# The Impact of Agricultural Land Ownership on Child Nutritional Status: Evidence from Rural Sudan

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# The Impact of Agricultural Land Ownership on Child Nutritional Status: Evidence From Rural Sudan


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# Contents

# List of tables

# Figures

# Abstract

This paper investigates the causal effect of agricultural landholding on child nutritional status in rural Sudan, using the 2014 Multiple Indicator Cluster Survey (MICS). Adopting propensity score matching (PSM) and instrumental variable (IV) techniques, the paper indicates that landholding significantly reduces child malnutrition for the full and female samples, implying that for children whose families have access to agricultural land, there is a reduced likelihood that they would be exposed to child nutrition problems such as stunting and underweight. For the male sample, the results reveal that agricultural landholding plays no significant role in improving the nutritional outcome of male children. This finding implies a gender disparity in the effect of landholding on children nutritional situation, as girls benefit significantly from agricultural landholding compared to boys. Therefore, policies that support land reform and a fair distribution of land would be a crucial part of a strategy to reduce the malnutrition of children under five in rural Sudan.



**Key Words:** *Agricultural land, Child nutritional status, Sudan, Africa*

**JEL:** *Q15, Q18, J13*

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# 1. Introduction

It is well documented that access to agricultural land is a key factor for reducing hunger and poverty, improving food security and promoting the nutrition situation in poor agrarian communities (International Food Policy Research Institute, IFPRI, 2011; Besley and Burgess, 2000). Landholding enhances agricultural production and, consequently, increases food availability and consumption, which improves the nutritional status of household members. The unequal distribution of land among the population may negatively affect agricultural production, thereby reducing the population's access to food, especially children, and eventually worsening their nutritional status. Therefore, the issue of land reform has gained considerable attention from governments of developing countries to enhance the role of agriculture in food and nutrition security.

Like other countries in sub-Saharan Africa, child malnutrition is a widespread phenomenon in Sudan, particularly in rural areas, where agriculture is the primary source of livelihood. The recent statistics of the 2014 Multiple Indicator Cluster Survey (MICS) indicates that Sudan suffers from a high prevalence of child malnutrition, as about one third (33%) of children under five are underweight, approximately two in five (38.2%) are stunted (too short for their age), and one in six (16.3%) children under five is wasted (too thin for their height). Regarding the gender variation in undernutrition, the MICS (2014) reports that male children are slightly more underweight, stunted, and wasted than female children. The same report also indicates regional inequality among children, as those residing in rural areas are more underweight and wasted.

The agricultural land in Sudan is unevenly distributed among the rural population and only a small segment of the population owns the bulk of the land while the majority of poor households possess very small plots (Elhadary, 2010). This is mainly due to a volatile land tenure system, as the country adopted many land acts after independence that deprived poor households from access to land (Elhadary and Abdelatti, 2016). Moreover, in the last decades the country witnessed a huge wave of land grabbing by other countries as the government allowed companies from many Arab countries to acquire land on an unprecedented scale (Babiker, 2013; Elhadary and Abdelatti, 2016). Thus, the uncertain and volatile land tenure system is one of key the constraints for agricultural productivity and food security in Sudan. The lack of land rights limits access to formal credit for the vast majority of farmers because land is used as collateral. The constrained access to land by rural households, coupled with the high prevalence of child malnutrition in Sudan, makes the effect of landholding on child nutritional status an important area of research that has been overlooked by the current literature on child nutrition.

Based on the above background, many questions related to this study can be raised, including the following: What is the impact of agricultural land ownership on child nutritional status in Sudan? To what extent does the effect of land ownership vary between male and female children? The study fills an important gap in the Sudanese literature as, to the best of our knowledge, this is the first study on this issue using microdata. This study is also timely, relevant, and seems to be consistent with the United Nations Sustainable Development Goals (SDGs) to be achieved by 2030 (specifically Goal 2: Zero hunger, and Goal 10: Reducing inequality).

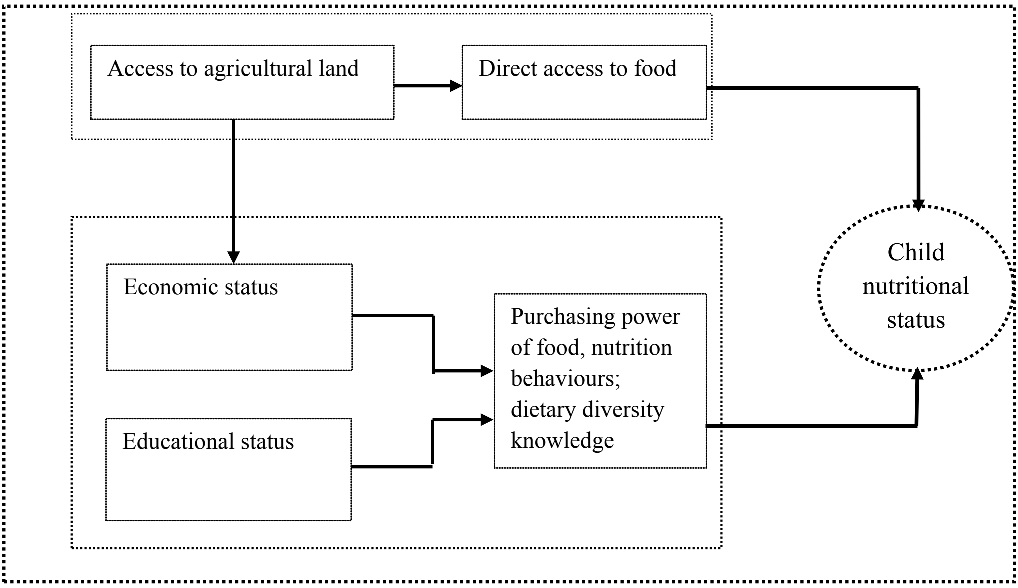
This study uses the 2014 Multiple Indicator Cluster Survey. To control for the problems of selection bias and possible endogeneity, the study adopts propensity score matching (PSM) and instrumental variables (IV) techniques. The results of the paper reveal that agricultural landholding significantly reduces child malnutrition for the full and female samples, implying that for children whose families have access to agricultural land, there is a reduced likelihood that they would be exposed to child nutrition problems such as stunting and underweight. The remainder of the paper is organized as follows: Section 2 outlines the conceptual framework and reviews the empirical literature on the linkage between agricultural landholding and child nutritional status, Section 3 presents the data and research methodology, Section 4 discusses the empirical results and main findings, and Section 5 provides the conclusion and some policy implications.

# 2. Conceptual framework and literature review

It is well documented that access to land first leads to investment in inputs, which could lead to increase in land productivity and an increase in income and, finally, improved child nutritional status. Figure 1 shows the pathways through which agricultural land ownership is expected to influence child nutritional status. Agricultural landholding encourages farmers to increase production, as land rights in many countries are used as collateral for credit and the adoption of advanced production technologies. The figure shows that there are two pathways through which landholding could affect child nutritional status. The first pathway reflects the direct route where access to land by households leads to an increase in production and, consequently, increased food availability and consumption that improves the nutritional status of household members. Many empirical studies indicate that increasing the household calorie intake reduces nutritional stunting in young children (e.g., Bloss et al., 2004; El Taguri et al., 2009;; Tiwari et al., 2013; Asfaw et al., 2015). Bouis et al. (1990) found that providing landless households in the Philippines with land resulted in some improvement in preschool children's nutritional status. However, for households that already owned land, the nutritional status of young children did not improve with an increase in income. In addition, in some agricultural production setting where production is primarily commercial rather than subsistence, some of the food is likely to be consumed at home, thus often improving dietary intake. Therefore, most of the existing evidence suggests that access to land has a direct positive and significant nutrition impact that occurs because household members regularly consume the food commodity being produced.

