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Women's Greater Participation in Agriculture: Implications for Energy Expenditure, Time Use, and Nutrition from a Case Study in Telangana, India

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ABSTRACT *Several aspects of rural transformation in LMICs call for greater participation by women in agriculture. However, empirical evidence does not show a clear link between greater participation by women in agriculture and improved nutritional status. This paper examines two key nutrition impact pathways – changes in energy demands and time-use patterns due to increased participation in agriculture. The study is based on data collected from rural agricultural households across agricultural seasons in Adilabad District, Telangana State, India. A novel aspect of the study is the use of accelerometers for energy expenditure assessments. Our findings show that increased participation by women in agriculture leads only to modest rises in energy demand and physical activity levels, as agricultural tasks are not much more energy-intensive than the domestic/care activities they replace. Increased energy expenditure due to more time spent on agricultural activities is generally offset by higher calorie intake, with no significant impacts on calorie adequacy. However, increased participation in agriculture significantly changes women's time-use patterns, reducing time for domestic work, leisure, and care, which may affect nutrition and wellbeing. Impacts on nutrition and wellbeing are more likely to arise from changes in time-use patterns than from increased energy demands of agricultural work.*

KEYWORDS: Women in agriculture; feminisation; time use; energy expenditure; nutritional outcomes; low- and middle-income countries

JEL CODES: 012; Q12; J16; J22

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1. Introduction

Many low- and middle-income countries (LMICs) are witnessing a process of 'feminisation' of agriculture associated with rural transformation processes and economic development (Slavchevska, Kaaria, & Taivalmaa, 2016). The definition of what constitutes feminisation varies with the context of agriculture in different LMICs (Farnworth et al., 2021; Padmaja, Pingali, Bantilan, & Kasala, 2018). Broadly understood, it refers to an increasing proportion of agricultural work being undertaken (either in absolute terms or relative to the share of men) by women in their capacity as producers, unpaid family labour, or as agricultural wage labour. Feminisation of agriculture thus suggests an increased sharing of agricultural work burdens by women.

There are several different perspectives on the drivers of feminisation in agriculture in LMICs. The economic development process in almost all countries has been associated with a decline in the share of agriculture in GDP and in the workforce. As economies develop, there is a shift of the workforce away from the primary (agriculture) sector towards secondary and tertiary sectors. However, this transition of the workforce away from agriculture is often gendered and is associated with the outmigration of men away from rural areas and into urban areas in search of employment (Padmaja et al., 2018). Women face substantial socio-economic or cultural constraints for migration and may be 'left behind' in rural areas to shoulder the burden of agricultural work and managing households. Feminisation of agriculture may also be driven by the introduction of new agricultural technologies and practices (for example, introduction of High-Yielding Varieties, input-intensive agriculture, double cropping facilitated by irrigation infrastructure, and so forth) under agricultural development programmes that call for greater participation of women in agricultural activities (Agarwal, 2022). Patterns of agricultural mechanisation that are oriented mainly towards agricultural activities primarily performed by men (for example, ploughing, tilling) could also increase the share of women in agricultural work. Feminisation in agriculture may also be driven by agricultural stagnation and resultant rural distress leading to outmigration of men, again leaving women to manage low-productivity agriculture (Pattnaik, Lahiri-Dutt, Lockie, & Pritchard, 2018). The nutritional, health, and well-being outcomes for women as a consequence of feminisation are uncertain as these different drivers may offer different opportunities and constraints for betterment.

