Instead, they took advantage of their position and purchased the subsidized inputs under favorable credit terms (Cohen, 1975; Brietzke, 1976). In the rare cases where tenants had access to limited GR technologies, they benefited from yield increase as sharecroppers. Still, their landlords, who owned the land, benefited the most from the tenants' payment. Landlords also evicted their tenants when they saw the benefits of using GR packages compared to sharecropping. For each new machine these landlords acquired to expand their commercial farms, they evicted about 20 sharecropper tenant families (Bondestam, 1974; Cohen, 1975). According to Cohen (1975), GR seeds' arrival led to the eviction of about 20–25% of 60,000 tenant households between 1968 and 1971. Here, the agricultural modernization discourse of Truman and other donors which adhered to the preconceived belief in technological solutions to hunger and poverty failed to recognize the underlying structural problems, primarily the exploitative land tenure system of the IEG and poor physical and institutional infrastructure (e.g., roads, irrigation), diversity of crops and agro-ecology in Ethiopia.

Moreover, the adoption of high-yielding bread wheat and hybrid maize varieties resulted in local genetic erosion of farmers' seeds (e.g., barley, durum wheat, and local maize). Loss of local seeds and positive yield advantage created a dependency on commercial seed producers for new seeds and varieties, which were not always readily available (Teklu and Hammer, 2006). Overall, the IEG's GR projects contributed to inequality, creating elite winner landlords and hungry loser tenants and consumers (Ståhl, 1973), triggering the early 1970s riots among students, teachers, and the working middle class. When examined closely by drawing on approaches to food contentions and movements, these riots articulated frustration about hunger and famine created by the exploitative land tenure system and modern agricultural input supply of the IEG that favored the regime's loyalists. The riots amplified into a revolution popularly known with the slogan "Land to the Tiller," leading to Emperor Haile Selassie's overthrow by the socialist government in 1974 (Crewett et al., 2008; Yemane-ab, 2016).

FOOD AND AGRICULTURAL CRISIS-INDUCED ALTERNATIVE SEED SYSTEM AND LOCK-INS IN THE GOVERNMENT-LED FORMAL SEED SYSTEM (1975 TO MID-2000s)

The Beginning of Seed Contestations and Movements in the Socialist Era in the Mid-1980s

The mid-1970s witnessed landmark reforms to eliminate the feudal order in Ethiopia. The Military Administrative Council (PMAC)—also called Derg—announced that it would eradicate the imperial regime's traditions of autocracy, inequality, and subjugation as soon as it assumed power in 1974 (Harbeson, 1977). Not knowing what political ideology and economic system the PMAC would follow, the US government, World Bank, United Nations Development Program, and several bilateral and multilateral development cooperations continued to provide financial assistance to keep the GR project going. The donors also wanted to keep the new government from getting too friendly with the Soviet Union. The US government supplied about USD 250 million in economic and military aid to the PMAC until it halted following the PMAC's inauguration of a National Democratic Revolutionary Program in April 1976. With this program, the PMAC declared a return to civilian democratic government, but it announced its firm position to fight feudalism, imperialism,

[4]The landlords were members of the royal family, church, and high ranking clergymen, and absentee landlords were war returnees, senior military, and civil servants.

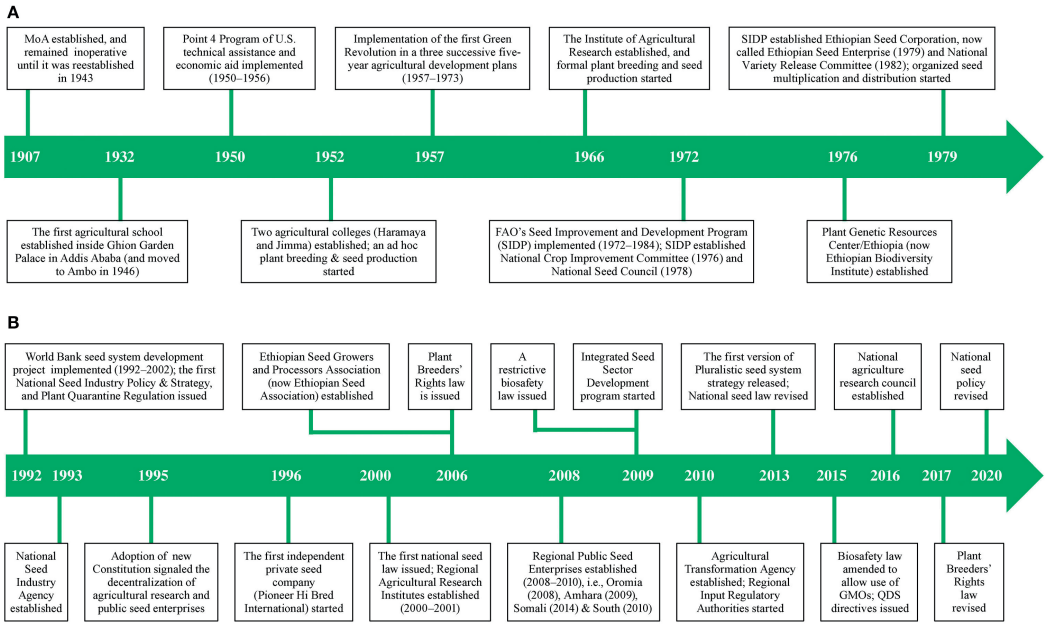

FIGURE 1 | Timeline of major historical landmarks of the Ethiopian seed system policy and institutional developments during **(A)** the imperial (1889–1974) and socialist (1974–1991) governments, and **(B)** the developmental state government regime after 1991.

and capitalism and Ethiopia's transition to socialism (McVety, 2012).