The second pathway involves the indirect route through which agricultural landholding affects child nutritional status. That is, access of households to land rights is expected to increase household income through the sale of surplus of production which, in turn, translates into increased food expenditure on high calorie and protein-rich foods, eventually leading to an improvement in child nutritional status (IFPRI, 2011;). In other words, an increase in agricultural production through access to land positively contributes to national economic growth, which might increase population income and improve access to healthcare and education. Therefore, agricultural landholding improves child nutritional status through enhancing the economic and educational status of households. As indicated in the figure, these two factors affect nutritional status through several channels, including: purchasing power, nutritional behaviours and dietary diversity knowledge. Therefore, the two pathways work together and enhance each other making agricultural landholding a crucial factor for increasing food intake and, in turn, the nutritional status of households.

**Figure 1: Pathways of effect of agricultural landholding on child nutritional status**




Source: Adapted from Gillespie et al. (2012).

Despite the clear theoretical link between farming land ownership and nutritional status, there is a dearth of empirical studies on this issue in Africa, which may be attributed to the scarcity of household surveys. However, a wide range of empirical literature has documented the link between agricultural landholding and nutrition in developing countries (The World Bank, 2007; Gillespie et al., 2012; Kadiyala et al., 2011). Some studies provide explanations for the widely accepted relationship between agricultural landholding and food security. For example, Rammohan and Prichard (2014) show that land is often the most important physical productive asset available to rural households, and returns from land account for a substantial proportion of household income. Land ownership allows households to generate income to fund both current consumption and investment activities, smooth consumption inter-temporally (as land can be used as collateral to access financial credit markets), and insure against idiosyncratic shocks due to ill health and adverse weather conditions. Furthermore, access to land and security of tenure is often key to having control over major decisions such as what crops to grow, what techniques to use, and the decision about what to consume and what to sell.

Earlier studies in the literature discussed the relationship between access to land and undernutrition. For example, Levinson (1974) finds that 54% of the children of landless labourers are moderately or severely malnourished, compared to less than 39% of landowners' children in one of the areas of Punjab. The FAO (1982) shows that gross consumption, and calorie and protein intake are increasing with the increase in farm size in Bangladesh. Some studies find similar results in the Philippines, Kenya, Haiti and Peru. Maharajan et al. (2006) find that land distribution (both quantity and quality) is a major factor responsible for maintaining household food security in Nepal. Babatunde and Qaim (2010) argue that farm size positively contributes not only to food security but also to farm income which, in turn, helps to improve nutrition security. Some studies find similar results in China, Ethiopia, and Uganda (Li and Brandt, 1998; Deininger, 2003; Deininger et al., 2008; Kyomughisha, 2008). Some studies indicate that the loss of agricultural land is indicated as the main reason for the massive undernutrition-related deaths in India; for example, the death of 200 children due to malnutrition among the tribal population of Attappady, Kerala (Manikandan, 2014). Savath et al. (2014) highlight the importance of land as an essential asset for rural livelihoods and nutrition security because of its importance for paving the way for the wellbeing of households. Santos et al. (2013) indicate that land rights have a direct link to increased food production and food security of the households. Kadiyala et al. (2011) support the argument regarding the linkage between agriculture landholding and nutrition. They argue that extending more land rights to women and increasing their participation in agriculture in rural areas is essential to India's nutrition security. Fan et al. (2012) show that targeting the safety nets by providing productive assets like land to [households] is important for the nutrition security of the households. Santos et al. (2013) find that land allocation has an impact on a range of outcomes that are expected to lead to future food security in West Bengal, India. Ownership of agricultural land and engagement in related activities makes access to food easier and ensures food security, which is strongly linked to nutritional outcomes, it therefore also becomes an important determinant of nutrition.[1]

Siddiqui et al. (2017) examined the linkages between ownership of households' agricultural landholding and child nutritional status in rural India. They find that land continues to be a critical determinant of the socioeconomic position of a family in rural India, and also a critical determinant of food security and the nutritional status of the household. They show that households' agricultural landholding and engagement in related activities affect nutritional status both directly and indirectly, which means that it not only affects direct access to food and diversity in food intake, but also economic and educational status. They find that children in households with larger agricultural landholdings are in an advantageous position compared to those in households with no landholding or marginal landholding. They also find that the proportion of stunted and underweight children decreased with an increase in the size of households' agricultural landholding in rural India.[2]

Despite increasing recognition of the association between agricultural landholding and food security, there are two important observations related to the relationship between food, nutrition and land. First, agricultural landholdings do not always shield households from food insecurity as average farm sizes have been steadily declining across many developing countries (Eastwood et al., 2010) and in many cases are below the minimum threshold for household provisioning. These households may need to diversify their collective sources of livelihood into the non-farm sector if they are to make ends meet. Second, the diversity of livelihood among rural households indicates a range of responses to food insecurity. However, a household's ability to cope with and withstand adverse economic shocks depends on its capabilities to utilize and adapt its assets (including the "five capitals": physical, human, financial, social and natural capital) to altered circumstances.[3]

The discussion has made clear that agricultural landholding plays an important role in improving food security in general, and in child nutrition in particular. Therefore, investigating the causal effect of land ownership on the nutritional status of children under five in Sudan will be crucial to understanding this neglected issue in the Sudanese literature. This also would provide more insight into the influence of a recent wave of land grabbing on child nutritional status.

# 3. Data and methodology

## Data and variables

The data for this study is sourced from the 2014 Sudanese Multiple Indicator Cluster Survey (MICS), a nationally representative household survey. The survey is carried out by the Central Bureau of Statistics (CBS) Sudan, as part of a broader international household survey designed by the United Nations Children's Fund (UNICEF). The survey covers 18,000 households, comprising 14,751 children under five years of age. The survey includes detailed information on the health, social and economic circumstances of women, children and other household members. The survey also covers child nutritional indicators as well as information on households' assets and access to agricultural land. The analysis in this paper focusses on the sample of children under the age of five who reside in rural Sudan (10,753 children).

In this study, the outcome variable is child nutritional status, measured by two anthropometric indicators, namely, height-for-age (HAZ) and weight-for-age (WAZ).[4] These indicators are computed in terms of standard deviation units (z-scores) from the median of the reference population. The estimates are based on the international reference population recommended by the World Health Organization (WHO, 2006). Children whose HAZ z-score is below minus two standard deviations (-2SD) from the median of the reference population are considered to be stunted (short for their age), while children with a WAZ z-score below -2SD from the median of the reference population are classified as underweight. Therefore, our outcome variables are binary taking the value of one if HAZ and WAZ are below –2SD from the median of the reference population for each nutrition category (i.e., stunted and underweight) and zero otherwise.

Our core explanatory variable is landholding, which is represented by a binary variable indicating whether a household owns land for agricultural purposes. Following the recent literature on child nutrition (e.g., Rastogi and Dwivedi, 2014; Musa et al., 2014; Rashad and Sharaf, 2019), the analysis controls for several variables including child-level characteristics, and household and parental-level factors, along with other socioeconomic determinants related to child nutrition. We also use regional dummies to control for regional heterogeneity. The definition and descriptive statistics of variables used in the analysis are presented in the Appendix.[5]

# Estimation strategy

Estimating the causal effect of agricultural landholding on child nutrition confronts many methodological challenges that require appropriate estimation methods. First, restricting our analysis on households with a positive land size may lead to the well-known problem of sample selection bias as landholders are not randomly selected from the pool of households. Second, landholding is potentially endogenous due to reverse causality as households of undernourished children are less likely to have land rights. In addition, omitted variable bias is another reason for endogeneity, which indicates that there is still a third (or more) variable(s) which influence(s) land ownership status as well as child nutritional status at the same time. For example, if the household head is unemployed he/she will contribute very little to the household income which, in turn, affects both child nutrition and household landholding status. Accordingly, conventional regression methods such as regular probit may result in biased estimators and only capture the simple correlation between landholding and child nutritional status. To address these methodological problems the study uses a propensity score matching (PSM) and instrumental variable estimation method (IV).

