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Women's Empowerment and Crop Diversification in Bangladesh

A Possible Pathway to Climate Change Adaptation and Better Nutrition

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Notices

ABSTRACT

The existing literature shows that climate change will likely affect several of the dimensions that determine people's food security status in Bangladesh, from crop production to the availability of food products and their accessibility. Crop diversification represents a farm-level response that reduces exposure to climate-related risks and it has also been shown to increase diet diversity and contribute to the reduction in micronutrient deficiencies. In fact, the Government of Bangladesh has several policies in place that encourage and support agricultural diversification. However, despite this support the level of crop diversification in the country remains low. Women empowerment has been linked to diversified diets and positively associated with better child nutrition outcomes. Furthermore, although traditionally their role in agriculture tends to be undervalued, women involvement has already been shown to affect agricultural production choices and enhance technical efficiency.

This paper connects three different areas of inquiry - climate change, gender and nutrition – by exploring whether women's empowerment in agricultural production leads to increased diversification in the use of farmland. Specifically, we use a series of econometric techniques to evaluate whether there is sufficient evidence to claim that a higher levels of empowerment lead to greater diversity in the allocation of farmland to agricultural crops. Our results reveal that indeed some aspects of women empowerment, but not all, lead to a more diversified use of farmland and to a transition for cereal production to other uses like vegetables and fruits. These findings provide some possible pathways for gender-sensitive interventions that promote crop diversity as a risk management tool and as a way to improve the availability of nutritious crops.

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Introduction

Rates of malnutrition in Bangladesh are among the highest in the world. As of 2014, a quarter of the population, 40 million people, remain food insecure and 11 million suffer from acute hunger (Osmani et al. 2016). Remarkably high levels of stunting are observed in children under the age of five, thirty-six percent of them suffer from chronic malnutrition and 14% are acutely malnourished (USAID 2018). Large gaps in prevalence are present across wealth quintiles and by urban (31%) and rural (38%) residence (National Institute of Population Research and Training, Mitra and Associates, and ICF International. 2016). Moreover, severe micronutrient deficiencies exist in children and women of reproductive age. About 84% of the country's 14.9 million farm households are smallholders who operate less than 1 ha of farmland and rice is the country's dominant crop (72% of cultivated land and 55% of agricultural value added) and a key staple of the population's diet (38 percent of daily food intake) (BBS 2018). More than half of the population (54%) has no source of income, while 16% is involved in the livestock and poultry sector and only some 5% is associated with non-agricultural work (IFPRI 2016).

It is in this challenging context that climate change will take place with potentially significant adverse effects for the agriculture sector. The existing literature indicates that climate change will affect people's food security and livelihoods by reducing farm production and deteriorating the general conditions in which smallholder farmers operate and by reducing the availability of food products. In particular, climate change is expected to adversely reduce rice production in all three growing seasons and have significant negative impacts on fisheries due to the increased intensity and frequency of extreme events, such as coastal cyclones and flooding (Ruane et al. 2013). In addition to the direct effects on crop productivity, new research finds that climate change will also affect the nutritional value of food products (Fanzo et al. 2017) and that some grains and legumes have lower concentrations of zinc and iron when grown under elevated CO_2 concentrations (Myers et al, 2014). Bangladesh's geographical exposure and the sensitivity of its farmers to the vagaries of the weather make Bangladesh one of the most vulnerable countries to the impacts of climate change.

A relatively rich literature is now available on the various strategies farmers can use to cope with climate change. For example, Kabir et al. (2017) found that farmers in the drought-prone areas of Western Bangladesh are changing cropping systems, cropping calendars, crop varieties, agronomic practices and adopt improved animal husbandry in response to raising temperatures and declining rainfall. Among the changes in strategies, crop diversification is a farm-level response that has potential to optimize the use of land and agricultural inputs, reduce exposure to climate-related risks, cope with the changing climate, and enhance resilience in farming systems (Bradshaw et al 2004; Huang et al. 2014; Mijatović et al 2013; Smit & Skinner, 2002). Diversification not only stabilizes, and at times increases, total farm output but it also generates employment opportunities and can contribute to increases in incomes of smallholder farmers (FAO 2012, Islam et al. 2018, Osmani et al. 2016). Beside risk reduction, potential income gains, and a less volatile stream of benefits, diversified systems can improve diet diversity, and address micronutrient deficiencies and malnutrition (Frison et al., 2006; Negin et al., 2009; Fanzo et al., 2013).

Admittedly, people's nutritional status does not depend solely on their own production and the efficient production of staple food items or cash crops can improve households' incomes with the ultimate effect of diversifying and stabilizing consumption (Ruel, 2003; FAO, 2012; Darrouzet-Nardi and Masters 2015; Passarelli et al. 2018). It is also possible that in some contexts excessive diversification leads to inefficiencies and to losses in dietary diversity due to foregone income (Sibhatu et al. 2015). However, evidence also suggests that in some rural conditions, the diversity of diets consumed by infants and young children is directly related to diversity in agricultural production in semi-subsistence households (Kumar et al 2015) and that more diverse production systems can contribute to dietary diversity and better nutrition outcomes (Jones et al. 2014, Sibhatu et al. 2014, Islam et al. 2018). In contexts such as Bangladesh, where monocropping and subsistence production are common, the potential for improved diets and nutritional status through production diversification is high (Heady and Hoddinott 2015). Over the years, there has been a significant increase in farm diversity in Bangladesh (Islam et al. 2018) as crop diversification is considered to be an important lever for improving nutrition and for increasing the availability of micronutrients. Several policy documents prepared by the Government of Bangladesh (e.g. the 7th 5-Year Plan, the Country Investment Plan for Nutrition-Sensitive Food Systems 2016-2020, the National Agricultural Policy, and the National Nutrition Policy), emphasize the need to diversify agricultural production and the government of Bangladesh has enacted initiatives such as the Crop Diversification Programme to encourage and support agricultural diversification (Government of Bangladesh 2015a, 2015b, 2015c, 2018).

