Gender-based discrimination and global crop yields

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Abstract

Many efforts have been made to increase crop yields to meet future food demand, such as through innovative technology use and agricultural input subsidy programs. However, yield gaps are still observed between farms managed by women and men with ambiguous underlying causes. Nowadays, women in agriculture still face discrimination that might affect yields. In this study, we investigate globally the relationships between the yields of the world's ten most important food crops and six dimensions of discrimination against women related to agriculture. These dimensions are household responsibilities, inheritance, secure access to land and non-land assets, secure access to formal financial services, and freedom of movement. Our results show that, in general, yields are negatively associated with gender-based discrimination. The relationships are most significant with household responsibilities and freedom of movement. This suggests that women's household workload, decision-making abilities, and restricted movement might influence crop production toward lower yield. This study provides policymakers the insight that providing equal access and opportunities between women and men might increase food availability, improving food security.

Keywords: women in agriculture; gender discrimination; inequality; crop yield; global study; sustainable food systems

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1. Introduction

One of the crucial challenges for humanity will be meeting future food demands without further undermining the stability of the earth systems. Agricultural systems are already significant forces of global environmental degradation, but population growth and increasing consumption are expected to roughly increase human food demand by 30 to 60% between 2010 to 2050 (van Dijk et al. 2021; Komarek et al. 2021). Though human food production is greater than ever, food availability is still unequal, leaving some areas food insecure (Duro et al. 2020). Responding to this challenge, researchers have been focusing on 'sustainable intensification' to increase yields on underperforming areas, i.e. closing yield gaps, instead of on land expansion for agriculture. Closing yield gaps is supported through, e.g., input subsidy, modern technology use, and knowledge and skills application (e.g., Subramanian 2021; Hemming et al. 2018). However, yield gaps have still been reported between farms managed by women and men with ambiguous underlying causes (Doss 2018). The gaps are, for example, 8% in Kenya, 12% in Rwanda, 13% in Uganda, 11-13% in Ethiopia, 16-30% in Tanzania, 18% in Niger, 28% in Nigeria, and 28-44% in Malawi (UN Women 2019; Slavchevska 2015; Palacios-López and López 2015; Oseni et al. 2015; Backiny-Yetna and Mcgee 2015; Aguilar et al. 2015). This issue is worth further analyzing, mainly because the proportion of women farmers is considerable (Doss et al. 2018). Furthermore, women still face discrimination in the agricultural sector, such as receiving less income compared to male farmers and difficulties in accessing productive assets (e.g., Aguilar et al. 2015; Karamba and Winters 2015; Fremstad and Paul 2020).

Studies on gender and agriculture usually use data focusing on specific areas, with countries in the Sub-Saharan Africa region receiving the most attention. However, the complexities and heterogeneities of individual cases may not indicate general validity. Therefore, broader-level research can complement those case studies and create a relevant contribution to a larger population. This study investigates how gender-based discrimination is associated with crop yields globally, being the first study to do so. We regressed the yields of the ten globally most important food crops on the index of gender discrimination in six dimensions related to agriculture. A critical prerequisite for identifying the relationships of these variables is to

understand better if yield gaps can be closed by providing equal access and opportunities to women and men farmers in certain aspects. Thus, addressing gender-based discrimination in agriculture could reduce the pressure of agricultural land expansion, increase food production, and improve food security.

2. Conceptual framework

There are several factors that can affect crop yields (Figure 1). Studies have shown that environmental factors such as extreme temperature, droughts, and floods have damaged crop production, thus lowering yield (Lesk, Rowhani and Ramankutty 2016; Heino et al. 2023). Furthermore, agricultural inputs, modern technology, and the application of novel knowledge and skills are proven to increase yield (Deng et al. 2021; Hemming et al. 2018).

