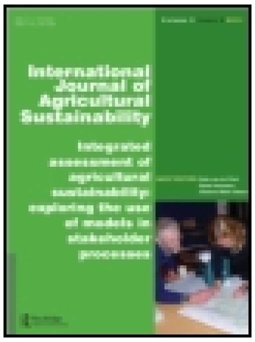

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Smallholder commercialization and climate change: a simulation game for teff in South Wollo, Ethiopia

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ABSTRACT
Replicable Business Models (RBMs) focus on reducing economic coordination, opportunism, and price risks but pay less attention to risks from natural shocks. A simulation game was designed to capture the impact of variable rainfall on teff production and commercialization in South Wollo Zone, Amhara region, Ethiopia. The game captured farmers' decision-making for three rainfall scenarios and three levels of market prices. The results showed that variable rainfall had little impact on the levels of teff production or commercialization. The exception was the scenario where rainfall failed in both crop seasons; however, the probability of this scenario was low. If rains failed in the first wet season (Belg) or if rains in the second and main wet season (Meher) were late, farmers maintained teff production by increasing the area planted and the share of teff that received inorganic fertilizer. Resource constraints – particularly shortage of land – limited farmers' production of teff. Despite these constraints, the simulation revealed that farmers will increase teff sales in response to higher prices. The risk simulation game provides a diagnostic tool to evaluate the performance of the RBM and the potential for smallholder commercialization in the face of natural shocks.

1. Introduction

The commercialization of staple food crops is widely viewed as a pathway from poverty for smallholders in Africa. However, the development of value chains for these crops must overcome 'systemic investment risks' (Dorward and Kydd, 2004). Market failures create economic coordination risks that reduce the availability of inputs like seed and fertilizer, while reducing output prices for smallholders. Opportunism risks expose smallholders to the purchase of low-quality inputs and low prices from unscrupulous buyers. Price risks reduce smallholders' income from crop sales in sudden, unpredictable ways. Finally, the risk of natural shocks means that the supply of agricultural products fluctuates from year to year in ways that smallholders cannot control, which may reduce the quantity they can offer for sale. Singly or in combination, these four systemic risks reduce the incentive for smallholders, traders and processors to invest in the development of value chains for staple food crops and thereby limit the potential benefits from smallholder commercialization.

Interventions to reduce systemic investment risks have focused primarily on improving economic coordination. Collective action by smallholder groups can address market failures and improve linkages to input and output markets. By contrast, less attention has been paid to the systemic risk from natural shocks, particularly variable rainfall. Yet the risk posed by variable rainfall is high in rainfed environments where smallholders lack access to irrigation and this risk may be growing thanks to climate

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change. The impact of this systemic shock on smallholder value chains is potentially devastating. In the short term, variable rainfall may reduce the volume smallholders can sell. Over the longer term, inconsistent supply due to variable rainfall may reduce the incentive for processors to buy from smallholders. Thus, the systemic risk posed by natural shocks may be critical for the development of smallholder value chains.

Teff (*Eragrostis tef*) in Ethiopia is an example of a successful smallholder value chain for a staple food crop (Minten, Stifel et al., 2018). Teff is a preferred cereal in high demand thanks to growing urban markets (Alem & Soderbom, 2018). However, the value chain is not free from systemic risks. Price risks are low because of high demand. But economic coordination risks are high. True, the output market is competitive, and growers already receive an 'astonishing' 78-86% of the final retail price, depending on quality (Minten, Tamru, Legesse et al., 2018). Thus, collective marketing is unlikely to result in higher prices for growers. But the market for inputs is another story. The supply of certified seed of improved varieties of teff is controlled by state-run seed farms that cannot meet demand (Spielman and Mekonnen, 2018). The main reason given by growers for not adopting improved teff varieties is that they cannot find seed (Minten, Tamru, Engida et al., 2018). In turn, this lack of access increases opportunism risks by forcing smallholders to use local markets where seed may be of poor quality. Finally, there is a high risk of natural shocks. Smallholder agriculture is almost entirely rainfed. Consequently, the supply of teff in any given year depends on the timing, distribution and quantity of rainfall. In combination, these two systemic risks – economic coordination and natural shocks – pose a threat to smallholder commercialization.

To identify systemic risks in the commercialization of teff, the Smallholder Risk Management Solutions (SRMS) project, which is part of the Sustainable Agricultural Intensification and Learning Alliance (SAIRLA) funded by UK Aid, held a Stakeholder Workshop with participants representing growers, buyers, and researchers (Weber and Tiba, 2017). Participants identified the main systemic risk to the commercialization of teff as a market failure in the supply of certified seed of improved, higher-yielding varieties. To manage this systemic risk, the Workshop designed a revolving seed fund to be run by government cooperatives (Weber and Tiba, 2017). In this business model, cooperative members receive 4 kg of certified seed of *Quncho*, an improved teff variety whose white grains attract a price premium (Assefa et al., 2011). Farmers return 8 kg grain which the cooperative then sells, using the income to buy more certified seed for distribution to a new cohort of farmers in the second year. For the revolving seed fund to be sustainable, smallholders must return grain to the cooperative, which depends on how much teff they harvest, which in turn depends on the risk of natural shocks. In a bad year, smallholders may be unable or unwilling to repay and have little or nothing to sell. However, the probability and impact of this risk are not known. In this article, we try to fill this knowledge gap and assess how the risk of natural shocks might affect commercialization and the sustainability of the revolving seed fund.

The general objective of this article is to analyse the impact of rainfall variability on the commercialization of smallholder teff production. The specific objectives are to:

(1) Develop a socio-economic profile of the smallholders participating in the revolving seed fund;
(2) Analyse the effects of rainfall variability on the production and sale of teff; and
(3) Assess the implications of the results for the commercialization of teff in the survey area.