An area of inquiry that still deserves exploration is related to the factors that encourage greater production diversification. In particular, women's influence on crop diversification and better diets deserves attention given women's role in sourcing and preparing foods and their increasing role in agricultural activities and decisions. Women in Bangladesh are not traditionally recognized as farmers and their growing role in agricultural production, particularly among poor households, tends to be undervalued (Sraboni et al. 2014). Women's empowerment has already been associated with greater efficiency in agricultural production (Seymour 2017) but the ways in which women's empowerment influences agricultural and spending choices, diet quality and nutrition outcomes vary with context-specific factors such as women's roles, decision-making authority, control over income, and preferences (Meinzen-Dick et al. 2012; Ruel and Alderman 2013; and Ruel, Quisumbing and Balagamwala 2018). Some evidence suggests that men's and women's preferences and perceptions influence land use decisions and investment choices across the landscape and that these choices have implications for diet and nutrition outcomes (Villamor et al. 2015). More generally, a growing body of evidence demonstrates positive linkages between women's empowerment and improved diets and nutrition outcomes (Cunningham et al. 2015; Ruel, Quisumbing, and Balagamwala 2018, Malapit and Quisumbing 2015, Sraboni et al. 2014, Sraboni and Quisumbing 2018) and higher levels of calorie availability and increased dietary diversity at the household-level (Sraboni et al. 2014, Seymour et al. 2019) and individual-level (Sraboni and Quisumbing 2018). Women's empowerment can influence diet quality and nutrition through women's increased participation in both production and spending decisions. In addition, women's labor burden and time allocation also influence their own nutrition requirements and time available for child feeding and care (Komatsu, Malapit, and Theis 2018).

This paper purposely brings three different areas of inquiry together - climate change, gender and nutrition – by exploring whether women's empowerment in agricultural production leads to increased diversification in the use of farmland. We acknowledge that crop diversification is only one of several alternative strategies for reducing risk exposure to climate change and we recognize that crop diversification is only an intermediate step towards improved nutrition outcomes—the ultimate nutrition benefits being dependent on how diversification affects consumption patterns, income, food prices, labor allocation and many other factors. However, given the role that diversification plays in several of the country policies we believe it is topic worthy of investigation. While diversification plans in Bangladesh include expanding the area allocated to wheat and maize, we are particularly interested in other crops other than cereals because they are physiologically more diverse and therefore provide additional protection towards climate change risks and because of their importance for nutrition and diets. In this paper we evaluate whether there is sufficient evidence to claim that a higher level of empowerment leads to greater diversity in the allocation of farmland to agricultural crops. Our results, based on the use of alternative econometric techniques, reveal that overall women's empowerment leads to a more diversified use of farmland. A disaggregated analysis further shows that different aspects of women's empowerment have different effects on land use allocation decisions with only some aspects influencing greater diversification of production. These findings provide some possible pathways for gender-sensitive interventions that promote crop diversity as a risk management tool and as a way to improve the availability of nutritious crops.

Climate outlook for Bangladesh

Records show that from 1948 to 2011 yearly mean temperatures have already risen by 0.64°C. Temperatures in the pre-monsoon and monsoon seasons rose by 6 and 11 percent, respectively (Ahasan, Chowdhary and Quadir, 2010; Bari et al 2016) and projections based on several global circulation models indicate this trend is expected to continue affecting several of the dimensions of food security. Mean temperatures are projected to increase about 1.4°C by 2050 and 2.4°C by 2100 from the 1960 baseline (USAID 2012). Changes in the mean daily maximum temperature of the warmest month—one of the standard indicators of potential heat stress for agriculture—are projected to range from 1.9 to 4.7°C nationally (Figure 1). Mean annual rainfall changes are projected to range from 164 to 352mm for Bangladesh (De pinto et al. 2017).

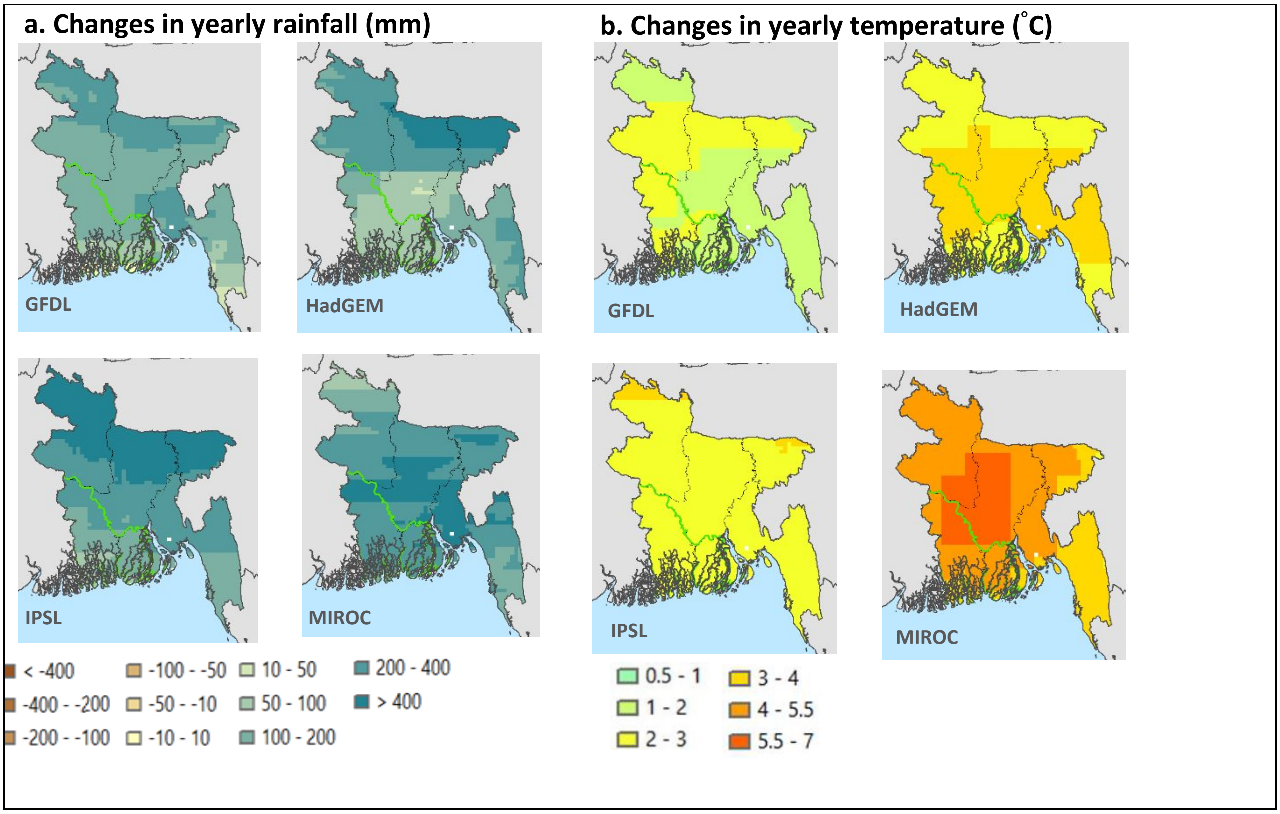

Figure 1. Predicted change in rainfall and temperature based on four climate models, 2000–2050

Source: De Pinto et al. 2017
Note: GFDL = Geophysical Fluid Dynamics Laboratory; HadGEM = Hadley Centre Global Environmental Model; IPSL = L'Institut Pierre-Simon Laplace; MIROC = Model for Interdisciplinary Research on Climate. Simulations are based on Representative Concentration Pathway 8.5. The zone of influence is delineated by the green lines.