## *Propensity score matching*

To tackle the selection bias problem, we first run a propensity score matching (PSM) analysis to mitigate for potential bias resulting from self-selection into landholding. PSM is often used in a programme evaluation setting, where the objective is to compare participant outcome with and without action/treatment. The PSM method first generates an index that summarizes the observable characteristics of the household into a propensity score index. The households are then divided into two groups: those who have access to agricultural land (treatment) and those who don't (control) and they are ranked according to propensity score. Finally, households in the treated group can be matched and compared with households from the control group who have similar characteristics in every aspect except that they don't have access to land. Based on the matching outcome, the PSM procedure compares the outcome between the treatment and control groups. Specifically, the propensity score (PS) could be specified as follows:

$$PS_i = Pr[L = 1|X] = E[L|X] \quad (1)$$

where $PS_i$ is the probability that a household i owns farming land (L = 1), conditional on all the observed characteristics (X) that can be used to balance potential confounding variables across the control group, consequently lowering any estimation bias. To calculate the propensity scores in Equation 1, we use a standard probit regression model, where the binary dependent variable represents the two alternatives that we want to compare, i.e., households who own land and those that do not. Next, we match the treated and control groups with the same propensity scores.

In the literature, a number of matching methods have been adopted to match treated and control groups with similar propensity scores; these include the nearest neighbour, caliper and kernel matching methods. This study adopts the nearest neighbour and kernel matching methods for the purpose of robustness. Before recognizing the matching results, we need to check whether matching sufficiently eliminates any significant association between treatment status and covariates. We use t-tests to examine the differences between the treated and control group on each covariate (Rosenbaum and Rubin, 1985). We follow Ho et al. (2007) in adopting the rule of thumb that the normalized difference should be no more than 25% of the standard deviation for the sample to be considered balanced on observables. We also compare the pseudo R-squared and likelihood ratio tests before and after matching, which indicates how well the covariates explain the treated effect.

## *Instrumental variable method*

Although PSM can address the problem of selection bias, it relies on an assumption that all selection bias is found in the observable characteristics (Becker and Ichino, 2002; Rosenbaum and Rubin, 1983). This assumption indicates that PSM only accounts for observed covariates, while factors that cannot be observed cannot be accounted for in the matching process. Therefore, we adopted an additional identification strategy, which is an instrumental variable (IV) two-stage least-squares (2SLS) approach.

For the purpose of comparison, we first estimate the probit equation as a baseline model that does not address the endogeneity problem. Following previous literature on the factors that influence child nutritional status (e.g., Rashad and Sharaf, 2019; Rastogi and Dwivedi, 2014; Musa et al., 2014; Slavchevska, 2015) the basic probit model that describes the impact of landholding on nutrition outcomes can be specified as follows:

$$P = \Pr\left(N_{ji} = 1 \middle| E\right) = \varphi(E'\gamma) \tag{2}$$

where N is a certain nutrition outcome (binary) variable understudy for child j born to household i. Pr is the probability, $\varphi$ is a cumulative distribution function (CDF) of the normal distribution, $\gamma$ is a vector of unknown parameters and *E* denotes the vector of the explanatory variables, which involve control variables in addition to our key independent variable (landholding). However, the probit model may result in bias estimators due to potential endogeneity, as previously explained. To address this methodological problem, we adopt the two-stage least-squares IV estimation approach (2SLS-IV).

In the first-stage equation, we use a variable that represents landholding as a linear function of a vector of exogenous variables (e.g., the vector of control variables and instrumental variables) and then use its predicted value in the second equation of nutritional status. Thus, the first equation in the form of a two-stage least-squares model (2SLS) can be written as follows:

$$Land_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + v_i \quad (3)$$

$Land$ is the landholding, which is a function of a vector of exogenous variables ($Z_1$); instrumental variable ($Z_2$); and $\mathrm{v_i}$ is the disturbance term. The predicted value of $\widehat{\mathrm{Land}}$ from Equation 3 is included in Equation 4 as a second-stage regression.

$$N_{ji} = \beta_0 + \beta_1 \widehat{Land}_i + \beta_2 X_{ji} + \varepsilon_i \quad (4)$$

Choosing an appropriate IV is a challenging task. The aim is to find a variable that affects the landholding but not the child nutritional status directly. We instrument access to land by the cluster average of land size. It is worth mentioning that the 2014 MICS survey divided its sample into clusters: villages in rural areas and districts in urban areas. The intuition behind using the cluster average of land size as an instrumental variable is that it reflects landholding opportunities in the living area and, more importantly, it shows the effectiveness of the local land market. Therefore, one can argue that living in a village where a significant segment of farmers own agricultural land will increase landholding opportunities.

The validity of the cluster average of land size as IV must be strongly associated ($i.e. \alpha_2 \neq 0$) with the land size (e.g., endogenous variable) and is exogenous in our basic model. The validity of the instrument will be tested using the Cragg–Donald (Cragg and Donald, 1993) and Wald F-tests for weak instruments. Moreover, the cluster average of land size is likely to influence child nutrition exclusively through landholding, $Cov(Z_2, \varepsilon) = 0$ (i.e., exogenous), and has no independent effect on child nutritional status, as land ownership is based on economic status.

As our two dependent variables (i.e., outcome and the potentially endogenous variable) are binary, the appropriate method of estimation is a bivariate probit model (i.e., biprobit command in Stata). However, using a bivariate probit model does not entail testing the validity of the instrument. Therefore, we adopt the ivprobit estimation procedure to examine the first-stage results and test whether the instrument is weak. Moreover, we account for clustering at the household level, as some households have multiple children who would have the same background characteristics; therefore, our standard error is also adjusted for that level of clustering.

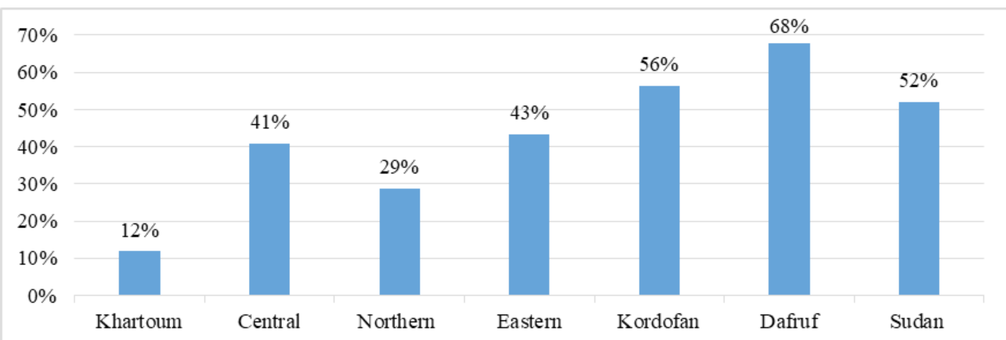
# 4. Empirical results and findings

This section presents the empirical results and findings. The section is divided into two subsections: Subsection 4.1 reports some descriptive statistics about access to agricultural land and child nutritional status in rural Sudan, while subsection 4.2 presents the estimation results of both PSM and IV estimation methods.

## Descriptive statistics

Figure 2 illustrates the distribution of agricultural landholding by region in rural Sudan. It reveals that the majority of rural households in Khartoum lack access to farming land, as about 88 per cent of the total rural population have no agricultural land. This can be explained by the fact that Khartoum is a more urbanized area and most of the existing agricultural land belongs to a small number of farmers and big companies. For the Kordofan and Darfur regions, Figure 2 indicates that most households have access to farming land, as agriculture is the main source of livelihood in these regions. Therefore, Figure 2 reflects a remarkable disparity in the distribution of agricultural land across regions in Sudan. Moreover, the figure points out that about 52 per cent of the rural population have access to farming land. This is relatively low as most of the rural population relies mainly on agriculture as their main source of income, hence, nearly half of the rural population lack access to agricultural land, which may intensify food and nutrition insecurity.