To address these objectives, we developed a risk simulation game. Farmers were presented with three different rainfall scenarios and asked to choose which cereal crops they would plant and fertilize. Based on these choices, the game simulated cereal production for each rainfall scenario. Farmers were then asked how much of the teff from each scenario they would keep for home consumption and how much they would sell, for three levels of market prices. The results provide interesting insights into farmers' decision-making for teff.

The application of simulation games to smallholder agriculture is not new. An early example is the *Green Revolution* game, which simulates farmer decision-making for irrigated rice in India (Chapman, 1973; Corbridge, 1985). More recently, the *African Farmer* game simulates farmer decision-making for rainfed agriculture (Futures Agriculture Consortium, 2018). Both these games operate at the farm level. Other games focus on a single crop. *Faridpur*, a simulation game developed for rainfed lowland rice in Bangladesh, asks players to make crop management decisions on fertilizer, crop protection, and hired labour based on rainfall scenarios that are randomly generated from historical daily rainfall data (Huke, 1985). Unlike conventional decision trees, which are limited in the number of decisions they can handle (Gladwin, 1989), simulation games allow us to model a wide range of decisions, to explore the interaction between them, and to assess their cumulative effects.

The simulation game presented here has a practical purpose. It differs from the examples cited above in three ways. First, it focuses solely on the risk from natural shocks, in this case rainfall variability, and does not include other aspects of decision-making that influence commercialization. Second, it was designed not as a learning tool for students or researchers but as a game that could be played by real farmers to give insights into actual decision-making. Finally, the game is light on data. It does not require meteorological data or rely on expert knowledge of crop modelling, but instead relies on stylized rainfall scenarios and information that can be obtained directly from farmers themselves. Although designed for teff in Ethiopia, the basic design of the game can be adapted to fit a variety of contexts and smallholder value chains. Thus, the game offers a prototype of a diagnostic tool that can provide practitioners with useful information for action research on smallholder value chains leading to recommendations for commercialization.

The article is organized in five sections. The next section describes materials and methods. Section 3 presents a socio-economic profile of the players and the results of the risk simulation game. Section 4 discusses the implications of these results for the future performance of the revolving seed fund. The final section concludes.

2. Materials and methods

2.1 Site description

The SRMS project operates in Tehuledere *woreda,* an administrative unit sub-divided into *kebeles*. This *woreda* was selected in the inception phase by three project partners – the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the Amhara Agricultural Research Institute (ARARI), and Wollo University (Orr et al., 2017). Three *kebeles* in this *woreda* (Hitecha, Gobeya, and Basso Mille/Jare) were then selected by participants in Stakeholder Workshop (Weber and Tiba, 2017). The *kebeles* were purposely selected because they were the site of complementary research activities by ICRISAT and Wollo University and they were accessible by all-weather road from Dessie town.

Amhara region lies in the north-western Highlands of Ethiopia. In terms of area planted, teff is the most important cereal exi, with 1 million ha, followed by sorghum (600,000 ha), wheat (500,000 ha), and maize (400,000 ha). Over 2.5 million smallholders in Amhara plant teff and the region accounts for 38% of national teff production (Orr et al., 2017). The optimal growing conditions for teff are between 1,800 and 2,100 metres above sea level (a.s.l.) according to Chamberlin and Schmidt (2012). Our research site – Tehuledere *woreda* in South Wollo Zone – lies in the *woina dega* agro-ecological zone, the Amharic name which is given to midlands approximately 1,500–2,000 metres a.s.l.

Cereal crops in Ethiopia have two growing seasons. Any crop harvested between March and August is a Belg season crop, while crops harvested between September and February are Meher season crops. Meher is the main cropping season and accounts for 75% of cereal production in Amhara (CSA, 2016). Smallholders in Ethiopia plant a variety of cereal crops. Figure 1 shows the crop calendar for Tehuledere *woreda* in a 'normal' year. In the first wet season (Belg), smallholders may plant wheat (*T. aestivum*), teff, or long-duration sorghum (*sorghum bicolor*). In the main wet season (Meher) they may plant early-maturing sorghum, wheat, or teff. The farmer's choice of cereal crop largely depends on rainfall.

2.2 Design of the simulation game

Based on the published literature, we can identify four types of rainfall risk:

1. Major drought: in extreme cases, the rains fail and grain yields are too low to be worth harvesting. The most recent occurrence was in 2015, when El Niño caused the failure of the Belg rains and the late arrival of the Meher rains. In Amhara, crops planted at the start of the Meher season either failed to germinate or withered in the early growth stages. Farmers replanted in August and even September, but these crops also failed and losses of at least 75% were reported for the season (AKLDP, 2016).
2. Late onset: in this case, planting is delayed and crop yields reduced. This is common in the