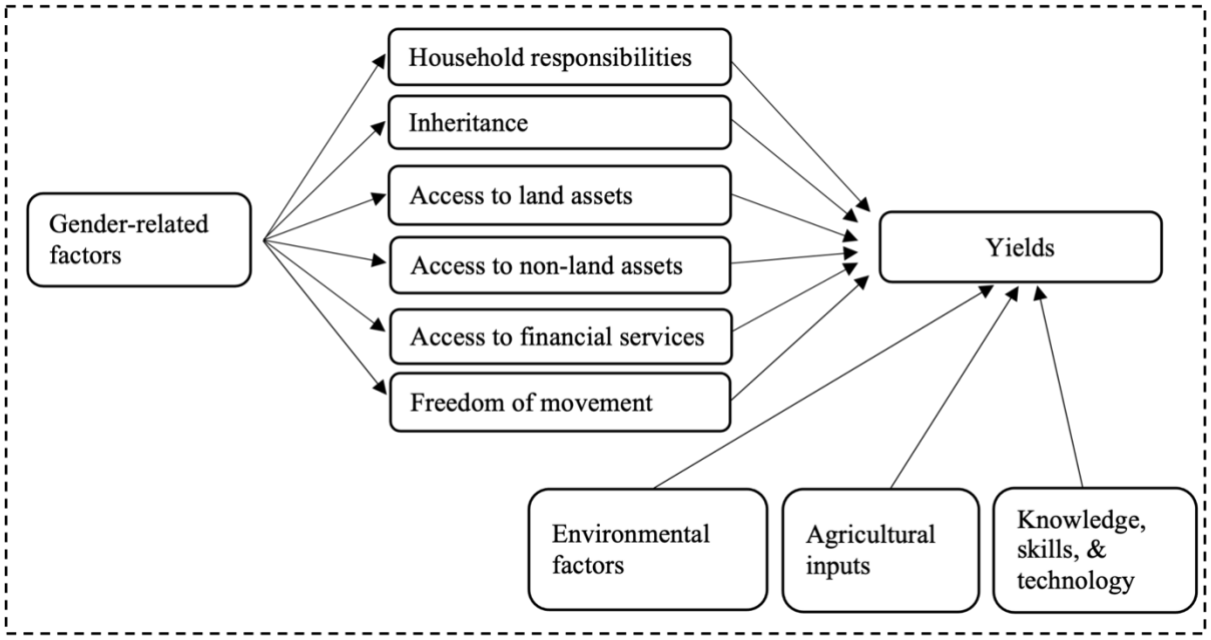

Figure 1. Possible mechanisms of the association between gender and yields

However, after controlling relevant variables, such as subsidy for agricultural input and farmers' characteristics, e.g., education and income, yield gaps are still observed between farms managed by male and female farmers in different countries (Aguilar et al. 2015; Karamba and Winters 2015; Slavchevska 2015; Doss 2018). This figure suggests that underlying gender-related issues could explain the different yields women and men produce. Gender variables

related to agriculture include household responsibilities, inheritance, access to land assets, access to non-land assets, access to financial services, and freedom of movement. These variables correspond to variables to construct the Women's Empowerment of Agricultural Index (WEAI) developed to measure women's empowerment and inclusion in the agriculture sector (Alkire et al. 2013).

Household responsibilities are related to workload in the household, which is a trade-off with time to spend on income-generating activities and leisure. Traditionally regarded as primary caregivers, women might spend more time than men doing household chores and taking care of children (Cerrato and Cifre 2018). Women's disproportionate time in the house will affect their time in other activities and their decision-making ability, for example, on-farm (Komatsu, Malapit and Theis 2018; Pierotti, Friedson-Ridenour and Olayiwola 2022). As sometimes women manage separate farms with men, even within the same household (Doss et al. 2018; Pierotti et al. 2022), the farm operated by women will be cultivated less extensively when they must work in the house, thus lowering yield.

In some communities, inheritance (usually in the form of land and non-land assets) is not distributed evenly between women and men (Htun and Weldon 2012). Even in some cases, when a husband dies, the inheritance goes directly to the son instead of the wife or daughter (Khodary 2018). As a result, women are forced to cultivate land that does not belong to them, lowering their willingness to invest in, e.g., agricultural inputs and thus affecting yield.

Land assets, non-land assets (e.g., agricultural machinery, vehicles), and financial services are productive resources essential for crop production (Johnson et al. 2016). It is crucial for farmers to have access to these resources and to be able to make choices on how to utilize them related to agricultural production. Yields can be lower when women do not have secure access to land assets, non-land assets, and formal financial services (Aguilar et al. 2015; Karamba and Winters 2015).

Freedom of movement is a condition where someone is free to move outside the house (e.g., to work, attend group meetings, and visit relatives, among others). Therefore, it relates to civil liberty, safety, and social connectedness. Freedom of movement is also relevant to agricultural production. Yield might be affected if women have restricted movement or feel unsafe, for example going to the farm or participating in farmers' groups (Bergman Lodin et al. 2019).

3. Data and methods

3.1 Gender-based discrimination and yield variables

We used the gender discrimination index to examine the relationship between gender and yield. The discrimination data was derived from Social Institutions & Gender Index (SIGI), which reflects discrimination against women in 180 countries (OECD 2022). SIGI comprises 16 indicators, but we utilized only six indicators most closely related to agricultural production (Figure 1) that conform with the WEAI. The six indicators are i) household responsibilities, ii) inheritance, iii) secure access to land assets, iv) secure access to non-land assets, v) secure access to formal financial services, and vi) freedom of movement. The indicator values range from 0 to 1. Value 0 means the country's legal framework provides women with the same rights as men, without legal exceptions regarding some groups of women (there are no customary, traditional, or religious laws, or practices that discriminate against women's rights) (Branisa et al. 2014). Meanwhile, value 1 means the country's legal framework fully discriminates against women's rights. The data is available for four different years, namely 2009, 2012, 2014, and 2019.