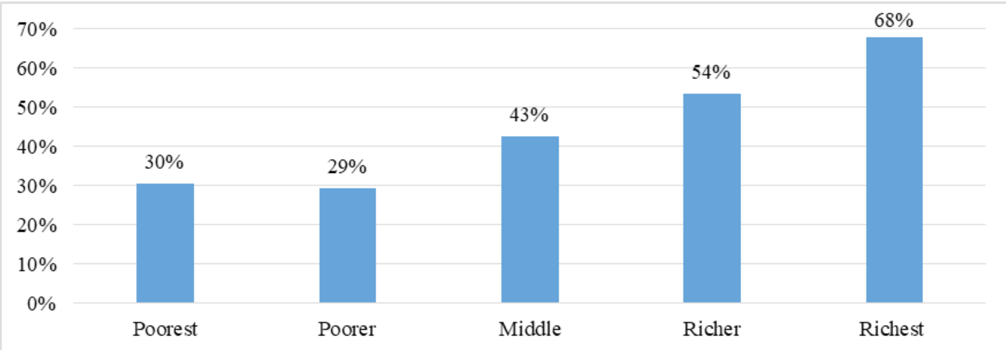
**Figure 2: Distribution of agricultural landholding by region, rural Sudan (%)**




Source: Adapted from Sudan MICS, 2014.

Regarding the distribution of agricultural land across wealth groups, Figure 3 reports the decomposition of land ownership by wealth quintiles. The figure shows that the poorest and poorer group have limited access to agricultural land, while most of the richest households have access to land for agricultural purposes. This reflects the situation in rural Sudan as most agricultural land is concentrated in the hands of rich families, indicating high inequality in land distribution among wealth groups. These results seem consistent with the results of earlier studies in the Sudanese literature (e.g., Elhadary, 2010; Elhadary and Abdelatti, 2016).

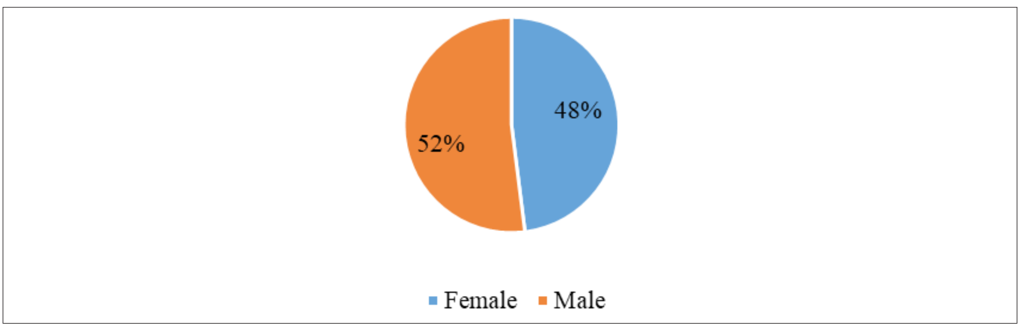
**Figure 3: Access to agricultural land by wealth quintile, rural Sudan (%)**




Source: Adapted from Sudan MICS, 2014.

Figure 4 presents the distribution of agricultural landholding by gender of head of household. It shows that more than half of households headed by a male own agricultural land. This statistic indicates that male-headed households are more likely to access farming land compared to their female counterparts. This could point to limitations on female ownership of agricultural land in rural Sudan. This is not surprising and can be explained by the prevalence of long-standing gender inequality in rural Sudan. These results might also relate to the limitations on landholding for females in rural Sudan, which is consistent with the many difficulties regarding land rights for women in many countries, as found in the international literature (see Allendorf, 2007).

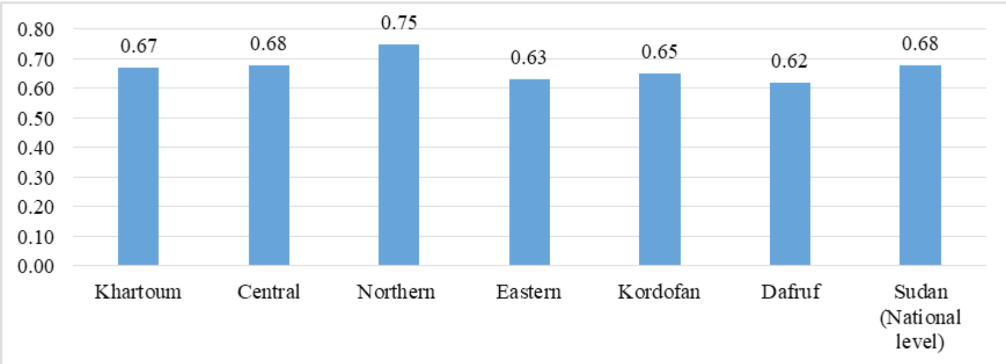
**Figure 4: Access to agricultural land by gender of household head, rural Sudan (%)**




Source: Adapted from Sudan MICS, 2014.

Concerning landholding inequality, Figure 5 reports the Gini coefficient of land size across regions. It illustrates high inequality in landholding at the national level, as indicated by a relatively high Gini coefficient (0.68). For the Northern and Central regions, the Gini indices are about 0.75 and 0.68, respectively. Overall, the Gini coefficients in all Sudanese regions are above 0.60, indicating high inequality in access to land. This finding implies that very high landholding inequality will most probably lead to high inequality in child nutritional status across regions. In addition, in view of the importance of agriculture as the main source of livelihood in rural Sudan, landholding inequality may deepen inequalities in other aspects of life such as income, labour participation and education in rural areas.

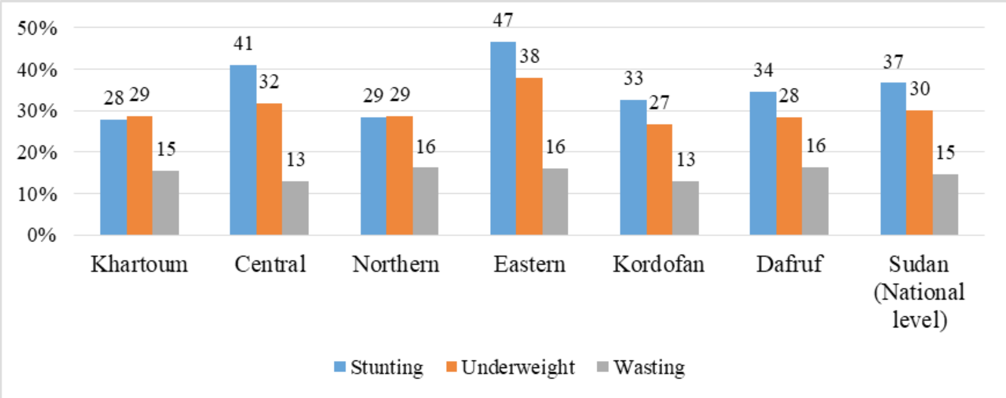
**Figure 5: Gini coefficient of land inequality by region, rural Sudan (2014)**




Source: Adapted from Sudan MICS, 2014.