The World Bank and other donors continued to support FAO's Seed Improvement and Development Program (SIDP), which started in 1972 in Ethiopia since the agriculture crisis was evident and hunger was looming at the time (Ker, 1979). The SIDP was implemented in many developing countries and aimed to develop the national capacity to multiply good quality seeds of high-yielding improved varieties, distribute them to farmers, increase production and productivity, and contribute to national and global food security (World Bank, 1980; FAO, 1984). In Ethiopia, the SIDP was probably the most notable second seed regime activity or public investment in crop improvement research and extension during the socialist government, mainly because of the limited funding from western development partners and political crises. The SIDP helped to establish Ethiopia's central institutions for the formal seed system between 1972 and 1984 (**Figure 1A**). Besides, it strengthened the EIAR's capacity in plant breeding and quality seed production by training plant breeders and agronomists. The EIAR conducted a plant breeding and adaptation trial of improved varieties introduced from Kenya, Mexico, Ecuador, and the US in partnership with the International Maize and Wheat Improvement Center and released 22 improved wheat varieties: 18 bread wheat and four durum wheat (Ker, 1979; Woldemariam, 1990). Although the SIDP contributed to the organizational development of the formal seed system, it did not develop a seed policy and regulatory framework in Ethiopia, unlike in other developing countries. Like in many developing countries, where it was implemented, SIDP also failed to create financial sustainability for the maintenance of the infrastructure and technical activities (e.g., seed laboratories, field inspection capabilities) in Ethiopia, which weakened the formal seed sector in the years that followed (Woldemariam, 1990; Cromwell et al., 1992).

That said, the socialist government introduced a radical land policy reform that abolished the feudalistic land tenure system by declaring all rural lands the collective property of the Ethiopian people and redistributed land to peasants previously held by landlords (PMAC, 1975). Moreover, the regime introduced an agricultural socialization policy that emphasized expanding state farms and cooperative farming through villagization, allegedly intending to increase crop production and productivity and eradicate famine in Ethiopia. However, although the land redistribution and cooperative expansion had increased the demand for improved seeds and chemical fertilizer, the government-led agricultural socialization, and subsidy on GR inputs failed to increase agricultural production and productivity. Both state and cooperative farms recorded the lowest yield (only 6% of the national output) between 1975/76 and 1985/86, resulting in an estimated grain deficit between 350,000 and 500,000 metric

tons despite the government's highest investment in these farms (Ghose, 1985; Cohen and Isaksson, 1988). The failure was due to a range of interlinked factors such as bureaucrats' lack of experience in mechanized farming, poor planning, inadequate input supply, mismanagement, discrimination of private peasants for input supply, and discouraging abusive peasant labor deployment (Ghose, 1985; Clapham, 1988). The overall consequence was low agricultural growth and a food crisis (Belete et al., 1991). Ultimately, the food and agriculture crises signaled the failure of modernization driven by agricultural socialization.

The combination of poor governance, civil war, and droughts of the mid-1980s and the resulting food and agriculture crisis (Keller, 1992) led to a new wave of seed contestation and movements (Cromwell et al., 1993). A coalition of environmentalists and local NGOs from Ethiopia joined an international movement advocating for on-farm management, facilitated access, and fair and equitable sharing of benefits from the use of plant genetic resources for food and agriculture (PGRFA)—hereafter referred to as the PGRFA movement (Pistorius, 1997). This coalition also advocated for strong farmer' seed systems in developing countries (Cooper et al., 1992). In Ethiopia, the major actor in the PGRFA movement was the Plant Genetic Resource Center/Ethiopia, now called the Ethiopian Biodiversity Institute (EBI). While actively participating in the international PGRFA movement that advocated for farmers' rights as a countermeasure to stringent IPRs (Pistorius, 1997), EBI worked to link farmers with genebanks through farmer-based PGRFA management projects since 1989 (Worede, 1992; Cromwell et al., 1993). As the PGRFA movement gained momentum in the 1980s and 90s, environmental sustainability discourses gradually pervaded science and technology. The Ethiopian PGRFA movement's discourse was that GR crops could not substitute Ethiopia's biodiversity treasure trove and did not consider the socio-cultural and agro-ecological diversity of the country linked to these resources. Proponents of the PGRFA movement argued that ensuring national food security and sustaining Ethiopian food culture requires promoting locally adapted diverse seeds and protecting valuable crop diversity (Worede, 1992). Their discourse attempted to frame locally adapted seeds as an alternative to GR varieties for Ethiopia's food and agricultural crisis. The discourse builds on the idea that local crop diversity is vital in providing yield stability and harvest security in the face of pests, diseases, and unfavorable environments (Clawson, 1985; Brush, 1992). Although this seed discourse did not yield a significant seed policy shift until 2013, it received recognition from the government and donors. Besides, it attracted several donors who supported projects for on-farm management of PGRFA and strengthened farmers' seed systems (Brink, 2013; Mulesa and Westengen, 2020). EBI and its collaborating local partners implemented several projects with the recognition of the MoA despite government emphasis on the use of GR technologies for agricultural development. From the late 1980s, EBI deployed local crop varieties from the national genebank to farmers' fields through a network of farmers and community seed banks in drought- and famine-affected areas and in the productive regions where GR modern varieties replaced local ones (Westengen et al., 2018).

The Developmental State's Resistance to Seed Sector Liberalization Since the Early 1990s

In 1991, Ethiopia entered another sphere of political reforms in a social and economic development system. The Ethiopian People's Revolutionary Democratic Front (EPRDF), an ethnic federalist political coalition, came to power after a decade and a half civil war, a war between the socialist government and oppositions. Clapham (2018) characterizes the EPRDF government as the clearest example of a 'developmental state' in Africa, which effectively captured "rents" from state monopoly of companies and forced loans accumulated from the private sector's deposits in government bonds to fund massive development projects. During the transitional period (1991–1995), the EPRDF government announced an agricultural development-led industrialization strategy as its overarching strategic framework for guiding Ethiopia's economic development and poverty reduction in 1993. They developed and promoted this strategy based on the 1960s and 70s development theories that commercialization of smallholder agriculture can ensure the availability of raw material for industrialization and drives economic growth (Ellis and Biggs, 2001; Alemu et al., 2002). The strategy aimed to intensify the use of GR technologies to boost smallholder farmers' agricultural production and productivity, increase food security, and achieve sustainable exports and import substitution. To implement it, the EPRDF government needed institutional reform for agricultural research, extension, and effective delivery of GR technologies, for which it requested financial assistance from donors (Spielman et al., 2010). At the time, the World Bank and International Monetary Fund (IMF) structural adjustment program had already begun to weaken public seed research and extension in developing countries (Bernstein, 1990; Bishaw and Louwaars, 2012).

Moreover, debates over the meaning and consequences of GR gave rise to a global environmental agenda affecting the development aid priorities of international donors (Sumberg et al., 2012). Amid these changes in international development politics, the EPRDF resisted the structural adjustment program and received substantial international assistance for agricultural research and development in Ethiopia. EPRDF got this privilege mainly because it dissociated Ethiopia from the alliance with socialist countries and new connections with western countries, and its commitment to democratic values and western economic policies (Clapham, 2019).