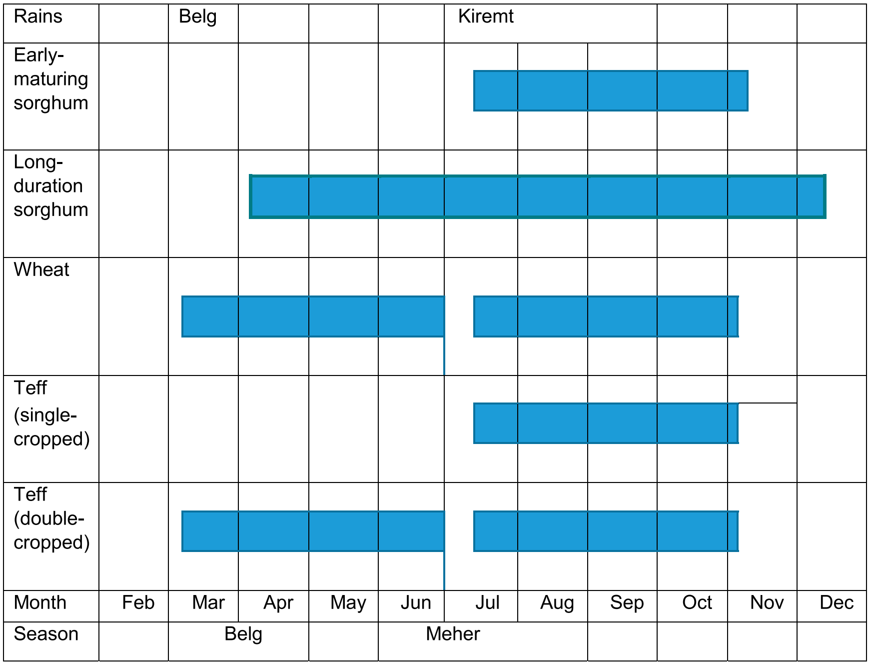

Figure 1. Cereal crop calendar in Tehuledere woreda, South Wollo Zone. Source: FGDs, Gobaya and Basso Mille/Jare *kebeles*, Tehuledere *woreda*, South Wollo, Amhara region.

Meher season. An analysis is available for Amhara region using meteorological data for the period 1978– 2008 (Ayalew et al., 2012). We have used the dates of the onset of rain from the Kombolcha meteorological station, which is the closest to the town of Dessie. In half the years, the median date for the onset of rain was 4 July, but in one quarter of the years the median date was 18 July (Ayalew et al., 2012). In other words, there is a one-in-four chance that planting in the Meher season will be two weeks late.

(3) Erratic distribution: crop yields reflect rainfall in specific months. Teff production is highly correlated with rainfall in August and September, while the production of sorghum is strongly correlated with rainfall in May and June (Bewket, 2009). Conversely, inadequate rainfall in any of these four months will reduce average yields of cereal crops.

(4) Shorter rains: rainfall data for the 30-year period 1980–2010 reveal that the Rift Valley, including Amhara region, saw a significant reduction in the quantity of rainfall received in the Belg season (Gummadi et al., 2017). Over this period, the consecutive number of dry days increased while the consecutive number of wet days decreased (Gummadi et al., 2017). For our study area of South Wollo, rainfall data for the period 1987–2007 also showed a decline in Belg rainfall and a later start of the Belg season (Rosell, 2011). As a result, a crop model for teff in South Wollo showed that in the period 1964–1996 only 18 years (45%) were suitable for teff in the Belg season (Rosell and Holmer, 2015). Shorter rains in the Belg season increase the risks to cereal crops in both crop seasons, since they also reduce the soil moisture available for crops planted in the Meher season.

In summary, climate change has increased the risk of natural shocks in the study region, reducing the quantity and distribution of rainfall in the Belg season, and with a high risk of late onset and erratic distribution in the Meher season. Based on this literature review, we identified four rainfall scenarios for the risk simulation game:

(1) A ‘normal’ season where farmers can plant in March/April in the Belg season and in June/July in the Meher season, and where there is rain in the first two weeks of September when crops are flowering.

(2) A failed Belg season where farmers cannot plant in March/April but the Meher season is normal, and farmers can plant in June and July and there is rain in the first two weeks of September when crops are flowering.
(3) A failed Belg season where farmers cannot plant in March/April and the Meher season is late, where farmers cannot plant in June/July but can plant in August, and there is rain in the last two weeks of September when crops are flowering.
(4) A failed Belg season where farmers cannot plant in March/April and a failed Meher season where planting is late (August) but there is not enough rain in the last two weeks of September when crops are flowering.

Since the fourth scenario results in almost total crop failure, only scenarios 1, 2, and 3 were simulated in the game. A 'weighted average' scenario was derived by asking the players to estimate the frequency of the four rainfall scenarios over the past 10 years. The results were 2.8 years (good Belg and Meher), 3.8 years (failed Belg, good Meher), 2.0 years (failed Belg, late Meher) and 0.18 years (failed Belg and Meher) (Orr et al., 2018). In combination, therefore, these four scenarios accounted for 8.72 years of the previous 10 years, with the residual 1.22 years representing rainfall scenarios that are not captured by the 'average' scenario.

Smallholders apply inorganic fertilizer to their cereal crops but because this is expensive they cannot fertilize all their land. Thus, fertilizer is rationed. Farmers usually apply fertilizer in two splits, as basal (Nitrogen-Phosphate-Sulphur-Boron or NPSB) and top-dressing (urea). For the purpose of the game, we ignored the timing of fertilizers, and asked farmers to choose whether to fertilize a cereal crop or not.

Teff prices have risen steadily since 2000 (Orr et al., 2017). Prices are seasonal, with a difference of 40% between the producer price at harvest and at the end of the season in August–October (Minten, Tamru, Legesse et al., 2018). To discover if farmers will increase the volume and share of teff production they sell in response to higher prices, we used three sets of prices. In Ethiopia, crop production is officially measured in quintals, or units of 100 kg. We used the 2017 price of 89 United States Dollars (USD) per quintal or 2,400 Ethiopian Birr (ETB) per quintal) as a benchmark and price increases of 15% (102 USD/quintal or 2,760 ETB/quintal) and 30% (116 USD/quintal or 3,120 ETB/quintal).

To simplify the design of the game, we imposed the following rules: (1) players cultivate a maximum of 0.625 ha of land (equivalent to five t*emads*, of 0.125 ha); (2) players can only plant units no smaller than 0.125 ha (one *temad*); (3) players can plant a maximum of 0.375 ha (three *temads*) of teff in any one season; (4) fertilizer is rationed to a maximum area of 0.375 ha (three *temads*) in any one season; (5) players can plant any combination of four cereal crops (teff, wheat, long-duration sorghum, and short-duration sorghum), omitting maize which FGDs reported to be uncommon; (6) soil is of uniform quality and suitable for any cereal crop; (7) we ignore the cultivation of non-cereal crops; and (8) cereal cropping is entirely rainfed and there is no irrigation.