To understand the child nutritional status in rural Sudan, Figure 6 depicts three nutrition indicators by region. It verifies the degree of poor nutrition as indicated by height-for-age (stunting), weight-for-age (underweight) and weight-for-height (wasting) data. Figure 6 indicates that Khartoum and the Northern region report low percentages of nutrition indicators. As expected, the Eastern region reports the highest percentages of stunting and underweight children compared to other regions. Moreover, Darfur is ranked second after the Eastern region in terms of the unfortunate nutritional situation of children. The high incidence of stunting and underweight in the Eastern and Darfur regions can be explained by the high rate of poverty and inequality in these regions. Moreover, Darfur suffers from a long civil conflict and political instability. Regarding the child nutrition indicators for the whole sample, Figure 6 indicates that about 37 per cent, 30 per cent and 15 per cent of all children under five suffer from stunting, underweight and wasting, respectively. This implies a high prevalence of a poor nutritional situation among children under five in rural Sudan. These figures confirm the national statistics, which hold that rural children experience high incidences of poor nutrition. We realize the high prevalence and severity of stunting and underweight compared to wasting, which implies that the proportion of children under five who are at risk of stunting and underweight are nearly double the proportion who are at risk of wasting in rural Sudan.

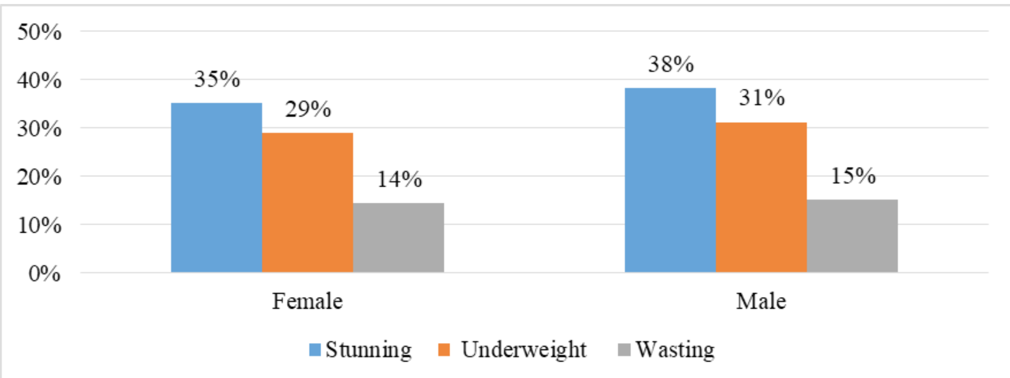
**Figure 6: Nutrition indicators by region in rural Sudan (2014, %)**




Source: Sudan MICS, 2014.

Figure 7 presents the child nutritional situation by sex of the child in rural Sudan. It shows that boys are more exposed to the incidence of nutrition problems compared to girls. That is, for all indicators, male children exhibit a high incidence of nutrition deficiency. These findings are in line with the those reported in other studies for sub-Saharan Africa, which indicate lower stunting rates for girls than for boys (e.g., Wamani et al., 2007).

**Figure 7: Nutrition indicators by gender of child in rural Sudan (2014, %)**




Source: Sudan MICS, 2014.

# Econometrics results

## *Propensity score matching results*

As outlined in the methodology, before recognizing the matching results we first tested whether matching sufficiently eliminates any significant association between treatment status and covariates. We estimated the t-test for the equality of means of covariates within the estimated propensity score for the two samples (i.e., the treated and control groups). The results of a balancing test show that before matching the groups are significantly different on several covariates and the normalized differences on many variables exceed 25%.[6] However, after matching all significant differences (at the 0.01 level) on most variables were eliminated. For most covariates, the normalized difference (percentage bias) is well below 25%, indicating that the matched sample is well balanced on observables. This also means that before matching several variables exhibited statistically significant differences, while after matching the covariates were balanced. Overall, the balancing tests support the hypothesis that both groups have the same distribution in covariates after matching. Thus, the balancing tests indicate that the treated and control groups are well balanced and that bias from observables has been significantly reduced, which is an important perquisite for an efficient matching exercise.

Having satisfied the balancing property, the next step is to match similar non-landholding households to each landholding household based on a set of covariates. If landholding and non-landholding households have similar sociodemographic characteristics except for landholding, then it is plausible that a difference in nutritional status between these two groups can be attributed to landholding. The matching is implemented by the nearest neighbour and a kernel matching algorithm. We conducted the matching procedure for both male and female children to examine whether the effect of landholding varies across the gender of the child. After similar non-landholding observations are matched to landholding observations, the average treatment effect on the treated (ATT) for both HAZ and WAZ is calculated. The results of ATT using the nearest neighbour and Kernel matching for full, male and female samples are presented in Table 1.

**Table 1: Propensity score matching results ,ATT estimates**

| | Full sample | | Male sample | | Female sample | |
|---|---|---|---|---|---|---|
| **Outcome variable Household has access to land (yes vs no)** | **Nearest neighbour** | **Kernel matching** | **Nearest neighbour** | **Kernel matching** | **Nearest neighbour** | **Kernel matching** |
| **HAZ** | -0.029** | -0.018* | -0.012 | -0.007 | -0.027** | -0.027* |
| | (0.012) | (0.010) | (0.011) | (0.015) | (0.011) | (0.015) |
| **WAZ** | -0.030** | -0.025** | -0.012 | -0.018 | -0.043** | -0.031** |
| | (0.013) | (0.010) | (0.014) | (0.014) | (0.018) | (0.014) |

Notes: Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The results of both nearest neighbour and kernel matching indicate that the differences in child nutritional status between the treated and control group is substantial. For both the full and the female sample the results indicate that ATT estimates are negative and statistically significant for height-for-age (stunting) and weight-for-age (underweight) indicators with both nearest neighbour and kernel matching. This implies that children under five whose households have farming land have a lower likelihood of being exposed to the incidence of stunting and underweight. Unexpectedly, the ATT coefficients of the male sample are found to be insignificant, implying that agricultural landholding has no significant impact on improving nutritional status of boys under five. The inconsistency between males and females regarding the effects of agricultural landholding on nutritional status adds an aspect of gender inequality. This can be interpreted along with the above observations concerning the differences between males and females regarding child nutritional status, as for all indicators male children exhibit a high incidence of malnutrition in rural Sudan.

## IV Estimation results

As indicated in the methodology, we first applied the probit method as a baseline model. The estimation results of the probit model in Table 2 indicate that the coefficients of land ownership are negative and significant, implying that in households who own land, the children are less likely to suffer from malnutrition. More specifically, the probability of being stunted and underweight is reduced for households with agricultural land.

As a potential endogeneity problem may exist between landholding and child nutritional status, the study adopted ivprobit and bivariate probit models, as outlined in the methodology. The cluster average of land size is utilized as an IV. Table 2 reports the estimation results of both the ivprobit and biprobit for the full sample of rural children (under five years). As discussed, we first tested the validity of the instruments. The test statistic of the Cragg–Donald Wald F-test exceeds the usual benchmark of 10 for all estimated models, rejecting the weak instrument hypothesis. The Wald test statistics also reject the null hypothesis that landholding is exogenous at any reasonable degree of confidence. Thus, we conclude that the land variable is endogenous, which constitutes a suitable justification for using the IV method. Moreover, the results of the first-stage regression reveal that the coefficient of the cluster average of land size is positive and statistically significant, indicating a positive correlation between child nutritional status and average land size in the neighbourhood of residence.[7] Therefore, the relevance assumption is satisfied and we can use the cluster average of land size as an IV, confirming that it is not correlated with the error term in the second-stage regression.

The results of the ivprobit and bivariate probit reveal that the impact of agricultural landholding is negative and significant for both HAZ and WAZ, indicating that landholding reduces the likelihood of children being stunted and underweight. This also means that children of families who have access to farming land are less likely to experience stunting and underweight. This finding confirms the results of the Wald F-test PSM outlined above, and supports the results discussed in many previous studies in the international literature (e.g., Allendorf, 2007; Menon et al., 2014; Rammohan et al., 2014; Siddiqui et al., 2017).