In 1992, the transitional government received USD 657.4 million from the World Bank, bilateral and multilateral donors to implement an emergency recovery and reconstruction program. The government allocated about 45% (USD 296 million) of this funding to agricultural intensification (World Bank, 1998), of which USD 22 million went to seed system development projects between 1992 and 2002 (World Bank, 2003). The government used USD 50 million for agricultural extension services per annum, emphasizing the promotion of high-yielding

varieties, chemical fertilizer, and pesticides among smallholder farmers (Spielman et al., 2012). In addition to the World Bank, the Sasakawa Africa Association and Global 2000 of the Carter Center (SG-2000)[5] also made considerable investments in agricultural extension services, focusing on adopting the GR technologies since 1993 (Berhane et al., 2020). These investments helped revive the crop improvement research and development activities after a long period of low activity during the socialist regime. Although there has not been a time since the 1950s when public research and development was not a priority in government-led agricultural modernization, the investment in the second seed regime was very significant during the EPRDF government. At the time, the EPRDF transitional government issued a new constitution (FDRE, 1995) based on liberal and democratic principles to challenge the dominance of one political force in Ethiopia, effectively and ostensibly decentralizing power to regional and local authorities (Vaughan and Tronvoll, 2003). With the decentralization signal, the new constitution granted agricultural and rural development programs implementation responsibilities to newly formed autonomous regional states. Nine (currently eleven) regional states are "delimited based on the settlement patterns, language, identity, and consent of the peoples concerned" (FDRE, 1995, Article 46.2) under the federal government policy framework in Ethiopia. The corresponding sub-regional administrations, zones, and districts are responsible for agriculture and rural development at the local level (Gebre-Egziabher, 2014). With donor support, the EPRDF government implemented its decentralization policy of agriculture and rural development, including physical and institutional infrastructure development in the regions (Bechere, 2007). In the seed sector, it established Regional Agricultural Research Institutes, Regional Extension of the Bureaus of Agriculture, Regional Input Regulatory Authorities, and Regional Seed Enterprises in addition to preexisting national institutions in the formal seed system such as the EIAR, ESE, and EBI. Explaining the then needed decentralization of agricultural research and extension—which the government implemented in earnest during the 1990s with the financial support from donors—a high government official said:

> "We [technocrats/experts/organizational leaders] were happy with the SG-2000 extension program and World Bank support. However, at the time, we noted a sharp increase in demand for improved seeds. Yet, we only had one public seed enterprise [the ESE] to produce and distribute certified seeds. Therefore, it was impossible to meet even half of the seed demand, especially for hybrid maize. So, the government decided to decentralize seed production and distribution by creating regional research institutes, parastatals[6]."

In the 1990s, donor support was the key driver for the development of formal seed systems. In addition to the decentralization and capacity-building of public institutions for research and extension, the government developed and implemented a national seed policy framework throughout the 1990s (**Figure 1B**). The outcome was seed production and distribution increase, although it was impossible to fully meet the growing demand due to increased government extension programs' coverage after the decentralization (Gebreselassie, 2006). Arising from GR's realization, which began in earnest in the mid-1990s (Rohne Till, 2020) and continued agricultural growth (Berhanu and Poulton, 2014; Bachewe et al., 2015), the government embarked on a further formalization of the seed system, including the implementation of seed regulations. For instance, the government prioritized strengthening the formal supply of quality seeds of high-yielding plant varieties in almost all government policy documents[7] on poverty reduction, food security, and agricultural growth and transformation until recently (Simane, 2008; Bishaw and Atilaw, 2016). One informant explained the 1990s government's seed system formalization and its constraints as follows:

> "The 1990s green revolution was the main triggering effect toward genuine seed system formalization in Ethiopia. As a result, the use of improved varieties and certified seeds would have increased significantly. But the lack of investment incentives for private seed companies and government-pricing of seeds affected the supply of quality seeds based on real competition[8]."

The statements from the above informants corroborate my analysis showing EPRDF resistance to seed sector liberalization and privatization and emphasis on government-led formal seed system development conforming to the developmental state model. The statements are also consistent with an explanation by one informant who described the failure of the World Bank support seed system project, especially the community-based seed production and distribution, which is one of the growing seed systems during the last decade, as discussed below. My informant said:

> "EPRDF refused to privatize the ESE and preferred to use the community-based seed production scheme supported by the World Bank as out-growers for the ESE instead of helping them to become viable seed entrepreneurs. The current expanding seed producer cooperative approach in the intermediate seed system is not new. It is the same World Bank type of project, but the

[5]SG-2000 was established in Geneva in 1987 with the initiatives of Philanthropist Ryoichi Sasakawa (founder and former Chairman of The Nippon Foundation) who contacted Dr Norman Borlaug (the only Nobel Peace prize winner in food and agriculture until 2020), and President Jimmy Carter (who was involved in peace negotiation in Ethiopia in the late 1980s) following the 1970s and 1980s conflict and famine in the horn of Africa to solve food security problems.

[6]Personal interview with a government official of the Ethiopian Seed Enterprise (Addis Ababa, February 5, 2018).

[7]The 1990s Agricultural Development Led Industrialization framework, National Five-Year Development Plan (2000–2004), Sustainable Development and Poverty Reduction Program (2002–2005), Plan for Accelerated and Sustained Development to End Poverty (2005–2010), The First Growth and Transformation Plan/GTP-I (2010–2015) and Second Growth and Transformation Plan/GTP-II (2015–2020).

[8]Personal interview with a senior researcher of the CGIAR (Addis Ababa, February 1, 2018).

current one integrates business model and technical skill training of farmers in seed production and marketing[9]."