A complete version of the simulation game applied is available at http://sudart.hu/game/game.php. Here we summarize the main features. The game was played in three Rounds, described below:

(1) Round 1: Players are informed that rainfall in the Belg season is 'normal' and asked to allocate 0.625 ha of land between teff, wheat, and long-duration sorghum. They are then asked to allocate inorganic fertilizer to 0.375 ha (three temads). The game then calculates the total production for wheat and teff in the Belg season. Next, players are informed that the Meher season is 'normal' and asked to allocate inorganic fertilizer over 0.375 ha (three temads). The game then calculates the total production for wheat, teff, long-duration sorghum and short-duration sorghum in the Meher season. Players are then asked, based on total production of teff in both seasons, how much teff they would sell at the current market price, at a price 15% higher, and at a price 30% higher.
(2) Round 2: Players are told that rainfall in the Belg season has failed, but that rainfall in the Meher season is 'normal'. The game then follows the same sequence for the Meher season as Round 1.
(3) Round 3: Players are told that rainfall in the Belg season has failed, and that rainfall in the Meher season is late. The game then follows the same sequence for the Meher season as Round 1.

2.3 Instruments of data collection

The study used mixed methods. Qualitative methods (Focus Group Discussions) were used to design the game and obtain feedback from farmers on the results. Quantitative methods (a household survey) were used to obtain a socio-economic profile of the players and measure their aversion to risk. The game itself was played on tablets programmed to capture the area planted and fertilized for each crop under three rainfall scenarios, and the quantity of teff farmers would sell under three sets of prices.

Focus Group Discussions (FGDs): Information required to design the game was obtained through two FGDs held with farmers in Gobeya and Basso Mille/Jare *kebeles*. The farmers who participated were cooperative members who had received improved teff seed. The FGD was designed to model three rainfall scenarios. First, farmers described a 'good' crop year. They described the months of planting and harvesting for three cereal crops (sorghum, teff, and wheat). Second, farmers provided the same information for a crop year when the Belg season was 'bad' but the Meher season was 'good'. Third, farmers provided the same information for a crop year when the Belg season was 'bad' and the Meher season was 'late', with rain arriving in August rather than in July. Farmers also provided information on the average yield (with and without fertilizer) for each crop in each of the three rainfall scenarios (for yield figures, see Orr et al., 2018). After the results of the game became available, we returned to the same two *kebeles* to share the findings and discuss them with cooperative members. These FGDs were tape-recorded, and the information from them was used to help interpret the results of the simulation game.

Household survey: The development agent in each of the three farmer cooperatives identified 100 cooperative members to receive 4 kg of certified seed of improved teff varieties. Recipients were selected based on their reputation as 'good' farmers and the expectation that they could be trusted to return 8 kg of teff grain to the cooperative after harvest. The cooperatives kept a written record of farmers selected to receive seed and this list was used as the sampling frame for the survey. Since the total number of farmers selected to receive certified seed in Year 1 was quite small – i.e. 300 farmers – we decided to interview all the farmers listed rather than just a subsample. Of the 300 named farmers, 21 were not interviewed because they had not in fact received any improved seed. As a result, only 279 farmers (93%) on the list of 300 were successfully interviewed. Of these, in 18 cases the names included members of the same family, which resulted in some households receiving more than 4 kg of seed. To avoid distorting the results by including these households, only the cases where the name was that of the head of the head of the household were included in the analysis. Consequently, the final sample size was 261 households. The risk simulation game was a separate module in the household survey. Hence, the players were those interviewed for the survey, namely the head of the household.

Risk aversion ranking: To measure farmers' degree of risk aversion, we adapted the approach used by Holden and Westberg (2016). This asks farmers to choose between two crops, the first crop with a high yield in a 'good' year and a low yield in a 'bad' year, the second crop with a lower yield in a 'good' year but a higher yield in a 'bad' year. By progressively reducing the yields of each crop over six choices, farmers can be categorized into six ranks based on their degree of risk aversion. The higher the rank, the greater the degree of risk aversion. We have called this a 'risk aversion ranking'. Pretesting this approach revealed that farmers were confused by the labels 'good' and 'bad' years, relating the suggested crop yields to experience on their own fields. This confusion was overcome when we relabelled 'good' and 'bad' years as 'Year 1' and 'Year 2' and explained that this was an imaginary experiment and not based on their own experience.

2.4 Data collection and processing

The FGDs were conducted and the survey questionnaire pre-tested in May 2018. The survey was administered in early April 2018 under the supervision of Oxford Policy Management (OPM). The enumerators were staff members from Wollo University with previous experience in household surveys. Data were collected on hand-held tablets. The dataset was analysed using the Statistical Package for the Social Sciences (SPSS), Version 25 (SPSS Inc, 2018). Results were presented in tabular form. Statistical significance for categorical variables was measured using the Chi-Square test, and for continuous variables using Analysis of Variance. Follow-up FGDs to obtain feedback from cooperative members were conducted in March 2019.

3. Results

3.1 The players

The household survey provided information on the players, their crops, and crop management for the

Table 1. Socio-economic profile of sample households, by farm size.