**Table 2: Results of ivprobit and bivariate probit: Full sample, marginal effects**

| Variable | Probit | | Ivprobit | | Biprobit | |
|---|---|---|---|---|---|---|
| | HAZ | WAZ | HAZ | WAZ | HAZ | WAZ |
| Land | -0.0204** | -0.0490* | -0.0713** | -0.0653*** | -0.1294** | -0.3425*** |
| | (0.0091) | (0.0286) | (0.0318) | (0.0240) | (0.0601) | (0.0287) |
| Child age, months | -0.000460 | -0.0112*** | -0.00048 | -0.0118*** | 5.90e-05 | -0.0030*** |
| | (0.00105) | (0.00120) | (0.0010) | (0.0012) | (0.0010) | (0.0003) |
| Male child | 0.125*** | 0.105*** | 0.1260*** | 0.1070*** | -0.5141*** | 0.2720*** |
| | (0.0265) | (0.0272) | (0.0266) | (0.0279) | (0.0352) | (0.0231) |
| Birth weight | -0.531*** | -0.997*** | -0.531*** | -1.061*** | -0.130*** | -0.0525*** |
| | (0.0338) | (0.0503) | (0.0338) | (0.0535) | (0.0504) | (0.0138) |
| Male head | 0.151*** | 0.203*** | 0.149*** | 0.198*** | 0.0164*** | 0.00037 |
| | (0.0495) | (0.0513) | (0.0496) | (0.0526) | (0.00615) | (0.0016) |
| Household size | 0.0155** | 0.00290 | 0.0175*** | 0.00607 | -0.0485** | 0.00250 |
| | (0.00607) | (0.00622) | (0.0066) | (0.0065) | (0.0198) | (0.0052) |
| No. of children < 5 | -0.0444** | 0.00764 | -0.0471** | 0.0104 | -0.00126 | -0.00014 |
| | (0.0194) | (0.0199) | (0.0201) | (0.0205) | (0.0213) | (0.0056) |
| Mother age, years | -0.000657 | -0.000466 | -0.0058 | -0.0011 | -0.1061** | 0.0145 |
| | (0.00209) | (0.00215) | (0.00211) | (0.00221) | (0.0499) | (0.0133) |
| Married – mother | 0.101** | 0.0599 | 0.103** | 0.0643 | -0.0483 | 0.0157* |
| | (0.0491) | (0.0506) | (0.0491) | (0.0518) | (0.0342) | (0.0090) |
| Mother education – primary | -0.0542 | -0.0576* | -0.0180 | -0.0585* | -0.214*** | -0.0545*** |
| | (0.0338) | (0.0345) | (0.0298) | (0.0354) | (0.0546) | (0.0148) |

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**Table 2 Continued**

| Variable | Probit | | Ivprobit | | Biprobit | |
|---|---|---|---|---|---|---|
| | HAZ | WAZ | HAZ | WAZ | HAZ | WAZ |
| Mother education – secondary | -0.216*** | -0.206*** | -0.0545 | -0.2001*** | -0.4210*** | -0.0741*** |
| | (0.0530) | (0.0545) | (0.0338) | (0.0568) | (0.0967) | (0.0259) |
| Mother education – higher | -0.431*** | -0.347*** | -0.216*** | -0.281*** | -0.0586* | 0.00680 |
| | (0.0905) | (0.0927) | (0.053) | (0.0992) | (0.0343) | (0.0090) |
| Father education – primary | -0.0477 | 0.0301 | -0.4310*** | 0.0256 | -0.0815 | -0.0093 |
| | (0.0338) | (0.0345) | (0.0908) | (0.0353) | (0.0479) | (0.0126) |
| Father education – secondary | -0.0244 | -0.0467 | -0.0470 | -0.0303 | -0.0313 | -0.0451** |
| | (0.0466) | (0.0477) | (0.0338) | (0.0497) | (0.0762) | (0.0207) |
| Father education – higher | -0.0425 | -0.171** | -0.0228 | -0.1621** | 0.1650 | -0.0169 |
| | (0.0745) | (0.0782) | (0.0466) | (0.0807) | (0.139) | (0.0355) |
| Central | 0.233* | 0.00160 | 0.0399 | -0.0555 | -0.168 | 0.00420 |
| | (0.122) | (0.122) | (0.0746) | (0.141) | (0.144) | (0.0366) |
| Northern | -0.0637 | 0.0381 | -0.2301* | 0.0226 | 0.1990 | -0.0008 |
| | (0.127) | (0.126) | (0.122) | (0.146) | (0.144) | (0.0369) |
| Eastern | 0.279** | 0.0689 | -0.0647 | 0.0321 | -0.176 | -0.0807** |
| | (0.128) | (0.128) | (0.1270) | (0.1470) | (0.1440) | (0.0374) |
| Kordufan | -0.0907 | -0.223* | -0.282** | -0.291** | -0.242* | -0.0787** |
| | (0.128) | (0.129) | (0.128) | (0.147) | (0.144) | (0.0373) |
| Darfur | -0.161 | -0.241* | -0.0909 | -0.335** | 0.0306 | 0.00574 |
| | (0.128) | (0.128) | (0.128) | (0.146) | (0.0405) | (0.0107) |

continued next page

**Table 2 Continued**

| Variable | Probit | | Ivprobit | | Biprobit | |
|---|---|---|---|---|---|---|
| | HAZ | WAZ | HAZ | WAZ | HAZ | WAZ |
| Toilet | 0.0216 | 0.0255 | -0.1710 | 0.02910 | 0.0051 | 0.0104 |
| | (0.0394) | (0.0404) | (0.1270) | (0.0421) | (0.0448) | (0.0117) |
| Water | -0.000926 | 0.0200 | 0.0222 | 0.0344 | 0.0664*** | -0.0215*** |
| | (0.0434) | (0.0442) | (0.0394) | (0.0461) | (0.0210) | (0.0056) |
| Wealth_index | -0.0631*** | -0.0770*** | -0.0822** | -0.0944*** | -0 .0635*** | -0.3420*** |
| | (0.0205) | (0.0210) | (0.0414) | (0.0220) | (0.0244) | (0.0287) |
| First stage R2 | | | 0.17 | 0.12 | | |
| Wald test of exogeneity | | | 6.01 | 7.17 | | |
| | | | (0.0091) | (0.0074) | | |
| Cragg–Donald test F-statistic | | | 614.518 | 926.790 | | |
| | | | (0.000) | (0.000) | | |
| Likelihood-ratio test of rho=0 | | | | | 0.0260 | 4.177 |
| | | | | | (0.871) | (0.0410) |
| Pseudo R2 | 0.072 | 0.066 | | | | |
| Observations | | | 10,753 | 10,753 | 10,753 | 10,753 |

Notes: Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Estimates account for clustering at the household level.

Concerning the control variables, the results of the probit, ivprobit and bivariate probit indicate that most of the variables are associated with the expected signs and their magnitudes agree with previous studies. For instance, the coefficient of child sex is positive and statistically significant, suggesting that male children are more likely to suffer from the risk of stunting and underweight compared to female children. The impact of birth weight is negative and significant in all models, indicating that a child born with a healthy weight is less likely to be exposed to nutritional problems. In addition, children belonging to a household headed by a male are more likely to experience stunting and underweight. Our results suggest that gender has an important effect on child nutrition in Sudan. As expected, the impact of the mother's and father's education is found to be negative and significant across all educational level, implying that a child with educated parents has few opportunities to experience nutritional problems. This outcome agrees with previous studies (e.g., Kabubo-Mariara et al., 2008; Rashad and Sharaf, 2019).

Interestingly, the effect of wealth is negative and significant, indicating that children from affluent families are less likely to suffer from poor nutrition. This result implies that disparities in the distribution of wealth do not only lead to inequalities in agricultural landholding for the current generation, as depicted in Figure 5 and as has been well documented in the Sudanese literature (see Elhadary, 2010; Elhadary and Abdelatti, 2016), but also adds a serious new aspect of inequality related to child nutritional status in rural Sudan. In our view, the observed inequalities in child nutritional status in rural Sudan are serious and will most probably intensify the prevalence of persistent inequalities for future generations in rural Sudan.