In agreement with Chinigò (2014), who examined the case of land administration in Ethiopia, my analysis shows that the decentralization of agricultural research and development is mainly an institutional expansion for strengthening the already hierarchical system of local administration and thereby extending the federal government's power to regions. In the seed sector, stringent federal regulations and centralized planning and control continued even after the decentralization of plant breeding, seed production, certification, and marketing in favor of the public seed sector. The EPRDF government resisted privatizing nearly all economic sectors, including land (Crewett et al., 2008), finance, and agriculture, for example, parastatal seed companies (Ojo and Ramtoolah, 2000; World Bank, 2003). Despite ideological differences between EPRDF and its donors[10] about the role of the private sector in economic development, Ethiopia has been a significant recipient (about USD 26 billion during the first two decades) of international development aid (Feyissa, 2011). Examined through Leach et al.'s (2020) food institution approach, we see the developmental state model overriding donors' neoliberal conditionalities to implement a competitive free market economy. According to Feyissa (2011) and Clapham (2018), EPRDF shielded Ethiopia from "neoliberal pressure" by playing a "sovereignty card" and placing itself diplomatically as a force for regional stability in an "unstable" region and as a leading partner in the Global War on Terror, for example as the largest contributor of troops (over 8,000) to UN peacekeeping. With the sovereignty narrative, which embodies power (Leach et al., 2020), and skillful negotiating strategy, Feyissa (2011) and Clapham (2018) argue that EPRDF buffered neoliberal influences. Seen through the food institution lens, donors' willingness to continue supporting Ethiopia is all about Cold War geopolitics and state alliances. Similarly, the EPRDF government's need for financial assistance did not mean that its political and economic development interests were the same as Western countries. As Feyissa's (2011) study shows, national sovereignty on policymaking and implementation was a priority for EPRDF.

Because the new constitution and EPRDF's agriculture and rural development policy also allowed non-state actors—including community-based organizations, local and international NGOs—to engage in development work and service delivery at the local level (Cerritelli et al., 2008), the PGRFA–movement coalitions (the EBI, local NGOs, and their partner western NGOs) continued to promote farmer-based seed system development. They promoted farmers' seed systems as an alternative to the dominant government-led formal seed system and resistance to privatization. At the international level, the rise of the environmental agenda favored the proponents of the global PGRFA movement to intensify the seed contestation and movements through project implementation and policy advocacy (Cromwell et al., 1993, pp. 71–75). This movement contributed to Ethiopia adopting international agreements such as the United Nations Convention on Biological Diversity and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) and corresponding funding mechanisms for supporting projects for their implementation. In Ethiopia, donor-funded projects strengthened the on-farm PGRFA management (e.g., participatory variety selection, community seed banking) during the 1990s (Mulesa and Westengen, 2020). There are two main reasons for reinforced support to implement community-based PGRFA management and farmers' seed systems. First, the Ethiopian delegates played a prominent role in international negotiations related to biodiversity agreements (Gebre Egziabher et al., 2011), which earned the country an international reputation as a progressive country in environmental governance. Second, Ethiopia's community-based PGRFA management work since the late 1980s (Worede, 1997) attracted international development actors for exchange and experience sharing with other developing countries (Dalle and Walsh, 2015). That said, the state's financial and institutional support primarily went to conventional GR seed research and development. The financial support provided for community-based PGRFA management projects was much less (about USD 5 million) than the funding that formal seed system development received (over USD 22 million) over 10 years period (Worede, 1991; IBC, 2007). Although implementation was incomplete, the government issued several policies and legislation to favor the farmers' seed systems. Recent studies provide an overview of these policy frameworks, which the EPRDF government issued in favor of farmers' seed systems in Ethiopia, and of the status of their implementations (Beko, 2017; Mulesa and Westengen, 2020; Mulesa et al., 2021).

Despite seed contestation and movements promoting farmers' seed systems since the mid-1980s, its role in supplying the most considerable quantities of crop varieties and seeds, and the approval of supportive policy frameworks, the EPRDF government continued prioritizing government-led formal seed system development. Viewed from a food innovation systems perspective (Thompson and Scoones, 2009; IPES-Food, 2016), we see agricultural modernization and the continuation of the historical legacies of the Ethiopian government's political interests and incumbent powers for top-down control of farmers by ignoring alternative development pathways to the formal seed system. Studies link the regime's predominant focus on supplying agricultural input through public institutions, including certified seeds, as an instrument for securing political control of rural constituencies throughout Ethiopia. These studies also show how wealthier model farmers benefit from government input supply at the expense of poor farmers (Lefort, 2012; Berhanu and Poulton, 2014; Hailemichael and Haug, 2020). The modernization path dependencies or "lock-ins" to agricultural development and government-led formal seed

[9]Personal interview with a senior technical staffer of an NGO, Bilateral Ethiopian-Netherlands Effort for Food, Income and Trade Partnership (Addis Ababa, February 14, 2018).

[10]USAID, the World Bank, IMF, the European Union, Britain's Department for International Development (DFID), German Technical Cooperation (GTZ), Canadian International Development Agency (CIDA) and many other bilateral donors.

TABLE 1 | Dominant and alternative pathways to policy practices in Ethiopia's pluralistic seed system development.