	Farm size tercile				
Indicator	1 (*n* = 87)	2 (*n*=87)	3 (*n*=87)	Mean/Sum (*n*=261)	Sig.-level (*p*>*.000*)[a]
Mean area cultivated (ha)	0.21	0.39	0.65	0.42	.000
Male-headed households (no.)	77	72	78	227	.351
Age of household head (years)	43	49	50	48	.001
Education (primary and above) (no.)	52	58	54	164	.768
Household size (no.)	5.4	5.4	5.7	5.5	.874
Dependency ratio [a]	0.55	0.59	0.52	0.58	.742
Households without plough oxen (no.)	22	16	16	54	.066
Plough oxen (no.)	1.1	1.3	1.3	1.2	.039
Households renting/borrowing oxen (no.)	69	52	56	187	.091
Total livestock units [b]	3.2	4.5	4.4	4.1	.003
Income from agriculture (%)	69	72	77	73	.380
Households hiring farm labour (no.)	11	10	27	48	.001
Households receiving food rations from government in 2016 (no.)	24	18	16	58	.316
Household eats own teff (months)	7.3	8.1	9.9	8.4	.000
Household eats own sorghum (months)	3.3	4.6	6.1	4.7	.001
Household eats own wheat (months)	2.9	2.5	3.5	3.0	.194

Source: SRMS Household Survey, 2018.

[a] ANOVA for continuous variables, Chi-square test for categorical variables.

[b] Household members aged <15 and 60>/household members aged 15-60.

[c] Tropical livestock units: cattle, donkey: 0.7; sheep, goats, 0.1.

previous crop year (2017-18). Since smallholders are not a homogeneous group, we stratified households by farm size, which was defined as 'the area suitable for cultivation'. To compare differences in indicators based on size of farm, the sample was divided into three equal-sized groups (terciles). Table 1 shows some significant differences between the players:

(1) Heads of household on the biggest farms were older, but otherwise there were no significant differences in the education of the household head, household size or the dependency ratio between the farm size terciles.
(2) Livestock assets increased with farm size, and bigger farms had significantly more plough oxen. By contrast, a significantly higher share of the smallest farms borrowed or rented oxen for ploughing.
(3) Household food security was significantly higher on the biggest farms, averaging 10 months for teff and six months for sorghum, compared to the average of seven months and three months on the smallest farms.
(4) One wealth indicator – the share of households that received government rations of wheat and oil after the El Niño drought of 2016 – did not differ significantly by farm size.

3.2 Simulation game

Figure 2 compares the simulation results for the three rainfall scenarios that were modelled in the game. In addition, we include an 'average' scenario based on the weighted frequency of the four possible scenarios described in Section 2.2.

Scenario 1: Good Belg and Meher seasons: In the combined Belg and Meher seasons, players planted more land to teff (46%) followed by wheat (43%). They planted only a small area to long-duration sorghum (7%) and to short-duration sorghum. Teff was prioritized for fertilizer allocation (67% fertilized), comparable to wheat (62%). Over the two crop seasons, teff production totalled 14 quintals. At this level of teff production, players reported they would sell 2.17 quintals of teff at current market prices, increasing to 2.71 quintals if market prices rose by 30%.

Scenario 2: Failed Belg season, good Meher season: In this scenario players compensated for a failed Belg season by increasing the area planted to teff (57% of the area planted) and short-duration sorghum (13% of the area planted), while reducing the area planted to wheat to 30% and abandoning long-duration sorghum. Once again, teff was prioritized for fertilizer allocation (74%). Total production of teff was 11 quintals or 3 quintals lower than in Scenario 1 when rains were good in both seasons. Given this level of teff