Finally, we estimated the model separately for boys and girls to see whether the causal effect of agricultural landholding on child nutritional status varies according to gender. The results of both the ivprobit and bivariate probit in Table 3 show that the male and female sample do not suffer from any problems with the instruments as indicated by the Cragg-Donald test. However, the Wald test statistic is significant only for the female models. Similar to the results of the full sample, the analysis of the female sample indicates that access to agricultural land has a negative effect on stunting and underweight. This suggests that girls under five whose households have access to farming land have less opportunity to be exposed to malnutrition. Unexpectedly, the impact of landholding does not appear to have any effect on the nutrition status of boys under five, implying that agricultural land does not play a significant role in improving the nutrition status of boys. This finding supports the results of the PSM analysis. This is not surprising as the descriptive statistics show that the incidence of poor nutritional status among male children is higher than that of females; hence landholding plays no significant effect in mitigating the nutrition problem of male children. This may suggest that the poor nutrition of male children is attributed to economic or endowment factors alongside household socioeconomic factors.

### Table 3: Results of ivprobit and bivariate probit: Male and female sample, marginal effects

| | Ivprobit | | | | Biprobit | | | |
|---|---|---|---|---|---|---|---|---|
| | Male Sample | | Female Sample | | Male Sample | | Female Sample | |
| | HAZ | WAZ | HAZ | WAZ | HAZ | WAZ | HAZ | WAZ |
| Land | -0.0322 | -0.0328 | -0.0813** | -0.0907*** | -0.0586 | -0.0578 | -0.3141* | -0.2572** |
| | (0.0349) | (0.0359) | (0.0323) | (0.0327) | (0.617) | (0.558) | (0.174) | (0.126) |
| Child age, months | 0.0045*** | -0.0137*** | -0.0047*** | -0.0111*** | -0.0016*** | -0.0037*** | -0.0015*** | -0.0039*** |
| | (0.00150) | (0.0018) | (0.00155) | (0.00172) | (0.0005) | (0.0006) | (0.0005) | (0.0007) |
| Birth weight | -0.499*** | -1.347*** | -0.563*** | -0.898*** | -0.201*** | -0.306*** | -0.169*** | -0.393*** |
| | (0.0484) | (0.0895) | (0.0492) | (0.0672) | (0.0173) | (0.0382) | (0.0201) | (0.0632) |
| Male head | 0.149** | 0.254*** | 0.0958 | 0.131* | 0.0362 | 0.0470* | 0.0505** | 0.0750*** |
| | (0.0713) | (0.0751) | (0.0725) | (0.0745) | (0.0258) | (0.0257) | (0.0245) | (0.0247) |
| Household size | 0.00913 | 0.0080 | 0.0312*** | 0.00501 | 0.0091*** | -0.0005 | 0.00245 | 0.0019 |
| | (0.00935) | (0.0095) | (0.00887) | (0.00915) | (0.00306) | (0.00302) | (0.00306) | (0.0027) |
| No. of children < 5 | -0.0421 | 0.00832 | -0.0479* | 0.0171 | -0.0204** | 0.00234 | -0.0138 | 0.0030 |
| | (0.0288) | (0.0296) | (0.0281) | (0.0288) | (0.0099) | (0.00970) | (0.00978) | (0.0086) |
| Mother age | -0.00176 | 0.00152 | -0.000950 | -0.00361 | -0.0002 | -0.0011 | -0.0005 | 0.0005 |
| | (0.00309) | (0.0031) | (0.00300) | (0.00309) | (0.0010) | (0.0010) | (0.00105) | (0.0009) |
| Married – mother | 0.163** | 0.0619 | 0.0545 | 0.0693 | 0.0186 | 0.0226 | 0.0544** | 0.0166 |
| | (0.0724) | (0.0742) | (0.0702) | (0.0727) | (0.0250) | (0.0248) | (0.0248) | (0.0218) |
| Mother – primary | 0.0285 | 0.0228 | -0.121** | -0.134*** | -0.0458*** | -0.0483*** | 0.00927 | 0.00599 |
| | (0.0494) | (0.0506) | (0.0485) | (0.0498) | (0.0172) | (0.0175) | (0.0168) | (0.0148) |
| Mother – secondary | -0.148* | -0.217*** | -0.259*** | -0.190** | -0.101*** | -0.0736*** | -0.0522* | -0.0656** |
| | (0.0785) | (0.0815) | (0.0783) | (0.0803) | (0.0276) | (0.0280) | (0.0267) | (0.0256) |

continued next page

**Table 3 Continued**

| | Ivprobit | | | | Biprobit | | | |
|---|---|---|---|---|---|---|---|---|
| | Male Sample | | Female Sample | | Male Sample | | Female Sample | |
| | HAZ | WAZ | HAZ | WAZ | HAZ | WAZ | HAZ | WAZ |
| Mother – higher | -0.153 | -0.266* | -0.680*** | -0.291** | -0.250*** | -0.106** | -0.0569 | -0.0803* |
| | (0.131) | (0.137) | (0.150) | (0.145) | (0.0530) | (0.0504) | (0.0440) | (0.0421) |
| Father – primary | -0.0820* | -0.00841 | -0.0296 | 0.0594 | -0.0081 | 0.0230 | -0.0281* | -0.0029 |
| | (0.0494) | (0.0504) | (0.0488) | (0.0499) | (0.0174) | (0.0170) | (0.0168) | (0.0147) |
| Father – secondary | 0.00133 | -0.0451 | 0.00691 | -0.0255 | -0.0002 | -0.0112 | -0.000906 | -0.0139 |
| | (0.0682) | (0.0703) | (0.0691) | (0.0709) | (0.0246) | (0.0241) | (0.0231) | (0.0207) |
| Father – higher | -0.00948 | -0.0992 | -0.0243 | -0.211* | -0.0170 | -0.0802** | -0.00339 | -0.0291 |
| | (0.109) | (0.114) | (0.109) | (0.115) | (0.0387) | (0.0397) | (0.0369) | (0.0336) |
| Central | 0.149 | -0.00039 | 0.211 | -0.113 | 0.0706 | -0.0460 | 0.0474 | -0.0004 |
| | (0.196) | (0.203) | (0.199) | (0.199) | (0.0717) | (0.0682) | (0.0666) | (0.0590) |
| Northern | -0.185 | 0.0786 | -0.129 | -0.0353 | -0.0503 | -0.0186 | -0.0674 | 0.0205 |
| | (0.205) | (0.211) | (0.206) | (0.205) | (0.0741) | (0.0700) | (0.0696) | (0.0612) |
| Eastern | 0.289 | 0.0596 | 0.165 | -0.0270 | 0.0547 | -0.0157 | 0.0876 | 0.0093 |
| | (0.207) | (0.215) | (0.206) | (0.206) | (0.0740) | (0.0704) | (0.0695) | (0.0614) |
| Kordufan | -0.126 | -0.236 | -0.182 | -0.363* | -0.0743 | -0.135* | -0.0484 | -0.0704 |
| | (0.206) | (0.213) | (0.207) | (0.207) | (0.0743) | (0.0718) | (0.0693) | (0.0623) |
| Darfur | -0.221 | -0.251 | -0.302 | -0.434** | -0.0963 | -0.137* | -0.0721 | -0.0646 |
| | (0.203) | (0.210) | (0.206) | (0.206) | (0.0740) | (0.0715) | (0.0692) | (0.0621) |
| Toilet | 0.0127 | 0.0166 | 0.0575 | 0.0439 | 0.0164 | 0.00991 | 0.0031 | 0.0041 |
| | (0.0586) | (0.0606) | (0.0575) | (0.0590) | (0.0205) | (0.0200) | (0.0198) | (0.0176) |