Changes in growing conditions are expected to have significant effects of crop production. Figure 2 shows the effects on yields for all major crops given the projection of four different climate models. Results show unequivocally negative effects on sugarcane and groundnut yields. Yields are projected to fall by 40 and 30 percent, respectively. Average yields of rice, wheat, and maize are also projected to fall, but comparatively less than those of sugarcane and groundnuts. There is also some uncertainty regarding these projections. Given the temperature and precipitation changes projected by the GFDL model, yields are expected to increase. All other models indicate a decrease in yields with particularly large negative effects on maize and irrigated wheat.

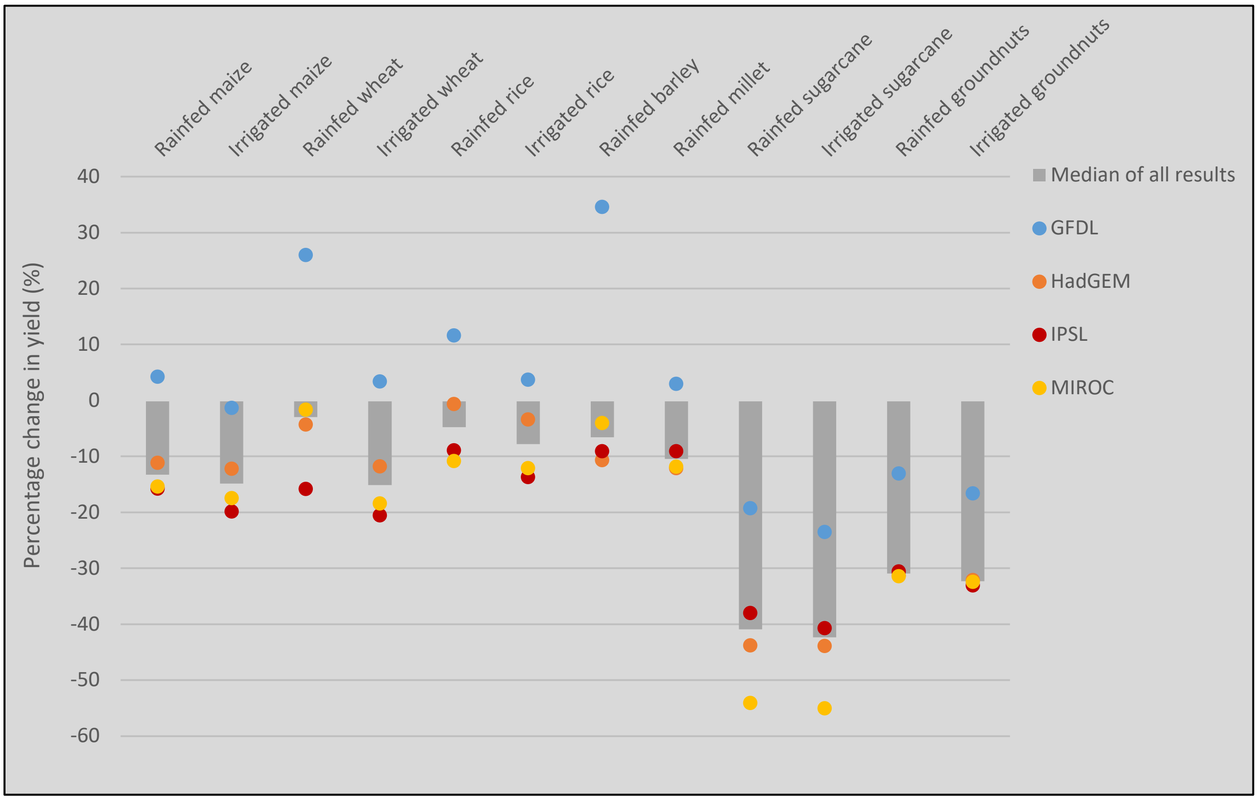

Figure 2. Percentage change in yields due to climate change based on four climate models, 2000–2050

Source: De Pinto et al. 2017
Notes: GFDL = Geophysical Fluid Dynamics Laboratory; HadGEM = Hadley Centre Global Environmental Model; IPSL = L'Institut Pierre-Simon Laplace; and MIROC = Model for Interdisciplinary Research on Climate.

In addition to these important negative effects on yields, it should be noted that by being located in a predominantly low-lying region at the intersections of the Ganga, Meghna, and Brahmaputra rivers and the Ganga-Brahmaputra delta, Bangladesh is one of the most vulnerable countries to flooding due to a combination of storm surge, sea level rise, and higher precipitation (Karim and Mimura 2008). Flooding is not the only threat to agricultural production; salinization from intruding sea water in coastal areas also limits crop yields and reduces agricultural land availability (Rabbani, Rahman and Mainuddin 2013).

Crop Diversification in Bangladesh

Crop diversification is an important component of agricultural policies in Bangladesh (Islam et al. 2018) since it is considered to be an indirect lever for improving nutrition. In fact, the first pillar of the second Country Investment Plan, which is the one with the highest budget allocation, prioritizes "diversified and sustainable agriculture, fisheries, and livestock for healthy diets" (Government of Bangladesh 2015b). These policies have multiple objectives and target multiple crops: expand wheat and maize acreage, increase area and production of other crops, such as potato, pulses, oil seeds, vegetables, fruits and spices, and expand production of cash crops such as jute and cotton.

Crop diversification refers to those ecologically-diversified production systems that depart from monocropping and single cereal-based farming systems and in combination with agricultural practices such as rotations, intercropping, and agroforestry, it has the potential to increase productivity at the farm level and improve farmers' livelihoods and resilience in smallholder agricultural systems. In several contexts, diversified cropping systems have been found to be more robust and better suited to cope with future climate risks (Werners et al. 2007, Smit & Skinner, 2002) and capable of stabilizing and increasing income from production under climatic shocks (Makate et al 2016). The literature documents several different contexts, including China and Malawi, where crop diversification is being adopted as a strategy to reduce the risks posed by extreme weather events (Huang et al. 2014, Ignaciuk et al. 2017).