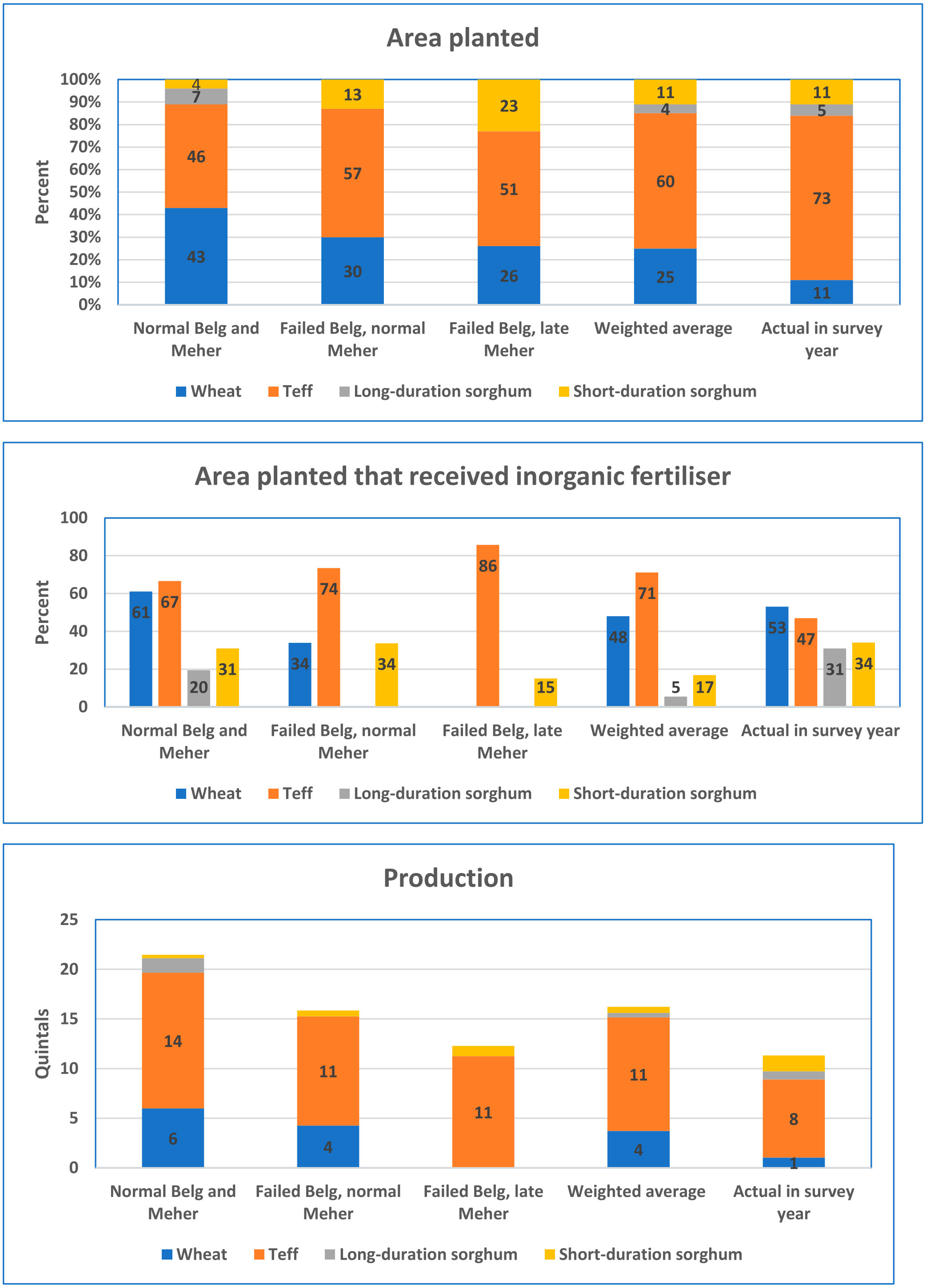

Figure 2. Results of simulation game, for three rainfall variability scenarios. Source: Simulation Game, 2018.

production, players reduced the amount of teff offered for sale to 1.3 quintals at current prices, increasing to 1.78 quintals if market prices rose by 30%.

Scenario 3: Failed Belg season, late Meher season: In this scenario players increased the area planted to short-duration sorghum (23% of the area planted) while reducing the area planted to teff and wheat (51% and 26% of the area planted, respectively), and abandoned long-duration sorghum. Once again, teff was given highest priority for fertilizer allocation, raising the area planted to teff that received fertilizer to 86%. Despite the late rainfall, therefore, players were able to maintain their level of teff production (11 quintals). Given this level of teff production, the quantity of teff offered for sale at current prices was 1.39 quintals, rising to 1.90 quintals if market prices rose by 30%.

'Weighted average' scenario

In the 'weighted average' scenario teff occupied 60% of the area planted to the four cereal crops. Teff was prioritized for fertilizer allocation, with 71% of the area planted to teff receiving fertilizer. Teff production averaged 11 quintals. At this level of teff production, players offered 1.57 quintals of teff for sale at current prices, rising to 2.07 quintals when market prices rose by 30%.

Survey year

Actual figures for the year 2017–18 from the household survey showed that teff occupied a higher share of the area planted (73%) than modelled in the simulation game. By contrast, the share the area planted to teff that received fertilizer (47%) was lower than in the simulation game. Finally, the average production of teff was also lower (8 quintals) than in the three simulated rainfall scenarios.

3.3 Commercialization

Contrary to our expectation, there was no significant difference between bigger and smaller farmers in their risk aversion ranking (Table 2). The mean rank was 2.84, hence a central position among the six possible ranks, which suggests that farmers were moderately and not severely risk averse. Risk aversion did not vary significantly by farm size. Generally, the level of commercialization was low. Only one-quarter (26%) of the sample households had sold any teff in the previous year, and the average quantity sold was only 0.4 quintals, valued at USD 23 or 617 ETB. This represented just 12% of the total value of all crops sold and 8% of the total value of livestock sales. At current prices, the volume of teff offered for sale ranged from 1.3–2.17 quintals per household. If prices rose by 30%, the volume offered for sale increased to between 1.78 and 2.71 quintals per household. For an 'average' season, this represented an increase of 32%. Average production of teff (3.99 quintals) was below the level required for self-sufficiency in home consumption (4.4 quintals). About half the sample households (51%) reported that they could not increase the area planted to teff because of a shortage of land, while 14% reported that they could not increase the area planted to teff because of a shortage of labour, primarily for weeding and threshing.

3.4 Farmers' feedback

Table 3 summarizes the feedback obtained from farmers on six major results of the simulation game. This feedback provides information on farmers' perception on the impact of climate change and rainfall variability on teff production (Results 1 and 2) as well as the potential for teff commercialization (Results 3-6). We will use the insights obtained from this feedback in our discussion in the next section.

4. Discussion

The simulation game gave useful insights into smallholder strategies for managing the risk of natural shocks, and the implications of these strategies for the commercialization of teff among cooperative members in the project area.

4.1 Strategies for teff

A striking result of the simulation game is that smallholders successfully managed rainfall risks to maintain a consistent level of overall annual teff production. Volumes reached a maximum of 14 quintals (scenario 1) but (except when the rains failed in both crop seasons) never dipped below 10 quintals (scenario 2). Thus, even when rains failed in the Belg season or when rainfall in the Meher season was late, the overall volume of teff production in a year remained remarkably consistent.

Climate change over the longer term has reduced the potential for cereal cropping in the Belg season. Farmers' feedback confirmed this trend, although they were vague about when it had begun ('since

Table 2. Teff commercialization, by farm size.

Variable	Farm size tercile 1 (*n*=87)	 2 (*n*=87)	 3 (*n*=87)	 Mean/Sum (*n*=261)	Sig.-level ($p > .000$)[a]
Risk aversion ranking (range 1-6)	2.76	2.51	3.15	2.84	.182
Growers selling teff (no)	17	22	29	68	.112
Total teff production (quintals)	2.99	3.62	5.35	3.99	.000
Total teff sold (quintals)	0.20	0.34	0.67	0.40	.393
Value of teff sold (USD)[a]	9	20	39	23	.005
Value of all crops sold (USD)[b]	127	180	269	192	.000
Value of livestock sold (USD) [b]	326	175	399	305	.004
Teff production needed to feed family (quintals)	4.6	8,8	5.6	4.4	.290
Can increase area planted to teff? (no.)	42	45	40	127	.550
Reasons:					
Shortage of land (no.)	42	41	34	117	.663
Shortage of labour (no.)	3	12	11	36	.017
Land not suitable (no.)	2	9	5	16	.069
Other (no.)	7	8	10	25	.473

Source: SRMS Household Survey, 2018.