Dimensions of policy practice	Government-led seed system formalization	Private-led seed system formalization	Farmer-based seed system localization	Community-based seed system integration
Dominant approach and underlying narratives for seed policy-making and actors' actions	*Agricultural growth and transformation*—Government institutions and farmer cooperatives/unions collaborate with public seed research and development institutions to provide reliable Green Revolution (GR) technologies[a] to increase agricultural production and productivity. On this account, national food and nutrition security can improve, and agriculture-led industrialization can accelerate.	*Renewed GR*—Commercially viable agro-dealers network linked to private seed research and development companies can effectively deliver GR technologies for all commercial farmers. Access to new GR technologies increases agricultural production and productivity and, consequently, can eradicate hunger and malnutrition and accelerate Ethiopia's transition to agro-industry.	*Biodiversity-based sustainable agriculture*—Government policies and investments that prioritize market-led GR technology supply have been ineffective to meet the diverse agro-ecological, socio-cultural, and economic needs, and people's livelihoods. The approach has jeopardized smallholder farming. Therefore, strengthening farmers' knowledge, practices, and institutions for supplying locally adapted crop varieties can have the potential to satisfy these diverse needs and sustain stable crop production.	*Sustainable agricultural productivity*—Trained and empowered farmer cooperatives and other local commercial groups linked to public seed conservation, research, and development institutions can deliver quality seeds of high-yielding GR crops for farmers in potential areas. They can also supply locally adapted diverse crops and varieties to increase agricultural production and productivity in marginal regions. Consequently, they can contribute to food security, entrepreneurship, and job creation.
Actors' coalitions articulating the dominant narratives	Federal, regional, and international agricultural research institutions; public seed enterprises; Ministry of Agriculture; the Ethiopian Agricultural Transformation Agency; extension and input supply authorities; input regulatory authorities; multipurpose farmers cooperatives and unions; the ruling party	Private seed companies (national and multinational); Ethiopian Seed Association; bilateral and multilateral donors; philanthropic foundations; Alliance for a Green Revolution in Africa; the Ethiopian Agricultural Transformation Agency; International agricultural research institutions	Ethiopian Biodiversity Institute, Local and western NGOs; Bioversity International; FAO's ITPGRFA Secretariat; Community Seed Bank groups; Dutch-government-supported ISSD program	ISSD program; Agricultural Faculties of Higher Learning Institutions; the Ethiopian Agricultural Transformation Agency; federal, regional, and international research institutions; seed producer cooperatives
Main critiques and actors' coalitions enunciating it	*Proponents of private-led formalization*: Centrally planned ineffective seed production and marketing cause untimely supply and poor-quality certified seeds. Consequently, seed carryover arises, and farmers' demand is unmated; the private sector should replace the public seed research and development institutions. *Proponents of localization:* The top-down seed research and development distribute poor-quality seeds that are less adapted to farmers' diverse agro-ecological and socio-economic needs and poses production risky, especially for poor farmers and farmers in marginal areas. *Proponents of integration*: Centralized, bureaucratic, and lengthy planning, production, and distribution of certified seed makes timely access to seeds difficult, which requires complementary local seed businesses.	*Proponents of localization*: Access to certified seeds is difficult for poor farmers due to high seed prices. Privatization creates a dependency on few improved varieties, drives genetic erosion, and creates seed enclosure and food control by a few powerful seed companies. *Proponents of government-led formalization*: Relying on the private sector is inadequate. They cannot meet national seed security needs due to their focus on commercially successful crops and profit; therefore, government intervention is necessary. *Proponents of integration*: Seeds from private companies are expensive for some commercial farmers, and seed producer cooperatives can offer affordable quality seeds.	*Proponents of formalization (private)*: Farmers have limited knowledge and skill in quality seed production, and they supply low-quality seeds of variable quantities. *Proponents of formalization (public)*: Promotion of local varieties should not be at the expense of the government agricultural transformation plan (i.e., use of a complete package of improved varieties, chemical fertilizer, pesticides, and improved agronomic practices) to increase crop production and productivity. The national genebank is responsible for guaranteeing the conservation of crop diversity. *Proponents of integration*: Skill training and provision of agricultural infrastructure (e.g., seed cleaning and storage facilities) for collective seed production and marketing can improve farmer-based seed production, storage, and marketing. Therefore, market orientation is necessary for sustainable local seed supply.	*Proponents of private-led formalization*: Commercial seed production and marketing by farmers bring unnecessary competition in the national seed industry, especially for economically critical commercial crops. Farmers have limited technological know-how in commercial seed production and marketing, and their seed business must be limited to local crops to avoid productivity loss.

(Continued)

TABLE 1 | Continued

Dimensions of policy practice	Government-led seed system formalization	Private-led seed system formalization	Farmer-based seed system localization	Community-based seed system integration
Dominant rules, practices, and relationships governing seed research and development	Seed research and development through public institutions are entrenched in state laws—the constitution, proclamations that establish the Ethiopian Institute of Agricultural Research, and Ethiopian Agricultural Businesses Corporation that includes seed parastatal (FDRE, 1995, 1997, 2015a). In addition, developmental state policy (Clapham, 2018) allows EPRDF government structures to maintain state control over agricultural research, inputs supply, and agricultural extension—the government-led seed system formalization.	EPRDF government developed a *sui generis* plant breeders' rights law (FDRE, 2017) to qualify for World Trade Organization membership. It also amended seed (FDRE, 2013b, 2016) to align with the COMESA Seed Trade Regulation and biosafety law (FDRE, 2015b) to allow the use of GMOs. However, the implementation lags. In addition, the developmental state administrative and institutional barriers (e.g., lack of access to land, seed import, and export restrictions) discourage private sector investment.	Sovereign rights on plant genetic resources articulated in the constitution and biodiversity policy (FDRE, 1995; EPA, 1997), farmers' rights provisions included in breeders' rights law (FDRE, 2017), access to plant genetic resources, and benefit-sharing rules issued (FDRE, 2006, 2009) and institutional arrangements established (FDRE, 2013a) to encourage biodiversity-based agriculture. However, implementation mandates of these laws and institutional arrangements are misplaced. i.e., under the ministry of environment, diverting the attention of the government investment through the MoA in farmers' seed systems.	EPRDF agricultural cooperatives sector development policy (FDRE, 2012), Quality Declared Seeds certification directives (MoA and ATA, 2015), and investment in local seed business model (Thijssen et al., 2015; Sisay et al., 2017) encourage seed production and marketing of local and improved varieties—an integrative approach to seed system development (Mulesa et al., 2021).

Green Revolution technologies in the seed sector often refers to certified seeds of high-yielding plant varieties.

system development have continued even after the launch of the PSSDS, as I discuss below.

AGAINST THE GRAIN: THE EMERGENCE OF PSSDS AND ITS IMPLEMENTATION PATHWAYS

Since the mid-1980s, diverse coalitions of actors have promoted alternative pathways to seed system development following the food and agricultural crisis. These alternatives (**Table 1**) were debated intensely for about 8 years, beginning in 2006 until the Ethiopian Agricultural Transformation Agency (ATA)[11] and MoA released the first version of the PSSDS in 2013 (MoA and ATA, 2017). The PSSDS in Ethiopia was the result of an externally funded intensive 1-year tailor-made training program[12] based on a multi-stakeholder process approach (Thijssen et al., 2008; ICARDA, 2009) and the Integrated Seed Sector Development (ISSD) program[13] that emerged from this process (CDI, 2009) and played a catalytic role by bringing diverse seed sector actors together. These actors debated policy and governance issues related to the different seed system development alternatives at different levels during the training. The debate continued during the first phase of the ISSD program implementation (2009–2011) and the PSSDS process under the auspices of the Ethiopian ATA (2011–2013). Overall, the impact of the externally funded 1-year training program and the ISSD program was significant in facilitating the PSSDS development (ICARDA, 2009; Borman et al., 2020). There are three major discourses in the contestation surrounding the current Ethiopian seed regime (privatization, localization, and integration) proposed by different actors while

[11]The establishment of Ethiopian ATA was initiated by the late Prime Minister Meles Zenawi after he approached Melinda Gates, Co-Chair of the Bill and Melinda Gates Foundation (BMG Foundation), and asked for the Foundation's support in identifying an innovative way to catalyze agricultural growth and transformation in his country. Following this request, the BMG Foundation financed a study that identified the lack of intersectoral coordination and integration within the agriculture sector, and implementation capacity as the main hindrances. Addressing this would require an organ to streamline coordination and transformation activities. In 2010, the Council of Ministers established ATA (Regulation No. 198/2010) as an autonomous federal organ to: (i) provide leadership in identifying, designing and effectively implementing solutions to basic hurdles in agricultural development; and (ii) provide policy directions and leadership in order to ensure that effective coordination is realized by different actors involved in agricultural development (FDRE, 2010).