Crop diversification in Bangladesh has been the subject of numerous studies. Metzel and Ateng (1993) find that that high input cost, high volatility in the opportunities to sell crops other than rice, and susceptibility to pests, all stand in the way of greater diversification. Similarly, Mahmud et al., (1994) find that high risks in market prices discourage diversification but they also find that the current irrigation systems, geared to rice production, pose a constraint. Rahman (2004) shows that education, experience, farm asset ownership, and non-income ownership affect the propensity of a farmer to diversify production and Barghouti et al. (2004) frame diversification as a form of sustainable agricultural development and find that it can favor rural development. Rahman (2008) investigates the productivity merits of diversified production and determine that crop diversification should be pursued as a strategy to grow the agricultural sector but that it needs infrastructure development to become viable. Akanda (2010) shows how in the future crop diversification can lead to changing diets patterns and reduce the pressure for ground water extraction. Islam and Ullah (2012) consider crop diversification as a tool to promote economic growth by increasing both agricultural and industrial production.

Climate change has renewed the interest in the benefits of diversification. Anik and Khan (2012) report that diversification has the potential to be widely accepted as a climate change adaptation measure. Alauddin and Sarker (2014) show that divesting land from rice production is one of the preferred farm-level adaptation strategies to alleviate adverse effects of climate change. Kabir et al (2017) find that economically, a maize-based production system that includes vegetables in rotations (i.e. maize-cucumber) is the least risky strategy among cereal-based systems.

While the evidence shows the many benefits of crop diversification in Bangladesh and despite the policy support from the government, the level of crop diversification in the country remains low although it has increased somewhat between 1970 and 2010 (Islam and Rahman, 2012). This suggests that, if diversification remains an objective for Bangladesh, further investigation into the mechanisms that favor it is warranted.

Gender and Agriculture in Bangladesh

Gender relations in Bangladesh remain staunchly patriarchal, whereby male household heads have authority over women family members, and women lack access to material resources and remain dependent on men for their basic needs (Kabeer 2011). However, rising economic opportunities outside the home and expanding social networks through community groups appear to be pathways for greater women's empowerment in recent years, leading to increased women's participation in household decisions (Kabeer 2017). In particular, women are migrating to work in new industries, such as garment factories (Heath and Mobarak, 2015; Mottaleb and Sonobe, 2011), and are engaging more in agricultural wage labor (Jaim and Hossain, 2011; Rahman, 2010).

Nonetheless, women still face many challenges. The religious practice of female seclusion (*purdah*), which requires women to be accompanied by men and/or covered when working outside the home or in public spheres, is still common in many parts of the country, though adherence to such norms can vary over space and time, as well as by caste, class, family, education, and age (Ahmed and Sen 2018; White 1992). Such norms act to largely limit women's economic and agricultural activities to those tasks that can be carried out within the homestead, most often subsistence farming or post-harvest processing, for which they receive no remuneration. Heintz et al. (2018) estimate that roughly 47 percent of women's total labor participation in Bangladesh is in home-based economic activities. Despite the existence of laws granting women the right to own and inherit land, traditional norms of patrilineal inheritance—the transmission of property through the male line—often persist in practice, resulting in women being largely excluded from landownership (Kieran et al., 2015). Women's access to and control over income, assets, credits, inputs and extension services is also severely limited (ADB

2013, FAO 2011, Quisumbing et al., 2013).

Despite these many challenges, women play an increasingly important role in agriculture in Bangladesh. 60 percent of women are employed in agriculture (World Bank, 2018), and women account for 45 percent of the agricultural labor force (BBS 2018). As noted above, much of this work can be attributed to unpaid, home-based work, such as unpaid agricultural labor on family farms and homestead gardening. Homestead gardening, in which families devote a portion of their homestead land to the cultivation of fruits and vegetables primarily for home consumption, is ubiquitous in Bangladesh (Ali 2005). Homestead gardening offers myriad benefits including, diversified sources of income and nutrient-dense foods (Mitchell and Hanstad 2004; Bushamka 2005; Ianotti et al. 2009; Patalagsa et al. 2015) and greater decision-making authority and control over income by women (Akhter et al. 2010; Patalagsa et al. 2015).

In general, research from Bangladesh suggests that increasing women's empowerment, and reducing the empowerment gap between men and women in the same households can lead to important development outcomes including greater technical efficiency in agricultural production (Seymour 2017), improved food security and nutrition, including higher levels of calorie availability and increased dietary diversity at both the household and individual levels (Sraboni et al. 2014; Sraboni and Quisumbing 2018) and, in Nepal, to be an important means of mitigating the effects of low production diversity on nutrition outcomes (Malapit et 2015). While Sraboni and Quisumbing (2018) find that women's empowerment is associated with improved dietary diversity and nutrient intakes of adults (men and women) in the household, they find only weak links between women's empowerment and diet quality of small children. Similarly, Malapit et al. (2019) find weak links between women's empowerment and child nutrition and education outcomes and demonstrate that different domains of women's empowerment influence these outcomes differently, suggesting that some pathways of empowerment may have a stronger effect on these outcomes than others. Gaps in women's empowerment in Bangladesh can be largely attributed to women's lack of community leadership and control over resources (Sraboni et al. 2014), which suggests that women's empowerment in this context is likely to be achieved through these pathways. Apart from measures of women's agency, several studies point towards the importance of women's education as a driver of improved nutrition outcomes for young children in Bangladesh (Malapit et al. 2019; Sraboni and Quisumbing 2018).

The literature reviewed here suggests there is considerable complexity in the linkages between women's empowerment and nutrition outcomes. Not only are there multiple pathways to achieving diet and nutrition improvements but different aspects of empowerment appear to influence these pathways differently. This paper examines the link between women's empowerment and production diversity as an intermediate step towards greater dietary diversity and nutrition outcomes. Several different measures of empowerment are used, including an index comprised of different domains of women's empowerment, the gap between the empowerment scores of men and women from the same household, and proxy measures for women's participation in agricultural decision-making, control over assets, and group membership.