Notes:

[a] ANOVA for continuous variables, Chi-square test for categorical variables.

[b] 1 United States Dollar (USD) = 27 Ethiopian Birr.

the Derg regime'). The sample farmers in the household survey estimated the frequency of a good Belg season as three years in ten, or just 30%. Consequently, teff production depends primarily on rainfall in the Meher season. Taking an average over the four rainfall scenarios, the Meher season contributed about four-fifths of the total volume of teff production compared to just one-fifth in the Belg season.

The simulation game suggests that the impact of climate change on aggregate teff production has been limited. Farmers compensate for a failed Belg season by increasing teff production in the Meher season. In scenarios 2 and 3 (a failed Belg season) farmers increased the area planted to teff in the Meher season. Farmers also maintained teff production by increasing the share of teff receiving inorganic fertilizer. In Scenario 1 (a good Belg season) the share of the area planted to teff that received fertilizer was 67%. In scenario 3 (failed Belg season, late Meher season) the share rose to 86%. Farmers in FGDs confirmed that, when the supply of fertilizer was rationed, they prioritized fertilizing teff over fertilizing wheat and sorghum. In combination, these two strategies – increasing the area planted and the share of teff that received inorganic fertilizer – meant that a failed Belg season reduced aggregate teff production by just one-quarter (24%).

4.2 Strategies for wheat and sorghum

Clearly, smallholders could only achieve consistency in the production of teff by sacrificing other cereal crops. Wheat production suffered. In scenario 1 (good Belg and Meher seasons) farmers harvested 6 quintals of wheat. However, in scenario 2 (failed Belg, good Meher) this fell to 4 quintals and in Scenario 3 (failed Belg, late Meher) farmers harvested no wheat at all. Farmers regarded wheat as a crop for the Belg season. In the Meher season, by contrast, farmers saw wheat as expendable, particularly when the rains were late. In this case, farmers switched from wheat to teff or to short-duration sorghum. A surprising result, however, was the relatively small area that farmers planted to long-duration sorghum in a good Belg season or to early-maturing sorghum in a good Meher season. This suggests that farmers viewed sorghum primarily as a strategy for managing the risk of rainfall variability. Long-duration sorghum (*Ahyo* or *Degalit*) was planted in order to have some yield late in the Meher season, while the area planted to early-maturing sorghum (*Girana 1*) only increased when rain in the Meher season arrived too late to plant wheat.

Why did farmers give a lower priority to sorghum and wheat? In the household survey, farmers were asked to rank cereal crops in terms of the risk of yield loss from rainfall variability. Farmers considered long-duration sorghum to be the cereal crop with the highest risk, followed by wheat. This is strong evidence that the decision to plant relatively small areas to long-duration sorghum and wheat can be explained by aversion to risk. However, in the FGDs, farmers gave other reasons besides risk. Wheat is not regarded as a substitute for teff because it is not

Table 3. Focus Group Discussions on results of the simulation game.

Result 1: Teff is not usually planted in the Belg season

- Rainfall is usually too erratic and varies between villages in the same *kebele*
- Even if teff is planted and germinates it still needs rainfall for flowering
- Before 1988, my father planted teff in both the Belg and Meher seasons
- Since the end of the Derg regime [1974-1987] rainfall in the Belg season has become more erratic

Result 2: Teff production does not go down if Belg rains fail or Meher rains are late

- If Meher rains arrive at end of July, we search for teff varieties that are early-maturing, and which can be harvested in October, one month earlier than local teff varieties
- If rains arrive after 25th August, we plant local chickpea instead of teff
- We apply the same level of fertilizer to teff whether the rainfall is normal or late
- If rains start in mid-August, the soil is 'hot' so teff matures more quickly and gives higher yields

Result 3: Area planted to teff is always higher than area planted to wheat or sorghum

- The price of teff is higher than the prices of wheat or sorghum
- We prefer to eat *injera* made from teff rather than *injera* made from sorghum
- Wheat is used to make bread which is a breakfast food and so is not a substitute for teff
- If Belg rains fail, land that would have been planted to long-duration sorghum is shifted to teff

Result 4: Teff receives a higher share of inorganic fertilser than sorghum or wheat

- If we have limited fertilizer we will apply only to teff, sometimes apply to small plot of wheat.
- Teff receives more fertilizer because more land is planted to teff
- Teff has the priority for fertilizer, then sorghum, but wheat is not usually planted on lowland

Result 5: Farmers will sell more teff if the price rises

- If the price of teff is high, wives will sell teff and buy sorghum – 50 kg of teff will buy 150 kg of sorghum
- Farms here are small, so most teff is used for home consumption, but wives usually sell a limited amount to buy cooking oil or soap.
- One *tassa*[a] of sorghum costs USD 0.9 (25 ETB) but one *tassa* of teff costs USD 1.2 (33 ETB)
- I don't sell teff because I can't produce enough to feed my family

Result 6: Farmers plant only small areas of long-duration or short-duration sorghum

- Area planted to long-duration sorghum (Gedalit) is gradually declining because of erratic Belg rains. Long stalks are useful for animal feed, fencing, and firewood. Gedalit grain is also used to make local beer (*tella*)
- Long-duration sorghum needs rain in April for planting, which is unreliable, and in September-October for flowering. It takes 8–9 months to mature.
- Unlike long-duration sorghum (Gedalit) short-duration sorghum (Girana 1) does not make good *injera*, because the *injera* is too dry and does not stretch but breaks too easily. For make good injera with Girana 1, you need to mix two parts teff to one part of Girana 1.