As the dependent variables, we use yields of the world's ten most important food crops derived from FAOSTAT, i.e., banana, barley, cassava, maize, potato, rice, soybean, sweet potato, tomato, and wheat (FAO 2022). The yields are expressed in metric ton per hectare per year (mton/ha/year).

3.2 Research hypothesis and regression approach

We hypothesized that gender-based discrimination is negatively associated with yield. We tested this hypothesis separately for the world's ten most important food crops. In addition to the descriptive analysis, we ran regression models of the following type:

$$Y_{i,j} = \propto + \beta . GDisc_j + \gamma . Z_j + \varepsilon_{i,j} \quad (1)$$

Where $Y_{i,j}$ is the yield measured in metric ton of crop i in country j. $GDisc_j$ is a variable that captures the gender-based discrimination in country j. Hence, β measures the effect of gender-based discrimination on yield, which is our variable of interest. We also controlled other relevant socioeconomic variables that may influence yield, such as GNI that can capture agriculture investment and technology. These are denoted by the vector Z_j. As part of it, we also included world regions to control for unobserved regional differences such as climate and agroecology and year to control for general trends. Lastly, $\varepsilon_{i,j}$ is a random error term.

3.3 Filling missing data

Some gender-based discrimination data had missing values, especially in the early years when SIGI was just developed (i.e., 2009 and 2012) and in developed countries. This is probably because gender-based discrimination is more experienced in developing regions, so initially, research in developed countries got less attention. We assume that legal frameworks that (in)discriminate against women will not change drastically in a short period (2 to 5 years). Therefore, we filled in the missing data using the nearest year's data. For example, if data for 2009 was missing, we filled it in with data from 2012. We limited the data filling only to the nearest year (e.g., filling 2009 data with 2014 data is not allowed).

4. Results and discussion

Women experience discrimination in many parts of the world (Figure 2). Discrimination is particularly high in African countries and in the Middle East. Meanwhile, in general, there is less discrimination in developed regions. However, discrimination against women related to household responsibilities is reported to some degree in almost all countries (Figure 2a). It means that women still experience discrimination within the family, even in developed countries, especially related to household headship, decision-making ability, parental authority, and household chores. Discrimination of this dimension is very high in the Middle East, Western Africa, Sudan, Central African Republic, Somalia, and Malaysia. In other dimensions, developed countries perform better with some exceptions (e.g., there is a practice that discriminates against women's access to land assets in Canada, where aboriginal women are particularly affected (Bourassa, McKay-McNabb and Hampton 2005)) (Figure 2c).