[12]The training program was supported by the Dutch Government through Wageningen Centre for Development Innovation of the Wageningen University and Research under a project titled "the improvement of farmer-based seed production scheme and revitalizing farmers' seed supply of local crops and varieties in Ethiopia." The project was implemented in partnership with International Center for Agricultural Research in the Dry Area's Seed Unit and the Ethiopian Seed Enterprise in 2006 (Thijssen et al., 2008; ICARDA, 2009).

[13]The ISSD program is part of the "Bilateral Ethiopia–Netherlands Effort for Food, Income and Trade Partnership supported by the Dutch Government through the Embassy of the Kingdom of the Netherlands in Addis Ababa since 2009. The Centre for Development Innovation of Wageningen University and Research Centre and the Royal Tropical Institute, the Netherlands, is operationalizing the ISSD program. It implements the program to support the African Seed and Biotechnology Program of the African Union Commission (African Union, 2008) through its local partners in Ethiopia, Mozambique, Nigeria, and Uganda.

formulating the PSSDS in addition to the government-led formal seed system (**Table 1**).

Proponents of private-led seed system formalization have been working to increase the roles of private actors in plant breeding and commercial seed production and marketing in Ethiopia, which has not yet been anchored in the country's formal seed system. For instance, they supported policy and regulatory reform, e.g., the development of plant breeders' rights and seed laws, seed quality control by seed companies, and capacity-building of government agencies for effective seed certification. They also provide financial and technical support for start-ups and small seed companies (O'Connor Funk, 2009; Holtzman et al., 2020). The donor and philanthropic support that goes to private-led seed system formalization is mainly a renewed commitment from the international community to invest in African agriculture following the food crisis that struck the world in 2008 (Scoones and Thompson, 2011). But it can also be piggy-backing on the influence of other actors' protests against the dominance of government-led seed research and development, as discussed below.

Most of the coalition of the second group of actors subscribing to the localization discourse has supported the seed contestation and movements (the PGRFA movement) at different times to strengthen farmer-based seed system localization since the mid-1980s (Cromwell et al., 1993). As a protest against privatization or seed enclosure through IPRs, and ineffective government-led seed supply systems, they have promoted participatory plant breeding, community seed banks, farmers' rights, and less stringent seed certification processes for seed producer groups' local seed marketing (Feyissa et al., 2013; Gotor et al., 2014). The third pragmatic coalition group of actors is proponents of the seed system modernization. They endorse the integration of formal and farmers' seed systems that are neither government-led nor private-led formalization but are instead a pragmatic approach to seed sector development. Building on experiences of the World Bank seed system project that partly supported community-based seed production and distribution in the 1990s, the coalition of these actors has supported the integration of formal and informal seed systems through SPCs. At the SPCs level, they support infrastructure development, skill training in planning, production, processing, packaging quality seeds, organizational governance, marketing strategy, and business management. For this purpose, they support the supply of early generation seeds of improved varieties to SPCs from agricultural research and quality declared seed certification schemes for seed marketing (Sisay et al., 2017; Borman et al., 2020). For example, the participation of some actors such as the ISSD program, ATA, and research institutions in the formal and local seed system while promoting the integrative community-based approach demonstrates their pragmatic approach to seed innovation.

These three alternatives in the PSSDS are competing with one another and the dominant government-led formal seed supply system. The seed sector privatization alternative seeks market-based seed supply of profitable crops, which increases commodification and seed enclosure through IPRs protection. It aims to access basic agricultural inputs (e.g., land) to have its breeding program, developed its crop varieties, and access improved varieties bred through public research for seed multiplication and marketing. Moreover, it aims to exclude other actors (e.g., public seed enterprises and SPCs) from certified seed production and marketing of target crops (e.g., hybrid maize). The localization alternative resists IPRs and privatization in favor of farmers' rights and aims to build local capacity to produce and distribute locally adapted seeds using non-market channels. Proponents of localization blame the government-led formal system for seed insecurity owing to ineffectiveness, despite the investment priorities it received from the government over the past decades. In return, the actors supporting government-led formal seed supply believe that an investment that promotes local varieties could impair the government's agricultural transformation. The integrative alternative seeks to increase local availability and access to quality declared seeds of diverse improved and local varieties with farmer-preferred traits. The alternative prioritizes the marketing of open-pollinated crops that the government-led formal seed supply has ignored for decades. **Table 1** shows how different actors' coalitions framed seed system development through particular discourses to promote specific policies and interventions to remedy their problem definitions. It also shows that the government-led formal seed system remains the dominant alternative despite critiques from opponents.

The actors' coalition narratives, values and goals, and priorities based on knowledge politics and dynamics of power led to adopting a pluralistic seed system. However, the direction, diversity, distributional effects, and democratic participation in PSSDS implementation show challenges, as I discuss below.

Moreover, there is growing optimism about possible liberalization and privatization of Ethiopia's agri-food system, including the seed sector, following a leadership change and reforming the developmental state's political and economic policies since 2018 (Geleti, 2020; Woolfrey et al., 2021). A widespread youth protest was an everyday experience between 2015 and 2018 due to two-and-a-half decades of growing inequality and multiple forms of youth exclusions from the developmental state's development future that unequally distributed the fruits of economic growth. Contestations around violent forms of government land-grabbing, farmer dispossession, youth unemployment, lack of political freedom, and human rights violations were at the core of the youth protest. This protest brought the "reformist" Prime Minister Abiy Ahmed to power in April 2018 (Abebe, 2020). The seed sector privatization optimism links to Prime Minister Abiy Ahmed's recent Homegrown Economic Reform Program of making Ethiopia the African icon of prosperity by 2030. The program received USD 5 billion from the IMF and the World Bank in 2019 and USD 3 billion from the United Arab Emirates in 2018, owing to its prioritization of the private sector (Collier, 2019; Kibsgaard, 2020). With this recent economic reform, the MoA has already issued a new strategy in 2019 to strengthen the private seed sector (MoA, 2019). However, when writing this paper, Ethiopia faces a political rift that has led to civil war, making the future uncertain (Walsh and Dahir, 2021; Ylönen, 2021). As a result, some western donor countries are undertaking evidence-based analysis of the country's fragility to

make informed bilateral relations and investment policies for the future (Rameshshanker et al., 2020).