Source: FGDs in Gobeya and Basso Mille/Jare kebeles, March 2019.
Note:
[a] One *tassa* = 2.5 cups = 1.25 kg.

used to make *injera* (a flat, spongy bread made from fermented teff flour) but bread which is eaten only as a breakfast (Table 3). Unlike wheat, the area planted to long-duration sorghum depends on timely rainfall in the Belg season. Without enough rain for planting at the start of the season, long-duration sorghum does not have enough time to mature. Yet farmers will plant this crop because it can be used to make *injera*, and its tall stems (above 2 m) provide fuel, fodder for livestock and material for fencing and roofing. In the case of early-maturing sorghum, the small area planted cannot be explained by aversion to risk. According to the household survey, the risk of yield losses from rainfall variability was the same for early-maturing sorghum as for teff. Furthermore, the early-maturing sorghum variety *Girana 1* performed well in the 2015 drought and is currently promoted by the regional Bureau of Agriculture for this very reason (Orr et. al., 2017). Farmers however avoided planting this variety because of taste preferences. *Injera* made with *Girana 1* was reported to be too dry and easily broken and required a mix of two parts teff to one of sorghum to produce *injera* of the desired quality (Table 3). Given a choice between planting early-maturing sorghum and teff, therefore, farmers saw no reason to opt for sorghum.

Obviously, farmers' decision to prioritize teff at the expense of wheat and sorghum reduces the total annual production of cereals. In scenario 1, (good Belg and good Meher) the total production of cereals was 21. quintals. By contrast, in scenario 2 (failed Belg, good Meher) the total production of cereals was 15 quintals, while in scenario 3 (failed Belg, late Meher) it was just 12 quintals. Thus, climate change in the Belg season and a late Meher season reduce the total annual cereal production by 29% and 43%, respectively. The same two scenarios also reduce the production of teff, but less severely. Aggregate production of teff fell by 24% and 18%, respectively. Thus, by increasing the risk to cereal production in the Belg season, climate change reduces the total amount of cereals available for home consumption which in turn reduces the amount that farmers may be willing to sell. Consequently, climate change has an adverse effect on smallholder commercialization. Nevertheless, farmers' adaptive strategies clearly protected teff production from the full impact of natural shocks. Evidence from crop simulation models suggests that, in the rainfed, semi-arid tropics, simply improving farmers' current management practices can more than compensate for reductions in yield caused by climate change (Cooper et al., 2009). Our evidence on farmers' risk management strategies for teff in the face of growing rainfall variability lend cautious support to this more optimistic view.

4.3 Prospects for commercialization

Generally, the level of commercialization was low. Nevertheless, farmers were willing to increase the amount of teff they sold in response to higher prices. However, two factors limited the scope for commercialization. One was resource constraints, above all the small size of farms, which limited the area that farmers could plant to teff. Given shortage of land, the commercialization of teff will require intensification to raise average yields through the adoption of improved varieties and improved management practices. This supports the SRMS project's strategy of a seed revolving fund, which provides a sustainable way to increase farmers' access to improved seed. The second factor limiting commercialization is the priority given to household food security. Clearly, teff was grown primarily for home consumption and contributed relatively little to cash income. In the simulation game, farmers reported that they needed an average of 4.4 quintals of teff to feed their families. However, in FGDs farmers were more flexible. Women would not necessarily keep all the teff they required for consumption but would sell some to buy household necessities. Furthermore, selling high-priced teff to buy a bigger quantity of cheaper sorghum was a common practice. To save on teff consumption and allow more for sale, *injera* (a flat, spongy bread made from fermented flour) was usually made from a mixture of sorghum and teff rather than purely from teff. Despite this, further research on the impact of the SRMS project has revealed that almost all the increase in teff production that can be attributed to the seed revolving fund was used not to increase sales but to boost home consumption (OPM, 2019). Farmers estimated the probability of a 'normal' Belg and Meher seasons as no more than three years in ten (see Section 3.2 above). In regions characterized by chronic food insecurity, like South Wollo, rainfall variability makes the commercialization of the staple food crop a high-risk strategy.

5. Conclusion

The general objective of this article was to analyse the potential impact of variable rainfall on the commercialization of smallholder teff production. We developed a risk simulation game in which farmers made decisions about the area planted to cereal crops, fertilizer use, and teff sales for three different rainfall scenarios.

Rainfall variability did not have the expected negative impact on the production and commercialization of teff. We simulated farmer decision-making for failed rainfall in the Belg season and late rains in the Meher season. In both scenarios, farmers were able to adapt to rainfall variability and maintain their level of teff production by increasing the area they planted to teff and the share of this area that received inorganic fertilizer. This was achieved at the expense of sorghum and wheat. When the rains failed in both the Belg and Meher seasons, these risk management strategies would be redundant and there would be no production of teff. However, the risk of a failed Belg and Meher season in the same year is low. We conclude that rainfall variability will have a limited impact on farmers' ability to repay grain to the revolving seed fund in the study area.

Risk aversion did not differ significantly by farm size, suggesting this was not a barrier to commercialization on smaller farms. However, the commercialization of teff was limited by resource constraints. Small average farm size and a labour constraint for weeding and threshing resulted in low teff production. Consequently, farmers used teff primarily as a staple food crop which left only a small amount for sale.

However, resources are not a binding constraint on commercialization since players were willing to increase sales in response to higher prices. In the average rainfall scenario, a 30% increase in prices resulted in an increase of 32% in teff sales. Raising the level of commercialization thus requires a strategy that combines increasing supply through higher yields with increasing demand through higher prices.

The simulation game provides a diagnostic tool to test the impact of climate change on the commercialization of teff in Ethiopia. Similar tools are needed for other contexts where a high risk of natural shocks may disrupt sales and reduce demand from processors who require consistent supply. Simulation games can be easy to design and play with farmers. As this example shows, games can give useful insights into farmer decision-making, their risk management strategies for natural shocks, and the prospects for smallholder commercialization.

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