A model of farmland allocation

We consider an agricultural production system in which different uses compete for shares of a fixed area of land. A household is assumed to face a one-period consumption budget B in which:

$$B = W + \Pi[\boldsymbol{R}, \boldsymbol{C}(\boldsymbol{u}, \boldsymbol{q}, \boldsymbol{z}, \boldsymbol{h})] * A \qquad \text{eq. 1}$$

where W indicates household wealth[1], Π is the per-hectare net revenues function of a vector of land use-specific revenues ($\boldsymbol{R}$) and of cost of using inputs $\boldsymbol{C}$ which is a function of variable inputs such as labor and fertilizers ($\boldsymbol{u}$) and of quasi-fixed inputs ($\boldsymbol{q}$) such as quantity of available farm tools and machinery, a vector of exogenous climate variables ($\boldsymbol{z}$), and household characteristics ($\boldsymbol{h}$) that can function as binding constraints on field activities such as the number of household members and the education level of the head of household. Use-specific net revenues are computed as $\Pi_j = a_j(p_j y_j - c_j)$ where a_j is the area allocated to $j = 1, \ldots\ldots, J$ uses[2]. It must be noted that $\sum_{j=1}^{J} a_j = A$

The household, who is assumed to be a price-taker, maximizes expected utility derived from farming available land holdings by allocating a_j to each available use j:

$$\max_{a_j}\{EU[\Pi|W, A]\} \qquad \text{eq. 2}$$

where U is a utility function describing the impacts on the decision maker's utility of the level of profits, conditioned on wealth, including land endowments.

Thus, there is an optimal area allocation $a_j^* = F[\Pi, W, A]$ to each use that solves the farmer's utility

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1 Although landholdings contribute to the general wealth of a household, in our modeling setting their contribution to the consumption budget is limited to the stream of benefits generated by their use in productive agricultural activities.

2 Each household faces a location-specific set of prices, yields and costs. Location and household will be later identified with subscripts l and n, respectively. We omit these subscripts for now for readability.

maximization problem. We assume that $a_j^* = F[\Pi, W, A]$ can be expressed as $a_j^* = A * f[\Pi, W, A]$. Accordingly, for each use j there is an optimal share allocation function:

$$s_j^* = \frac{a_j^*}{A} = f[\Pi, W, A]\ ^3 \qquad \text{eq. 3}$$

Farm-level allocation shares, which are observed in the household survey, are a function of profits, household wealth and farm area. The probability that a farmer chooses to grow a particular use j is given by $P_j = Pr(U_j > U_i \forall\, j \neq i)$ and the expected area allocated to that crop is given by $A * P_j$. Therefore, the expected share s of farmland allocated to use j is $s_j = \frac{1}{A}\left[A * Pr(U_j > U_i \forall\, j \neq i)\right]$. This means that the share allocated to a use j is equal to its probability P_j to be chosen by a farmer. Acknowledging that $U = V + \boldsymbol{\xi}$ where V represents a knowable-by-all component of the utility function while $\boldsymbol{\xi}$ is known to the farmer but unobserved by the researcher and assuming that $\boldsymbol{\xi}$ has an *iid* Type 1 EV distribution, then the probability of observing s_j is given by a multinomial logit formula:

$$s_j = \frac{exp\{\boldsymbol{E}[\boldsymbol{V_j}]\}}{\sum_{i=1}^{J} exp\{\boldsymbol{E}[\boldsymbol{V_i}]\}} \qquad \text{eq. 4}$$

and, given our modeling settings, the optimal share allocation function can be written as:

$$s_j^* = \frac{exp[s(\Pi_j, W, A)]}{\sum_{i=1}^{J} exp[s(\Pi_i, W, A)]} \qquad \text{eq. 5}$$

Data

The data used for our analysis comes from the Bangladesh Integrated Household Survey (BIHS), collected in 2015 under supervision by the International Food Policy Research Institute (IFPRI, 2016). The BIHS is a multipurpose household survey covering a breadth of topics, ranging from women's empowerment to agricultural production. Covering the 2015 crop year, the survey provides information on land allocations among crops and crop-specific revenues, but only limited information is available about costs of production. It is statistically representative of rural Bangladesh. It covers 6,500 households and is statistically representative of rural Bangladesh. The BIHS provides information on crop-specific land allocations and revenues for each of the three growing seasons: *Kharif 1* (mid-March to mid-July), *Kharif 2* (mid-July to mid-November), and *Rabi* (mid-November to mid-March). A significant number of farmers does not report any planted area in the survey and other key information for the

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[3] Note that since $\sum_{j=1}^{J} a_j = A$ it follows that $\sum_{j=1}^{J} s_j = 1$.

regression is at time missing (e.g. information on women empowerment or on crop area, prices and production costs). Once the observations with the missing information is rejected, the sample size used for the empirical analysis is 3,373.

Land allocations

Land allocations are based on the primary crop reported in the survey for each plot. Table 1 shows land allocation proportions by large crop categories, as well as to land used for non-agricultural purposes. Given that it is common practice in Bangladesh for crops to be grown year-round, we aggregate across the three growing seasons. Thus, the denominator for the land allocations in Table 1 is the total land owned or operated by a farmer during the 2015 agricultural year. The survey indicates that most (66 percent) of land is allocated to cereals. Vegetables occupy 9 percent of land, other crops 8 percent, and fruits less than 1 percent. For reference, we also categorize land based on who makes the decision about what to plant on the plot. Specifically, we calculate the proportion of land devoted to each type of crop for which a woman is listed as one of the three main decision-makers. For the majority of land across all four categories, decisions about what to plant are made exclusively by men—women decision makers are reported for only between 9 and 12 percent of land, depending on the crop category.

Table 1. Land allocation by crop category

	Cereals	Vegetables	Fruits	Other crops	Non-agricultural use
Proportion of total area owned or operated by farmer	0.66	0.09	0.005	.08	.165
Proportion of land with female decision-maker[A]	0.09	0.12	0.11	0.09	-

Notes: [A] Based on the question, "Generally, who takes decision regarding type of crop to be planted?", with response structure allowing for reporting of up to 3 household members.
Source: 2015 BIHS, Authors' calculations

According to the survey, crops are not grown on 17 percent of total land area in use. There are several reasons to treat this figure as an overestimate of the actual percentage of land used for non-agricultural purposes. First, the BIHS excludes questions on homestead gardening in the agricultural production module. As a result, any homestead land devoted to growing fruits and vegetables will be wrongly categorized by the survey to land used for non-agricultural purposes. This accounts for nearly a fourth (24 percent) of land categorized as non-agricultural (Table 2). Second, the BIHS does not collect information about the crops grown on pieces of land rented or leased out to other farmers. Rented or leased out land accounts for 68 percent of cultivable land not used for non-agricultural purposes. The remainder of non-agricultural land can largely be attributed to land currently kept fallow (37 percent of total non-agricultural area) or non-arable, derelict, or commercial/residential land.