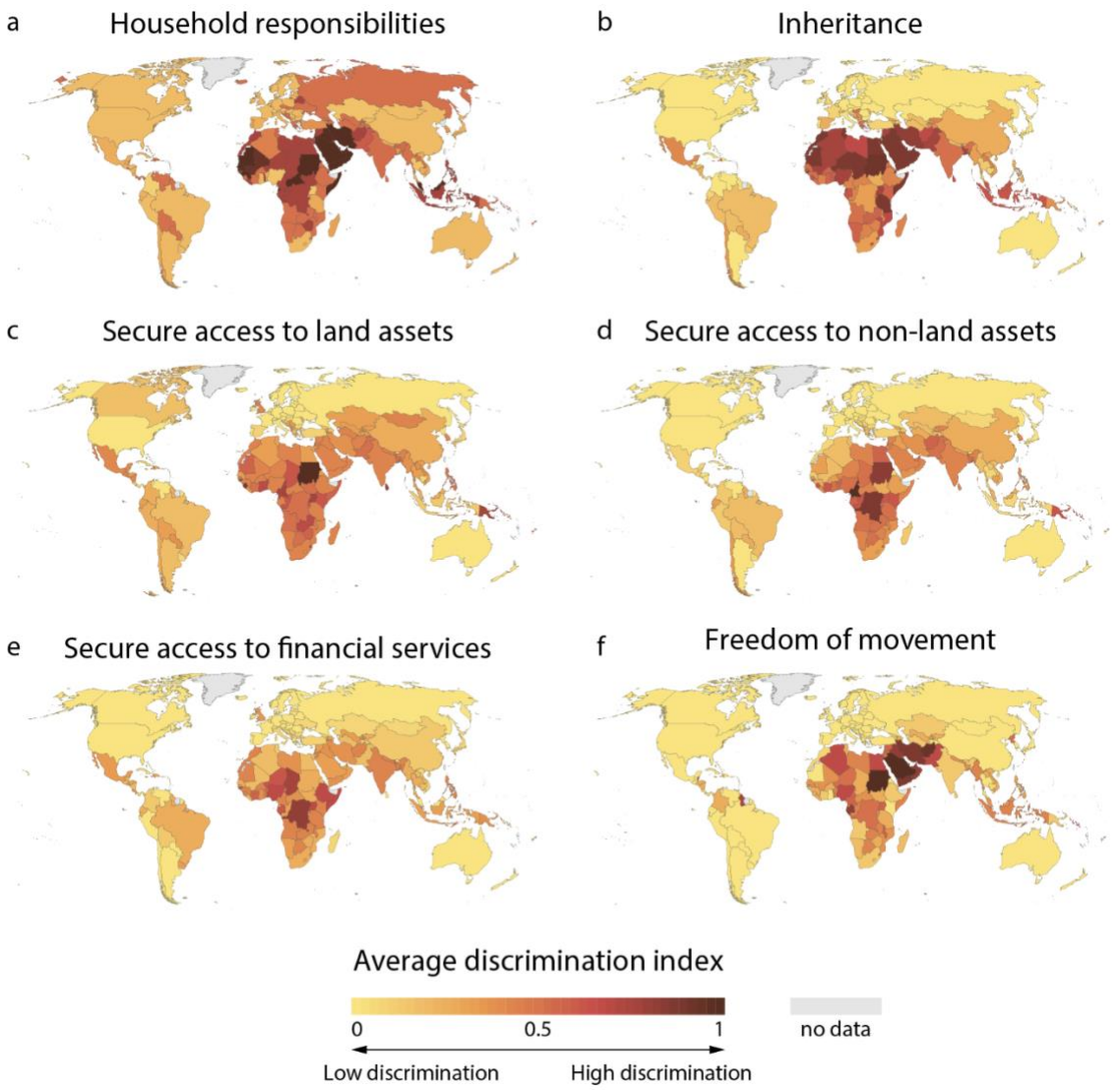

Figure 2. Dimensions of gender-based discrimination in the world (against women). Discrimination related to household responsibilities (a), inheritance (b), secure access to land assets c), secure access to non-land assets (d), secure access to formal financial services (e), and freedom of movement (f). The values are mean discrimination values of the pooled data, i.e., the years 2009, 2012, 2014, and 2019. The Figure is the authors' illustration based on Social Institutions & Gender Index (SIGI) dimensions (OECD 2022).

Discrimination to inherit the land and non-land assets is highly experienced by women in Africa, the Middle East, and parts of Asia (Figure 2b). Regarding access to productive assets (land, non-land, and financial services), discrimination is observed highly in Africa and moderately in Asia and Latin America. The insecure access is particularly high: in Sudan, Sierra Leone, Sri Lanka, and Papua New Guinea (land assets); in Sudan, Cameroon, and DR Congo (non-land assets); and in DR Congo and Chad (financial services) (Figure 2c-e).

Meanwhile, women's movements in the Middle East, Sudan, Algeria, Nigeria, Gabon, and Guyana are highly restricted (Figure 2f).

Yields of different crops are varied around the world (Figure 3). In the Americas, potato, rice, and soybean have high yields (Figure 3e-g), while the highest yields of tomato are observed in Northern Europe (Figure 3i). Western Europe has high yields of barley, potato, and wheat (Figure 3b, e, and j). Cassava's highest yield can be seen in India and Guyana (Figure 3c). Meanwhile, banana's highest yields can be observed in some parts of Asia, Africa, and Central America (Figure 3a).

Now we look at the yields of global crops based on different levels of discrimination of different dimensions (Figure 4). The results show that, in general, yields in countries where there is low discrimination are higher or above average. On the contrary, where gender-based discrimination is high, the yields are usually lower than average. The associations of low discrimination and high yields are pronounced for inheritance, land assets, non-land assets, and financial services, especially in sweet potato and tomato (Figure 4b-e), implying that those dimensions might be the most critical dimensions related to yield.

Some exceptions are observed. For example, sweet potato has a high yield in countries where discrimination in household responsibilities and freedom of movement are high (Figure 4a, f), and high yield barley in high discrimination of land assets (Figure 4c). Three countries with the highest sweet potato yields are Guyana, Ethiopia, and Senegal, with high discrimination levels. In the case of barley, the figure is skewed probably because of the low number of observations in the high discrimination of land assets group (N=9) (Table A1 in the Appendix).