THE "4Ds" OF ETHIOPIA'S CURRENT SEED POLICY AND PRACTICE

Following Leach et al.'s (2020) 4D approach to the study of food politics and development, I assess the outcomes of the PSSDS through four questions: What has been the direction of the seed system development; What diversity of technical and institutional innovations have resulted, to what extent has the development been democratic and inclusive and; what have been the distributional outcomes for marginalized people.

The direction of seed system development under Ethiopia's PSSDS framework is still the dominant government-led formal seed system emphasizing the development and use of GR technologies, including improved varieties as a response to food and nutrition insecurity, climate change, and rural poverty. This dominance is also unexpected given that Ethiopia is the most significant international aid recipient and has approved policies and strategies on paper in favor of a free-market economy, including privatization. It shows the marginal effect of donor influence compared to other developing countries where power asymmetry between governments and donors is at play in setting seed sector development policies (Scoones and Thompson, 2011). One respondent explained how the dominance of the public seed sector (e.g., in major food crops) had been maintained by the Ethiopian government as follows:

> "Our developmental state fears that there could be a risk of food insecurity if competent private seed companies overtake the public enterprises and cannot supply affordable seeds, especially for food crops like hybrid maize. They do not say it, but we know they also fear a loss of political support and income if the private sector overtakes the public enterprise and extension services for the key food security crops. However, the government is for competent private seed companies in horticulture to increase foreign currency gain from seed and food exports. Still, institutional capabilities are too poor to appropriately implement existing policies and laws, such as the revised plant breeders' rights protection law in 2017, which discourages companies from entering the sector[14]."

The state's power as entrenched in developmental state policy and skillful negotiation with donors that continue to support the GR approach to agricultural development is the driving force for this dominant path. Describing state power and development practices in government institutions, one informant with intimate knowledge of Ethiopian seed policy said:

> "Ethiopia's developmental state economic policy goes beyond directing, supporting, and guiding executive bodies of public institutions because the government wants to implement everything related to agricultural development by itself. The organizational leaders that I have interacted with told me that they must deliver inputs, including certified seeds, to farmers. The agriculture bureaus at the regional, zonal, and district levels think that seed distribution is their primary responsibility, and others cannot play a central role except helping them. They believed that public parastatals should be the leading seed producer, and the extension at the bureau of agriculture is responsible for its distribution to farmers through cooperatives. I see a symbiotic relationship between government staff unwilling to give up the seed distribution job to agro-dealers and government use of seed as a political commodity, i.e., maintaining strong links with and controlling farmers[15]."

Explaining the continued donor supports, despite the government's unwillingness to sign up to neoliberal institutions and encourage seed sector liberalization and privatization, one informant said:

> "Several donors such as BMG Foundation, USAID, the World Bank, and the Dutch government have provided aid for agricultural research and development during the past decade in Ethiopia. Simultaneously, they have been pushing for policies for seed sector privatization. For example, they provided technical and financial assistance through AGRA, ATA, ESA, and the ISSD program to develop seed and PVP laws[16]. The government approved these laws, but they are not enforcing them, making it difficult for the private sector to operate. For example, the DUS test and issuing of PVP certificate is almost nil as there are no directives issued, making variety import and export very difficult for the private companies. On top of this, regulatory services at the federal level are centralized and bureaucratic. Besides, Ethiopia has not acceded to the WTO and is unwilling to join UPOV. Unfortunately, the government continues to discourage privatization, and it is not easy to change the government's [politicians/executive leaders] negative attitude toward the private sector[17]."

In addition to community seed banks that EBI and NGOs promoted since the 1990s in Ethiopia, community-based seed production and marketing (through SPCs) emerged as an additional alternative during PSSDS formation and its implementation. As a result, the SPCs and community seed banks have contributed to the diversification of the country's seed systems regarding farmers' choice of crops, varieties, and seed sources (Sisay et al., 2017; Alemu et al., 2019; Andersen, 2019).

The distributional effect of dominant government-led seed research and development that marginalized the private sector in the formal system and farmers' seed systems is evident from a recent field study conducted on farmers' seed security in the central highlands in Ethiopia (Mulesa et al., 2021). The study identified seed insecurity in a commercially oriented wheat farming district and a subsistence-oriented tef (*Eragrostis tef*) growing community. The study links the limited availability

[14]Personal interview with a senior technical staffer working for donor funded seed system development program (Addis Ababa, January 18, 2018).

[15]Personal interview with a senior technical staffer working for donor funded seed system development program (Addis Ababa, January 18, 2018).

[16]Acronyms: Alliance for a Green Revolution in Africa (AGRA), Ethiopian Agricultural Transformation Agency (ATA), Ethiopian Seed Association (ESA), Integrated Seed Sector Development (ISSD) and Plant Variety Protection (PVP).

[17]Personal interview with a senior manager working for donor funded seed system development program (Addis Ababa, February 1, 2018).

of improved varieties and specially certified seeds of these to the ineffectiveness of the public institutions and the availability of few commercial actors. The PSSDS acknowledges the importance of diversity on paper, but the bias of supporting the dominant modernization approach is pulling in another direction. However, it is important to note that Ethiopia's seed system is mainly farmer-based, and agriculture is—in comparison to most of the world—highly diverse in terms of crops, varieties, and seed sources. We also observe a lack of locally adapted varieties linked to a lack of democratic participation in priority setting, technical and institutional innovation, for example, with priority crops for breeding, participatory variety development of such crops, and involvement in policy processes (Beko, 2017). For instance, farmers in wheat and maize growing agro-ecologies benefited from the formal seed system more than those growing other indigenous crops due to the concentration of the public breeding, dissemination, and adaptation work in the two crops since the first GR. Moreover, farmers' differentiated access to preferred seed and information (including wheat and maize commercial areas) according to sex, age, and wealth, links to gender inequality and political allegiance that the developmental state extension institutions use to select model farmers, favoring the wealthier ones for seed access.