Table 2. Breakdown of land used for non-agricultural purposes

Type of land	Total area (hectare)	Fallow area (hectare)	Rented/leased out area (hectare)	Share of total area operated	Share not in use	Share rented/ leased out
Homestead	271.83	270.52	0.43	0.24	1.00	0.00
Cultivable/arable land	573.87	33.69	387.58	0.50	0.06	0.68
Pasture	2.14	1.83	0.20	0.00	0.86	0.09
Bush/forest	36.44	34.03	0.68	0.03	0.93	0.02
Waste/non-arable land	23.04	20.83	1.43	0.02	0.90	0.06
Land in riverbed	22.85	22.50	0.31	0.02	0.98	0.01
Other residential/commercial	4.07	1.81	0.06	0.00	0.45	0.01
Cultivable pond	154.13	4.26	1.70	0.13	0.03	0.01
Derelict pond	15.49	12.58	0.36	0.01	0.81	0.02
Garden (wood/fruit)	22.60	14.36	0.49	0.02	0.64	0.02
Floating pond	0.06	0.00	0.00	0.00	0.00	0.00
Only for seed bed	20.01	1.76	0.23	0.02	0.09	0.01

Source: 2015 BIHS, Authors' calculations

For our modeling purposes, all other crops (i.e. crops that are not part of the cereals, vegetables or fruits categories) are grouped together with all other uses in single category. This categorization is based on the decision to use a discrete choice model to investigate the determinants of land allocations. This class of models relies in part on the stream of monetary benefits that derive from the different land allocations but the dataset does not provide sufficient information on the possible gains accruing from other uses besides crop production. By joining other crops with other uses we assume that the benefits generated by other crops are a sufficient proxy for those generated by all other land utilizations.

Revenues and production costs

The 2015 BIHS reports crop yields and for the most, crop specific revenues but unfortunately production costs are not sufficiently disaggregated to be reliably be attributed to each crop. Therefore, to control for the effects of production costs on land allocation choices, we use the cost off-farm labor for one day's work and the unit cost of fertilizers reported in the survey. To control for the implicit management cost of allocation choices and binding constraints on potential allocations deriving from limiting quantities of quasi-fixed inputs, we included the number of household members and the reported value of agricultural assets which is the value of farming tools and machineries present on the farm. Other factors can constrain households' crop allocation choices by limiting the time in which field activities can be carried out (e.g. field operations like sowing, harvesting, processing). Ideally, we would control for them by including the both the value of the max temperatures and of precipitations in the set of explanatory variables given that these two variables affect the timing and the cost of field operations. Unfortunately, there is very little variation in the precipitation variable to make a meaningful difference in the econometric estimation and therefore only maximum temperatures were used.

Household wealth endowment and size of landholdings

According to our land allocation model which follows basic utility theory and is supported by the literature (Chavas and Holt 1990, Saha 1993, Chavas and Holt 1996), wealth endowment affects farmers' decision making. As proxies for household wealth we use two variables, the number of livestock owned and the declared off-farm revenues. The size of the land farmed by each household is also included as not only is an indicator of wealth but it can also affect risk-coping strategies.

The Women's Empowerment in Agriculture Index

The Women's Empowerment in Agriculture Index (WEAI) is a survey-based index that uses individual-level data collected from the primary male and female decision-makers within the same households to measure respondents' empowerment across five domains (production decision-making, control over resources, control over income, leadership, and time allocation) within the agriculture sector (Alkire et al., 2013). In this study, we measure women's empowerment in terms of four variables derived from the WEAI. The first is the empowerment score, which measures a woman's achievement of empowerment based on ten weighted indicators across the 5 domains (see Table 3 for detailed descriptions and weights). Each indicator takes a value of one if a woman achieves adequacy according to cut-offs defined by Alkire et al. (2013) or zero otherwise. The empowerment score is calculated for each woman by taking the weighted sum of the ten indicators.

We also measure women's empowerment in terms of two indicators derived directly from sub-components of the WEAI (ownership of assets and input in productive decisions, respectively) which we expect might affect decisions about farm diversity. The first is the number of assets (including agricultural land, large and small livestock, fish ponds/fishing equipment, mechanized farm equipment, and housing) for which the woman reports having sole or joint ownership, and the second is the proportion of household activities (from the list of possible activities asked about in the survey including: food crop farming, cash crop farming, livestock raising, non-farm economic activities, wage and salary employment, and fishing or fish culture) for which the woman reports having input into most or all of the decisions. Greater asset ownership or involvement in decision-making by women may reflect greater bargaining power in household decisions about farm diversity.

Table 3. Descriptions of the Indicators in the Women's Empowerment in Agriculture Index

Domain	Indicator	Description	Weight
Production	Input in productive decisions	Sole or joint decisionmaking over food and cash-crop farming, livestock, and fisheries	1/10
	Autonomy in production	Decisions about agricultural production reflect his or her own beliefs and values, rather than external pressures (e.g., punishment or social disapproval)	1/10
Resources	Ownership of assets	Sole or joint ownership of land and assets (e.g., large and small livestock, fish ponds, farm equipment, house, household durables, cell phone, non-agricultural land, and means of transportation)	1/15
	Purchase, sale, or transfer of assets	Sole or joint decisionmaking over the purchase, sale, or transfer of land and assets	1/15
	Access to and decisions on credit	Access to and participation in decisionmaking over credit	1/15
Income	Control over use of income	Sole or joint control over income and expenditures	1/5
Leadership	Group membership	Respondent is an active member in at least one economic or social group (e.g., agricultural marketing, credit, water users' groups)	1/10
	Speaking in public	Respondent is comfortable speaking in public concerning various issues such as intervening in a family dispute, ensuring proper payment of wages for public work programs, etc.	1/10
Time	Workload	Time poverty (i.e., excessive workloads) with respect to productive and domestic tasks	1/10
	Leisure	Satisfaction with available time for leisure activities	1/10

Source: Alkire et al. (2013)

Table 4 provides an overview of the explanatory variables used in the models and their descriptive statistics.