When we look at regression results, gender-based discrimination is generally negatively associated with yield (Table 1 & 2). We averaged the gender discrimination variables and regressed yield on it. The negative relationships are significant in banana, maize, potato, and rice. However, some ambiguous results can be seen in barley and wheat (Table 1). The results are also similar when we separate the gender-based variables (Table 2). Significant correlations are observed between yields and discrimination related to household responsibilities and freedom of movement.

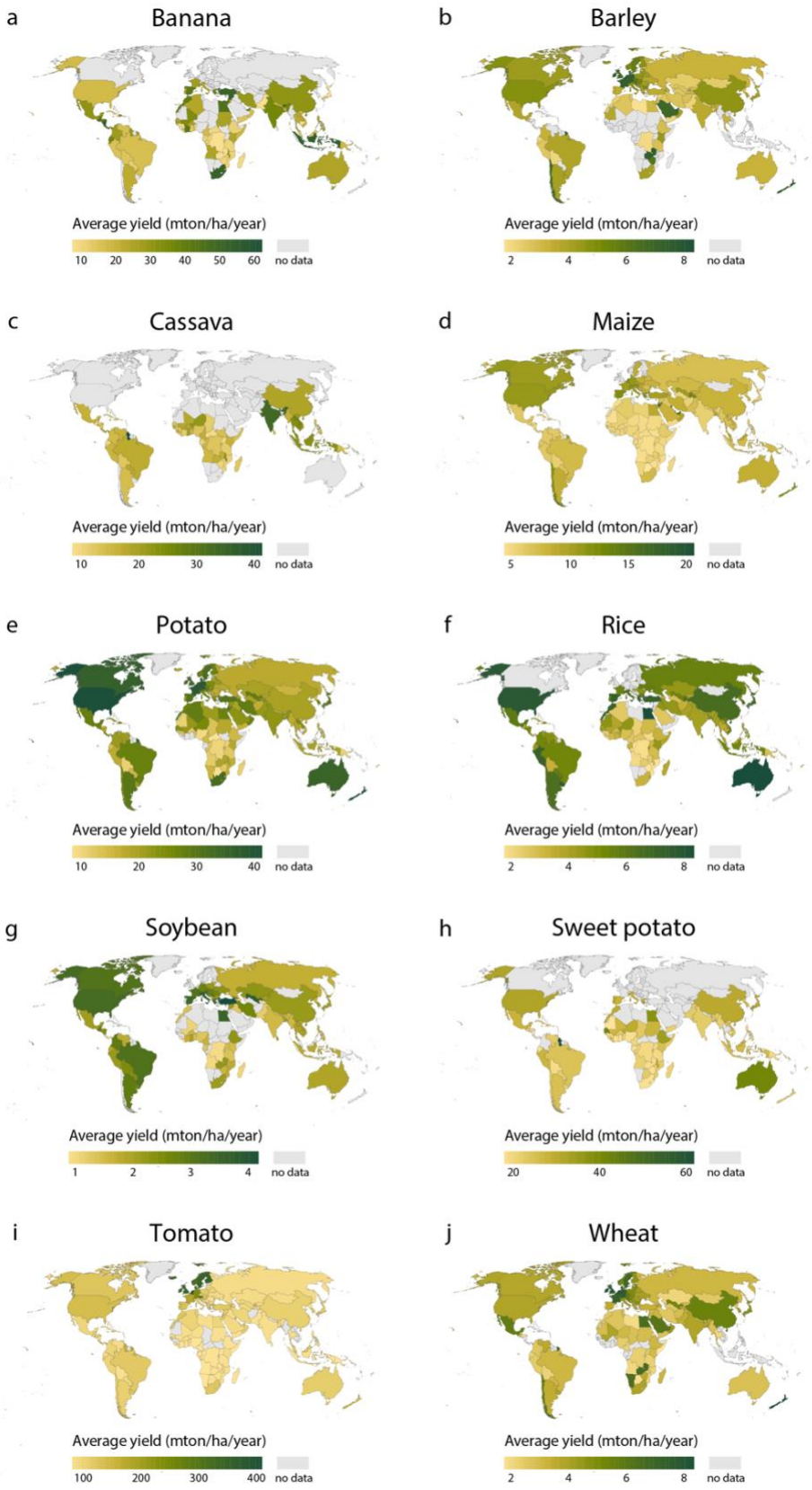

Figure 3. Yields of the ten most important food crops in the world: banana (a), barley (b), cassava (c), maize (d), potato (e), rice (f), soybean (g), sweet potato (h), tomato (i), and wheat (j). The values are mean yields of the pooled data, i.e., 2009, 2012, 2014, and 2019. The Figure is the authors' illustration based on FAO's crop yield data (FAO 2022).