continued next page

**Table 3 Continued**

| | Ivprobit | | | | Biprobit | | | |
|---|---|---|---|---|---|---|---|---|
| | Male Sample | | Female Sample | | Male Sample | | Female Sample | |
| | HAZ | WAZ | HAZ | WAZ | HAZ | WAZ | HAZ | WAZ |
| Water | 0.0551 | 0.0109 | -0.0491 | 0.0501 | -0.0126 | 0.0228 | 0.0191 | 0.0030 |
| | (0.0654) | (0.0671) | (0.0630) | (0.0640) | (0.0224) | (0.0218) | (0.0222) | (0.0195) |
| Wealth_index | -0.0870*** | -0.0871*** | -0.0721** | -0.102*** | -0.0194* | -0.0278*** | -0.0280*** | -0.0245** |
| | (0.0307) | (0.0315) | (0.0304) | (0.0311) | (0.0106) | (0.0106) | (0.0105) | (0.0098) |
| First stage $R^2$ | 0.13 | 0.13 | 0.12 | 0.12 | | | | |
| Wald test of exogeneity | 1.191 | 0.73 | 7.00 | 8.09 | | | | |
| | (0.271) | (0.391) | (0.008) | (0.004) | | | | |
| Cragg–Donald test F-statistic | 446.601 | 446.601 | 469.858 | 469.858 | | | | |
| | (0.000) | (0.000) | (0.000) | (0.000) | | | | |
| Likelihood-ratio test of rho=0 | | | | | 0.002 | 0.006 | 0.235 | 0.704 |
| | | | | | (0.98) | (0.938) | (0.626) | (0.401) |
| Observations | 5,438 | 5,438 | 5,315 | 5,315 | 5,438 | 5,438 | 5,315 | 5,315 |

Notes: Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Estimates account for clustering at the household level.

Overall, the results of the PSM and IV analysis imply that land ownership has a negative and significant effect on reducing malnutrition in children under five. This suggests that families who have access to agricultural land are more able to offer nutritious food and protect household members from food shortages. In fact, the dominance of subsistence agriculture in rural areas means most families with farming land have more opportunity to attain food and nutrition security. In addition, an important assumption for a child to benefit from landholding is that the additional income gained from farming production should be spent on food and healthcare, which would improve the child's nutritional status. However, our results indicate that the effects vary between boys and girls, as girls benefit more from agricultural landholding than boys.

# 5. Conclusion and policy implications

Motivated by the high prevalence of child malnutrition in rural Sudan, this study examined the causal effect of agricultural landholding on child nutritional status in rural Sudan using the 2014 Multiple Indicator Cluster Survey (MICS). To account for sample selection bias and the endogeneity problem, the study adopted both propensity score matching (PSM) and instrumental variables (IV) methods.

The results of both the PSM and IV analysis indicate that landholding has a negative and significant impact on child malnutrition for full and female samples, implying that children whose families own agricultural land are less likely to be exposed to child nutrition problems such as stunting and underweight. For the male sample, the results reveal that agricultural land ownership plays no significant role in improving the nutrition outcome of male children. This finding means that there is gender disparity in the effect of landholding on the nutrition situation of children, as girls benefit significantly from agricultural landholding compared to boys.

Based on the above findings, policy actions that boost agricultural development may serve as a crucial strategy to enhance the nutrition situation for children under the age of five in rural Sudan. Therefore, any policy aimed at achieving food and nutrition security should consider land reform as a top priority for the policy agenda in Sudan. Moreover, an equal distribution of land needs considerable attention from policy makers, as landholding inequality is a widespread phenomenon in rural areas. We recommend the adoption of more appropriate regulations and legislation to eliminate land grabbing and and at the same time encourage land ownership by farmers to enhance agricultural production, and to improve food security and child nutritional status in rural areas. Finally, we recommend the elimination of gender disparities in landholding (achieving SDG5 and SDG10); supporting women's land ownership would contribute to an improvement in child nutritional status in rural areas.

# Notes

1. See Siddiqui et al. 2017: 6–7.

2. See Siddiqui et al. 2017: 3, 7, 12.

3. See Rammohan et al. 2014: 597–8.

4. In practice, there are three main anthropometric indicators: height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height (WHZ). However, the current study excludes WHZ, as its performance is reasonable, while most child nutritional problems in Sudan are concentrated on stunted (HAZ) and underweight (WAZ) children (see Appendix).

5. We are aware that the term "land use” is a broader concept implying access to land and use of land through both landholding and land hiring. Given the lack of reliable information regarding land hiring in Sudan, for the purpose of the analysis in this paper we use the term “land use” to refer to/to measure landholding in Sudan.

6. The results of balancing tests are available on request. The results of balancing tests for male and female children samples replicate the full sample analysis results.

7. The results of the first-stage regression of the IV 2SLS estimation are available on request.

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# Appendix

## Descriptive statistics of variables used in regression analysis

| Variable | Definition | Mean | Std. Dev. |
|---|---|---|---|
| Height-for-age (HAZ) | 1 = if stunted (below -2SD), 0 = otherwise | 0.3669 | 0.4820 |
| Weight-for-age (WAZ) | 1 = if underweight (below -2SD), 0 = otherwise | 0.3012 | 0.4588 |
| Weight-for-height (WHZ) | 1 = if underweight (below -2SD), 0 = otherwise | 0.1479 | 0.3550 |
| Land | 1 = if own agricultural land, 0 = otherwise | 0.5185 | 0.4997 |
| Land cluster average | Cluster average of land size in feddan | 16.4045 | 20.1686 |
| Land size | Measured by the number of feddan | 7.5843 | 19.5791 |
| Child age | Child's age in months | 28.7681 | 17.1596 |
| Birth weight | Weight of child at birth: 1 = if average and above, 0 = otherwise | 0.6421 | 0.5141 |
| Male – child | Sex of child – male | 0.5057 | 0.5000 |
| Male – head | Sex of head – male | 0.9096 | 0.2868 |
| Household size | Number of household members | 6.3723 | 2.6586 |
| child_num5 | Number of children under five years in household | 1.8924 | 0.7731 |
| Mother age | Age of mother in years | 28.4145 | 7.4720 |
| Married (mother) | 1 = if mother currently married, 0 = otherwise | 0.8071 | 0.3945 |
| Maternal education: Primary | 1 = if mother completed primary level | 0.3199 | 0.4665 |
| Maternal education: Secondary | 1 = if mother completed secondary level | 0.1059 | 0.3078 |
| Maternal education: Higher | 1 = if mother completed higher level | 0.0314 | 0.1745 |
| Husband education: Primary | 1 = if father completed primary level | 0.3176 | 0.4656 |
| Husband education: Secondary | 1 = if father completed secondary level | 0.1421 | 0.3492 |
| Husband education: Higher | 1 = if father completed higher level | 0.0398 | 0.1955 |

*continued next page*

## Appendix continued

## Descriptive Statistics of Variables used in Regression Analysis

| Variable | Definition | Mean | Std. Dev. |
|---|---|---|---|
| Central | 1 = if reside in Central region, 0 = otherwise | 0.2561 | 0.4365 |
| Northern | 1 = if reside in Northern region, 0 = otherwise | 0.0790 | 0.2697 |
| Eastern | 1 = if reside in Eastern region, 0 = otherwise | 0.1251 | 0.3308 |
| Kordufan | 1 = if reside in Kordufan region, 0 = otherwise | 0.1867 | 0.3897 |
| Darfur | 1 = if reside in Darfur region, 0 = otherwise | 0.3405 | 0.4739 |
| Toilet | 1 = if access to piped water, 0 = otherwise | 0.2192 | 0.4137 |
| Water | 1= have flushing toilet, 0 = otherwise | 0.1980 | 0.3985 |
| Wealth index | Wealth index factor score (5 quantiles) | 2.1973 | 1.2515 |

## Mission

To strengthen local capacity for conducting independent, rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa.

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