Table 4. Variable Sample Means and Ranges

Variable	Mean	Std. Deviation	Notes
Gross annual revenue cereals (*taka/decimal*)	67.20	101.20	1 taka is approximately US$0.012
Gross annual revenue vegetables (*taka/decimal*)	250.41	454.31	
Gross annual revenue fruits (*taka/decimal*)	999.77	898.61	
Gross annual revenue other crops (*taka/decimal*)	708.32	2,629.25	
Annual cost of labor (*taka*)	191.39	137.32	
Annual cost of fertilizers (Urea) (*taka*)	15.38	6.76	
Farm size (decimal)	153.58	186.20	247.158 decimals are equivalent to 1 hectare
Value of household assets (*taka*)	63,958.34	91,861.57	
Off-farm revenues (*taka*)	31,487.11	67,079.96	
Number of household members	5.23	2.00	
Highest level of education	3.75	6.34	Highest school grade attended by the head of the household
Maximum temperature	34.35	1.26	Max. temperature (°C) for the warmest month
Empowerment score	0.69	0.19	
Empowerment Gap	0.12	0.16	
Proportion of household economic activities for which woman (solely or jointly) make decisions[A]	0.74	0.23	
Proportion of major household assets that are (solely or jointly) owned by woman[B]	0.36	0.25	
Number of groups women belongs to	0.29	0.55	

Source: 2015 BIHS, Authors' calculations

Notes: [A] Includes decisions related to the following activities: food crop farming, cash crop farming, livestock raising, non-farm economic activities, wage and salary employment, and fishing/aquaculture. [B] Includes the following assets: agricultural land, large livestock, small livestock, poultry, fish pond/fishing equipment, mechanized farm equipment, and house (and other structures)

Empirical Analysis

We begin our analysis by exploring the relationship between women's empowerment and crop-production diversity and verify whether there is any statistically significant connection between the recorded level of women's empowerment and diversified land allocations on the surveyed farms. For this, we construct a household crop-allocation diversity index is using the Gini-Simpson index which is a function of households' farmland allocations to each crop:

$$GSI = 1 - \sum_{i=1}^{J} s_i^2$$

where s is the share of farmland allocated to particular crop category and i indicates one of the J possible crops grown by farmers. The Gini-Simpson (GS) index ranges from zero to one, the higher the index the more diversified land allocations are.

To understand with more specificity how women's empowerment might affect land allocations and how it might draw land away from the highly predominant cereal production, we use the fractional multinomial implied by equation 5. To estimate this model we assume that the optimal share function for each crop can be approximated by a linear-in-parameters combination of explanatory variables such that $\ln\left(\frac{s_{jln}}{s_{0ln}}\right) = \boldsymbol{\beta_j X_{jln}} + \boldsymbol{\xi_j}$, where $\boldsymbol{X_{jln}}$ is a vector of already defined explanatory variables $(R_{jn}, u_n, q_n, z_l, h_n, W_n, A_n)$, $\boldsymbol{\beta_j}$ is a vector of parameter to be estimated, $\boldsymbol{\xi_j}$ an error term and the subscript 0 in s_0 indicates a reference crop, l identifies the location of the n household. The parameters $\boldsymbol{\beta_j}$ are estimated using a pseudo-maximum likelihood as proposed by Mullahy (2015). Given S_j^*, and the observed land allocations (s_{nj}^O), the quasi-log-likelihood function to be maximized with respect to the parameters $\boldsymbol{\beta_j}$ is:

$$L = \sum_{n=1}^{N} \sum_{j=1}^{J} s_{nj}^O \log S_j^*(\boldsymbol{X}, \boldsymbol{\beta})$$

We refer the interested reader to Mullahy (2015) for the calculation of the score equation and the parameters' asymptotic variance. With this model, we explore several alternative specifications which differ in terms of which measure of women's empowerment is included among the explanatory variables.

Results

While data reveal no direct correlation between the Gini-Simpson (GS) index and the women's empowerment in agriculture index (WEAI) (correlation value: -0.0062), a strong relationship between women's empowerment and GS is revealed by regressing the GS index on the aggregate individual empowerment score while controlling for a series of household characteristics. Table 5 reports the parameter estimates of this simple OLS regression.

Table 5. Parameter estimates for OLS regression

Parameters	**Estimates**
Intercept	0.7286 (.)
Number of Household Members	-0.1158 (*)
Highest level of educations	0.0287
Total farm size	0.0377 (***)
Empowerment score	**2.7310 (***)**
Off-farm profit	-1.4920
Value of farm assets	2.680 (*)
R^2	0.3172

Note: significance codes: (***) 0.001; (**) 0.01; (*) 0.05; (.) 0.1

The low R^2 indicates that much of what determines crop diversity is absent from the regression but the parameter estimate for the empowerment score is highly significant indicating that women's empowerment is associated with increased crop diversity on the farm.

We now turn to the results of the fractional multinomial logit model. Across three alternative specifications listed in Table 6, the parameter estimates for the explanatory variables, for which we have strong prior hypotheses, mostly meet our expectations. This is the case for gross revenues for which an increase in their value increases the probability of allocating land to cereals, vegetables, and fruits. High maximum temperatures discourage farmers to allocate land to cereals, vegetables, and fruits and lead them to allocate more land to all other uses. An increase in labor costs appears to disproportionally affect land allocated to vegetables, reducing it in favor of greater allocations to cereals and fruits, while more assets and off-farm revenues lead farmers to shift land away from cereals in favor of vegetables and fruits.

Table 6. Parameter estimates for the multinomial logit model (reference category is "other uses")

	Model 1			Model 2			Model 3		
	Cereals	Vegetables	Fruits	Cereals	Vegetables	Fruits	Cereals	Vegetables	Fruits
Constant	11.6916**	2.4737**	2.7594*	12.0169**	2.5836*	3.0078**	12.1644***	2.5934*	2.9994**
Gross revenue	7.6919**	2.4553*	4.3853***	1.2460**	0.1962**	1.4609**	4.7652**	2.3385*	5.5846**
Labor cost	0.1398***	-0.0211*	0.0339***	0.1181**	-0.0249**	0.0257**	0.1195**	-0.0248*	0.0256*
Urea cost	-0.7149*	-0.5398**	-0.3151**	-0.4943*	-0.3717*	-0.1915***	-0.5578***	-0.3499*	-0.1893***
Farm area	0.0273***	0.0002	0.0196**	0.0256***	0.0003	0.0180***	0.0233***	-0.0002	0.0186***
Value of farm assets	-0.0042**	0.0001*	0.0025*	-0.0044*	0.0003*	0.0002*	-0.0041**	0.0005	0.0026**
Off-farm revenues	-0.0209*	0.0553*	0.0118*	-0.0252**	0.0628**	0.0128*	-0.0217*	0.0577***	0.0106**
Number of household members	-0.7280*	0.8507***	-0.6221*	-1.2806**	0.9363***	-0.9618*	-1.3514**	0.8879***	-0.9152**
Highest education level	-0.7587**	0.1995*	-0.1616**	-0.9268**	0.22647**	-0.2353**	-0.9520*	0.2644*	-0.2242**
Max. Temperature	-2.5687*	-0.7009**	-0.9199*	-2.6810**	-0.7500**	-0.9836**	-2.7075**	-0.7351**	-0.9783**
Empowerment score	**-18.2154****	**-2.2057****	**1.8339***	-	-		-	-	-
Empowerment gap	-	-	-	**2.5142****	**14.4200****	**8.8033****	-	-	-
Proportion of household economic activities for which woman (solely or jointly) make decisions	-	-	-	-	-	-	**-10.9130****	**0.8713****	**-1.6659****
Proportion of major household assets that are (solely or jointly) owned by woman	-	-	-	-	-	-	**6.6596****	**-16.0576****	**0.1267***
Number of groups women belongs to	-	-	-	-	-	-	**-9.2061***	**3.4901****	**1.2935****
No. of observations	3,373			3,373			3,373		
Log-Likelihood	**-4552.9642**			**-4557.6835**			**-4057.6835**		