It is also meaningful to look at crops separately, as some countries might only produce certain crops. For example, if a government wants to increase banana yield, focusing on access to land assets might be worth it. Meanwhile, access to financial services plays an important role in maize production.

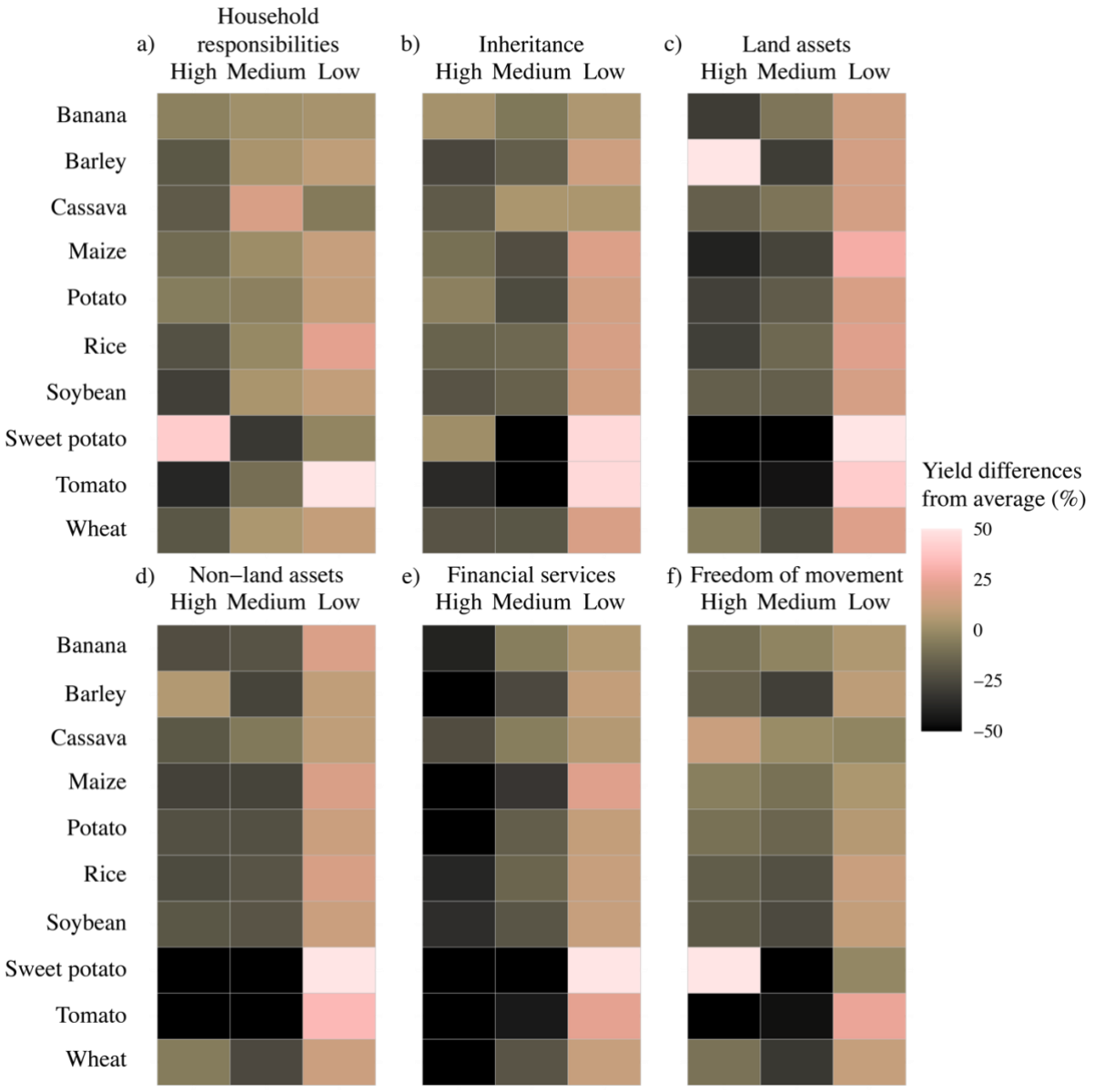

Figure 4. Associations of yield difference of global crops with gender-based discrimination in different dimensions and levels: household responsibilities (a), inheritance (b), secure access to land assets (c), secure access to non-land assets (d), secure access to formal financial services (e), and freedom of movement (f). The actual average yield values are in Table A1 in the Appendix.