CONCLUSIONS

This article analyzed the historical evolution and current policy practices in the Ethiopian seed sector development, focusing on actors' interests and actions and political and economic priorities of three different governance regimes (imperial, socialist, and developmental) since the 1950s. Despite agricultural policy changes from commercial farming of the feudal system to state enterprises and cooperativization of the socialist government to the developmental state's commercialization of smallholder farmers, all governance regimes have retained public seed research and development in Ethiopia. Moreover, these governance regimes also held public seed research and development as a priority despite awareness, recognition, and policies on paper about how diverse seed systems can increase access to enough good quality seeds of suitable plant varieties by farmers.

The power analysis allowed me to identify some insights concerning this specific Ethiopian seed policy and practice. Of historical significance is Ethiopia's idiosyncratic historical patterning of the seed regimes compared to most colonial territories and industrial countries. The first colonial seed regime never took hold, and the third corporate seed regime has never been anchored in the formal seed system. Consequently, Ethiopia's seed system development remains government-led. Related to this, we see two paradoxical aspects of Ethiopian government policy practices. First, the Ethiopian governments have received financial assistance from western donors, including neoliberal financial institutions, while disagreeing with them and establishing the distinct seed sector development policies in line with the agricultural development ideology of the governance regimes. For example, the EPRDF government has received funding from the IMF and the World Bank to finance public agricultural research and development, including during the structural adjustment program in the 1990s. Still, Ethiopia is not a member of WTO and UPOV[18], which are the key neoliberal seed institutions. Second, Ethiopia's positions in environmental governance, climate change, and UN development goals are perceived as "progressive" on the international scene. At home, the government has sidelined alternative development pathways in support of these positions. For example, support for the farmers' seed systems mainly comes from multilateral institutions, local and international NGOs.

Ethiopia has a very centralized and top-down state-led seed sector development policy. Practically, the government has sidelined both its development partners' democratic values and neoliberal economic policies as well as measures to implement its policies on alternatives to the dominant public seed research and development. That said, the two perspectives have common ground in notions of independence, sovereignty, skepticism against foreign forces, liberalization, and free-market ideology. In the end, the government investment emphasizes state-led seed sector development, leaving other alternatives to NGOs and smaller overseas development assistance projects. While heavily dependent on external funding, the Ethiopian example of paradoxical state-led policy development and action exemplifies variations specific to countries in international politics and development work.

In line with other studies (Alemu, 2011; Beko, 2017), we see a link between the nature of the Ethiopian state and the marginalization of alternative seed sector development in the country. Decades of centralized planning and execution of agricultural development, state control of rural constituencies, elite interests, and agricultural modernization path dependency have contributed to the lack of inclusive and equitable seed sector development. In addition, the historical events and processes are vital elements that have shaped the practices of the Ethiopian state in the governance of seed sector development. For instance, the limited participation of the private sector in the formal seed system links to the first colonial seed regime that never took hold in Ethiopia compared to other African countries such as neighboring Kenya, which has signed over to the neoliberal institutions. In agreement with McCann (2011), we see that policymaking and implementation in Ethiopia treat external influences and the international seed market as of lesser importance. Again, resonating with McCann's (1990) observation, we find that the state and elite's vested interest in maintaining the status quo of the agricultural cycle for resource extraction from the farming community is the major hindrance to breaking the cycle and bringing an inclusive and equitable seed sector development to Ethiopia.

For inclusive and equitable seed sector development to happen in Ethiopia, there needs to be a political will to establish effective institutional arrangements and allocate an adequate budget for the recent PSSDS. One motivating factor or source of inspiration in this direction is the growth of

[18]WTO is the acronym for World Trade Organization and UPOV is the acronym for Union Internationale pour la Protection des Obtentions Végétales (French) or International Union for the Protection of New Varieties of Plants (English), which is also the name of the organization that established the International Convention (called the UPOV Convention).

community-based seed production and marketing. However, other matters deserving attention are the biased attitudes and bad governance, including legal hurdles in the seed sector that marginalize other alternatives and actors, for instance, farmer-based seed system innovation and participation of the private sector in seed research and development.

Finally, when applying Leach et al.'s (2020) plural approaches to power analysis in developing countries, it is vital to carry out a historical analysis of the policies and institutions involved in seed system governance, as this study has done in the case of Ethiopia. Analyzing seed regime patterns allows one to examine how historical conflicts or cooperation between donors and governance regimes have shaped distinct seed policies and practices in developing countries. In considering the particular historical, political, and institutional factors within each country, a more nuanced picture is created by going beyond existing institutional, infrastructure, and financial limitations that donors often focus on for their intervention.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available upon request to the author.

ETHICS STATEMENT

The study was conducted according to the guidelines for research ethics of the Norwegian University of Life Sciences and Norway's guidelines for research ethics in the social sciences, humanities, law, and theology. A notification form was submitted to the Norwegian Center for Research Data (NSD) before data collection based on these guidelines, and approval was received from NSD (Harald Hårfagres gate 29, N-5007 Bergen, Norway) on 18.09.2017. The guidelines did not require explicit ethics approval in Ethiopia. However, I informed the authorities, which gave a letter of permission to carry out the interviews and discussions. Voluntary informed consent was obtained from all research participants after explaining the research project's objectives, the implication of their participation, and how their information is used.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

FUNDING

This research was funded by the Research Council of Norway. Grant Numbers are RCN-277452 and RCN-288493.

ACKNOWLEDGMENTS

This article is based on a research project conducted in completion of the Ph.D. degree by the author. The author would like to thank all interviewees for their time and contributions to this study. The author also thanks Ola T. Westengen and Ruth Haug in Norwegian University of Life Sciences (NMBU) for their guidance and invaluable help throughout this research project. The author wishes to thank the NMBU for the scholarship to carry out this research and the Research Council of Norway (RCN) for financial support under grant numbers RCN-277452 and RCN-288493. The author is thankful to the International Maize and Wheat Improvement Center (CIMMYT) in Addis Ababa for hosting him and facilitated his fieldwork during the period.

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ISBN: 978-82-575-1863-9
ISSN: 1894-6402

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