Note: significance codes: (***) 0.001; (**) 0.01; (*) 0.05;

Of primary interest are the effects associated with the women's empowerment variables. In model 1, an increase in the women's empowerment score is are associated with a decrease in land allocated to cereals and vegetables and an increase in land allocated to fruits and other uses. Given that most of the farmland is allocated to cereals, these results support the previous finding based on the GSI coefficient that increasing women's empowerment is associated with increased crop diversity[4]. In model 2, an increase in empowerment gap (the gap in empowerment scores between men and women in the same household) leads to land being taken from other uses and allocated to cereals, vegetables, and fruits; a reallocation that, given the already existing predominance of cereals, doesn't favor diversification. This suggests that when women are less empowered relative to the male head of household, they have less influence on land allocation decisions and more land is allocated towards cereals.

Model 3 provides insight into three specific measures of empowerment—women's participation in production decision-making, asset ownership, and group membership—through which this effect may operate. The results show these mechanisms appear to operate in opposing directions. On one hand, as women's role in decision-making increases, less land is allocated to cereals and fruits and more land is allocated to vegetables and other uses. Similarly, as women's group membership increases, more land is allocated to vegetables and fruits and less to cereals. These results suggest that the dimensions driving the relationship between women's empowerment and production diversity are related to increasing women's participation in agricultural decision-making and expanding their social relationships outside the home. On the other hand, as women's share of household assets increases, more land is allocated to cereals and fruits and less land is allocated to vegetables. One possible explanation for these contradictory findings relates to women's preferences for different livelihood activities based on their wealth (as represented by their asset holdings in this case). The literature suggests that the poorest women are more likely to seek less socially acceptable forms of work, such as in garment factories or agricultural wage work (Heintz, Kabeer, and Mahmud 2018). Women with fewer assets may also be more heavily engaged in agricultural production activities and may influence land allocation towards

[4] To better understand how this is possible it is useful to go through a hypothetical situation. Assume that a farmer with 100 decimals of land distributes it across uses according to the allocations observed in the survey: cereal 66, vegetables 9, fruits 0.5 and other uses 24.5. This distribution is equivalent to a GS diversity coefficient of 0.49. The elasticities implied by the parameter estimated indicate that a 1% change in the empowerment score would lead to the following changes in areas: cereal -2.50, vegetables -0.15, fruits +0.02, other uses +2.62 and the resulting allocations: cereals 63.50, vegetables 8.85, fruits 0.52, other uses 27.12 and a GS coefficient of 0.52.

crops they provide more labor input on, which tend to be vegetables, pulses, and other cash crops such as jute and cotton (Rahman 2000). Similar preferences may be at play within households whereby women opt out of work on family farms as their wealth increases. The positive correlation between women's share of household assets and land allocations to cereals may be a product of this relationship, as wealthier women exhibit less say in planting decisions, and thus the effect of women's empowerment on crop diversity is muted—or, as in this case, reversed. These results suggest that the positive impact of women's asset ownership on dietary diversity found in previous studies (e.g. Sraboni et al. 2014) is likely achieved through a different pathway (e.g. women's control over household income and spending decisions or decreased labor burden or both).

Conclusion

Climate change represents a significant threat for agricultural production in Bangladesh and for the livelihood of millions of people. One of the main reasons for the country vulnerability to climate change is the overwhelming predominance of rice among the crops cultivated in the country. Because of this, the government of Bangladesh together with international agencies has been promoting crop diversification as a risk diversification instrument and as a method to increase the availability of nutritious foods in local markets. Women's empowerment is increasingly becoming the object of investigation in agricultural development studies since women's empowerment is linked to important well-being outcomes, such as improved diets and nutrition outcomes, higher agricultural yields, and higher adoption of climate change adaptation measures. This study analyzes the relationship between women's empowerment and crop diversification, since diversification is one promising strategy for reducing climate risk and improving nutrition outcomes in Bangladesh.

A straightforward linear regression indicates that increasing the women's empowerment score increases crop diversification. A more sophisticated analysis based on a model of land allocations to different crop categories, confirms these results and a specification that uses the empowerment gap between men and women shows that when women are less empowered relative to men in the household, more land is allocated to cereals. Finally, the use of key components of the empowerment index as explanatory variables reveal a deeper and more complex role of women's empowerment. Crop diversification increases when particular measures of women's empowerment increase (namely women's participation in production decisions and women's participation in groups) while another measure (women's control over assets) seems to drive results in the opposite direction. This may be because women in Bangladesh tend to disengage from agricultural production and decisions on family farms as they get wealthier.

These results show the complexity of the relationship between crop diversification and various aspects of women's empowerment and they are consistent with other research on women's empowerment in Bangladesh that show that different measures of empowerment can drive outcomes—such as those related to child nutrition and education—in different directions (Malapit et al. 2019). Notwithstanding the considerable complexity in the relationship between aspects of women's empowerment and development outcomes, it is imperative that researchers continue to work on developing a better understanding of these mechanisms to better target interventions.

Furthermore, work on gender issues is increasingly becoming common among practitioners and researchers alike and the use of the WEAI in applied research is growing. Our study provides further evidence that WEAI can provide important and nuanced insights into the links between various aspects of women's empowerment and well-being outcomes. These insights depend on a careful use of aggregate measures of empowerment, such as the empowerment score and empowerment gap, but also of the disaggregated measures related to specific WEAI indicators of interest. While the different types of measures will often produce similar results, this will not always be the case. Contrasts in the magnitude—or as in our study, the direction—of the effects associated with indicator-level measures can provide important nuance for contextualizing overall results.

While the results in this paper offer some valuable insights into the links between aspects of women's empowerment and production diversity, additional research is needed to uncover the pathways through which more production diversification may lead to greater food security and improved nutrition outcomes. Women's empowerment may lead to other changes outside of the realm of crop production that also influence nutrition outcomes. These can be better child feeding, care and WASH practices, or more spending on health care and education and these too should be explored. Policies and programs would greatly benefit if these different pathways were understood better.

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