Table 1. Associations between mean gender discrimination and global crop yields

	Banana	Barley	Cassava	Maize	Potato	Rice	Soybean	Sweet potato	Tomato	Wheat
GNI (log)	0.42	0.97***	-0.64	1.25***	3.76***	0.14	0.16***	-0.65	24.62***	0.74***
	(0.88)	(0.09)	(0.45)	(0.13)	(0.40)	(0.10)	(0.04)	(0.51)	(3.19)	(0.09)
Gender discrimination (average)	-18.53***	1.00**	-4.06	-1.35*	-5.31**	-1.93***	-0.40	-4.10	-25.14	1.08**
	(5.15)	(0.51)	(2.90)	(0.76)	(2.28)	(0.57)	(0.27)	(3.23)	(19.55)	(0.51)
Year is included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
World region is included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	363	353	299	551	538	417	345	350	544	428

Notes: Coefficient estimates of regression models are shown with standard errors in parentheses. ***, **, * are significant at 1%, 5%, and 10%, respectively.

Table 2. Associations between different dimensions of gender-based discrimination and global crop yields

	Banana	Barley	Cassava	Maize	Potato	Rice	Soybean	Sweet potato	Tomato	Wheat
GNI (log)	0.66	0.96***	-0.78*	1.21***	3.76***	0.13	0.16***	-0.80	26.09***	0.73***
	(0.90)	(0.09)	(0.45)	(0.13)	(0.41)	(0.10)	(0.04)	(0.51)	(3.29)	(0.09)
Household responsibilities	-6.46*	0.12	-1.37	-1.14**	-1.02	-0.81**	-0.55***	3.40*	-18.16	0.40
	(3.68)	(0.38)	(1.66)	(0.52)	(1.56)	(0.35)	(0.16)	(1.99)	(13.31)	(0.37)
Inheritance	1.80	-0.15	-2.57	0.90*	1.10	0.55*	-0.10	-0.94	-14.18	0.25
	(3.25)	(0.33)	(1.62)	(0.48)	(1.47)	(0.33)	(0.15)	(1.88)	(11.88)	(0.33)
Land assets	-1.20	0.52	-3.89**	-0.76	-1.82	-0.66	0.09	-3.47	3.33	-0.19
	(4.28)	(0.45)	(1.95)	(0.62)	(1.92)	(0.40)	(0.18)	(2.28)	(15.50)	(0.44)
Non-land assets	-6.44*	0.30	-0.97	0.53	-1.96	-0.13	0.16	-3.56*	-7.28	0.45
	(3.85)	(0.41)	(1.86)	(0.58)	(1.79)	(0.39)	(0.18)	(2.14)	(14.85)	(0.41)
Financial services	-0.75	-0.50	2.17	-1.73***	-0.79	0.04	-0.09	0.16	24.59*	0.03
	(3.72)	(0.42)	(1.74)	(0.56)	(1.71)	(0.36)	(0.16)	(2.04)	(14.40)	(0.39)
Freedom of movement	-5.29**	0.59*	2.87**	-0.01	-1.02	-0.95***	-0.10	1.76	-7.07	0.12
	(2.69)	(0.33)	(1.37)	(0.44)	(1.38)	(0.29)	(0.14)	(1.58)	(10.88)	(0.31)
Year is included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
World region is included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	363	353	299	551	538	417	345	350	544	428

Notes: Coefficient estimates of regression models are shown with standard errors in parentheses. ***, **, * are significant at 1%, 5%, and 10%, respectively.

5. Conclusion

Closing the yield gap has been proposed to satisfy the growing food demand because of increased consumption and human population without further crossing planetary boundaries. However, though efforts to increase yield have been made (e.g., through subsidy and technology use), the difference in yields of plots managed by women and men is still observed. This study tested the relationships between the yields of the ten most important food crops and six gender-based discrimination dimensions.

Our results show that yields are negatively associated with gender-based discrimination. The relationships are mainly significant with discrimination against women regarding household responsibilities and freedom of movement. The results indicate that the disproportionate workload between women and men in the family affects women's work on the farm, thus lowering yields. This is also observed when women's mobility is restricted, affecting movement related to agricultural production (e.g., going to the farm to take care of crops). Therefore, paying attention to those variables might be important to increase yield.

We should mention the limitation of our study. Trying to conduct a global study, we could not rule out endogeneity entirely as we could not control all variables that might affect yields due to data availability. In addition, heterogeneities in the local settings might also be overlooked in this study. Therefore, our results should be interpreted carefully, and case studies to confirm our results are highly encouraged.

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Appendix

Table A1. Average global crop yields in different level of gender-based discrimination

	Household responsibilities									Inheritance									Access to land assets								
	High			Medium			Low			High			Medium			Low			High			Medium			Low		
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N
Banana	20.72	1.51	135	21.86	1.47	137	22.24	1.63	97	22.07	2.25	78	19.95	1.35	133	22.62	1.34	158	15.14	2.11	31	19.80	1.17	178	24.72	1.48	160
Barley	2.39	0.21	84	3.08	0.15	141	3.25	0.16	132	2.21	0.22	61	2.46	0.18	86	3.39	0.13	213	4.86	0.66	9	2.09	0.12	137	3.45	0.13	214
Cassava	9.46	0.58	98	13.65	0.75	128	10.81	0.64	79	9.47	0.79	55	12.04	0.67	120	12.02	0.66	130	9.66	0.74	35	10.59	0.52	153	13.42	0.77	117
Maize	3.81	0.37	161	4.38	0.24	238	4.88	0.25	163	3.91	0.44	111	3.36	0.25	180	5.20	0.22	274	2.64	0.55	41	3.19	0.19	245	5.64	0.25	279
Potato	18.40	0.79	144	18.71	0.65	226	21.58	0.89	174	18.68	1.00	102	14.84	0.60	163	22.50	0.65	282	14.01	1.85	30	16.03	0.57	236	23.01	0.63	281
Rice	2.98	0.19	119	3.77	0.15	181	4.67	0.17	123	3.24	0.22	82	3.31	0.15	153	4.47	0.15	191	2.71	0.27	40	3.32	0.13	203	4.61	0.16	183
Soybean	1.19	0.09	64	1.73	0.07	154	1.84	0.07	129	1.32	0.12	44	1.41	0.06	120	1.92	0.06	186	1.39	0.15	21	1.39	0.06	155	1.95	0.07	174
Sweet potato	11.38	0.90	111	10.18	0.82	149	10.66	0.78	95	10.72	1.02	75	9.83	0.70	132	11.47	0.84	151	7.70	1.12	39	9.69	0.58	168	12.62	0.89	151
Tomato	33.64	2.51	150	48.31	5.56	239	82.80	9.29	162	34.24	3.19	102	23.23	1.66	164	78.91	6.79	288	20.26	5.73	35	29.79	2.91	220	76.14	6.35	299
Wheat	2.51	0.15	112	3.26	0.15	176	3.46	0.18	148	2.47	0.18	91	2.50	0.14	116	3.70	0.14	232	2.95	0.55	22	2.37	0.11	186	3.75	0.14	231

	Access to non-land assets									Access to financial services									Freedom of movement								
	High			Medium			Low			High			Medium			Low			High			Medium			Low		
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N
Banana	16.59	2.51	30	17.03	1.15	145	25.68	1.34	194	13.10	3.74	13	20.43	1.30	140	22.78	1.23	216	19.04	2.43	68	20.9	1.7	91	22.7	1.1	211
Barley	3.15	0.64	14	2.17	0.16	95	3.26	0.12	251	1.02	0.21	5	2.23	0.16	96	3.28	0.12	259	2.52	0.32	38	2.12	0.2	61	3.23	0.1	261
Cassava	9.31	0.99	27	10.74	0.60	126	12.65	0.63	152	8.85	1.36	18	10.95	0.63	119	12.30	0.58	168	13.00	1.45	46	11.5	0.8	75	11.2	0.5	185
Maize	3.15	0.66	37	3.19	0.22	193	5.17	0.22	335	1.52	0.14	20	2.97	0.20	190	5.26	0.22	355	4.14	0.48	83	3.93	0.4	119	4.54	0.2	364
Potato	15.21	1.93	31	15.22	0.65	170	21.99	0.56	346	8.44	1.83	15	16.21	0.68	173	21.55	0.55	359	17.55	1.08	72	16.7	0.8	116	20.8	0.6	359
Rice	2.89	0.41	30	3.02	0.13	163	4.49	0.13	233	2.37	0.28	20	3.27	0.14	157	4.28	0.14	249	3.15	0.24	60	2.97	0.1	100	4.29	0.1	266
Soybean	1.34	0.19	19	1.33	0.06	116	1.88	0.06	215	1.08	0.17	13	1.33	0.06	110	1.87	0.06	227	1.35	0.14	35	1.26	0.1	74	1.84	0.1	241
Sweet potato	9.15	1.54	34	8.86	0.60	141	12.42	0.77	183	7.19	1.59	20	9.08	0.69	128	12.03	0.69	210	12.58	1.98	55	9.58	0.7	86	10.7	0.6	218
Tomato	23.63	6.05	33	23.87	1.72	174	72.32	5.72	347	9.87	2.67	17	30.92	3.85	165	66.56	5.23	372	27.16	3.20	82	29.1	2.9	111	68	5.5	362
Wheat	2.94	0.51	24	2.34	0.12	138	3.53	0.13	277	1.48	0.17	14	2.48	0.15	132	3.49	0.12	293	2.84	0.23	54	2.14	0.2	91	3.48	0.1	294

SE = standard error; N = number of observations