The available empirical evidence suggests that there is no clear link between feminisation of agriculture and the nutritional outcomes for women as that may depend on the impacts on agricultural productivity, the ability to invest in agriculture (for example via remittance inflows), women's role and empowerment in decision making and utilisation of household resources, and intrahousehold distribution of labour and income (Johnston, Kadiyala, Stevano, Malapit, & Hull, 2015). Several systematic reviews in the literature have failed to find a clear link between productivity enhancing agricultural interventions and nutritional improvements in LMICs, especially for women and children (Webb & Kennedy, 2014). While this has been attributed to lack of sufficient research and evaluation (Girard, Self, McAuliffe, & Olude, 2012), it has prompted a closer examination of the 'agriculture-nutrition disconnect' in India and other developing countries (Gillespie, Harris, & Kadiyala, 2019) and the pathways through which the links to nutritional improvements may operate. Ruel et al. (2013) identify six pathways that link agriculture and nutrition: (1) agriculture as a food source, (2) agriculture as an income source, (3) food prices affecting household food security, (4) women's socio-economic status and their ability to influence household decision-making, (5) women's ability to manage care, feeding, and health of young children, and (6) women's own nutritional status affected by work-related energy expenditure, dietary diversity, and hazardous agricultural practices. The role of energy expenditure in the determination of nutritional outcomes has been clearly recognised in the literature but has received limited attention in the empirical work. This may be attributable to the challenges of accurately measuring energy expenditure in observational studies of free-living populations. Empirical assessments of energy expenditure in agriculture and rural livelihood activities that rely on standardised figures for energy intensity of different activities (derived from the FAO/WHO/UNU (2004) or other sources) may not be robust as such an approach does not account for the heterogeneity of individuals or the context and the periods of rest or pauses within any stretch of activity. To address this, recent studies in the literature have attempted to use wearable devices such as accelerometers to obtain accurate and reliable energy estimates of energy expenditures associated with rural livelihood activities (Srinivasan et al., 2020, Picchioni, Zanello, Srinivasan, Wyatt, & Webb, 2020; Zanello, Srinivasan, & Nkegbe, 2017). Golan and Hoddinott (2023) have used accelerometers to validate two widely used in-person questionnaires, the global physical activity questionnaire (GPAQ) and the 24 hour perceived exertion recall survey (PERS).

The energy expenditure dimension of agriculture work has been examined in the literature on the drudgery reduction associated with farm mechanisation in the context of modernisation of agriculture and the adoption of input-intensive technologies. These studies focus on demonstrating the benefits of mechanisation and improved implements on the physiology of work using indicators for effort such as energy expenditure, heart rate and so forth (Gite & Singh, 1997; Kishtwaria & Rana, 2012; Mohanty, Behera, & Satapathy, 2008; Nag, Sebastian, & Mavlankar, 1980; Nag & Nag, 2004; Singh, Gite, Agarwal, & Majumder, 2007). However, these studies typically do not extend to examining the implications of mechanisation for the overall daily energy demands of agricultural workers. Studies that relate employment in agriculture to nutritional and health outcomes have been limited (Gillespie et al., 2019). These studies have attempted to assess the energy expenditure associated with household and agricultural activities, the variations in energy expenditures across seasons and the impact of physical activity and food intakes on neo-natal size and indicators such as BMI, by occupation and gender (Bains, Kaur, & Mann, 2002; Barker, Chorghade, Crozier, Leary, & Fall, 2006; Durnin, Drummond, & Satyanarayana, 1990; Griffiths & Bentley, 2001; Headey, Chiu, & Kadiyala, 2011; Rao, Gokhale, & Kanade, 2008).

The nutritional and health impacts of women's greater participation in agriculture via the time-use pathway have received greater attention in the literature. These impacts primarily arise from trade-offs against time spent on household activities such as food preparation (Hyder et al., 2005) and childcare. The nature of these trade-offs is likely to vary with the type of agricultural activities undertaken by women and with agricultural seasons. Johnston, Stevano, Malapit, Hull, and Kadiyala (2018) reviewed the role of time-use as a determinant of nutritional outcomes in rural areas of LMICs, noting that women's agricultural roles may negatively impact nutrition due to reduced time for food preparation. While time-use patterns affect nutrition, impacts may vary as households respond differently to increased workloads. A key message from the review is that productivity-enhancing agricultural interventions may not improve nutritional outcomes unless women's time constraints and trade-offs between productive and reproductive activities are considered (Hyder et al., 2005; Padmaja, Pramanik, Pingali, Bantilan, & Kavitha, 2019, Herforth, Jones, & Pinstrup-Andersen, 2012, Kadiyala, Harris, Headey, Yosef, & Gillespie, 2014, Jabs & Devine, 2006; Behrman & Deolalikar, 1990; Pitt & Rosenzweig, 1985; Senauer, Sahn, & Alderman, 1986; Vemireddy & Pingali, 2021). While time use has been the main indicator of work burdens of women in empirical studies, its limitations have long been recognised in the literature. Time use does not reflect the intensity of work or 'effort' in relation to the work capacity of the individual[1] (Palmer-Jones & Jackson, 1997). The work intensity of agricultural work may be more relevant for nutritional and health outcomes than time allocation. There is evidence that high intensity agricultural work can have adverse effects on health through exhaustion, biological damage, and impairment of the immune system (Chiong-Javier, 2009; Habib, Hojeij, & Elzein, 2014, Pitt, Rosenzweig, & Hassan, 1989). Dasgupta (1997) outlines scenarios where long-term nutritional deprivation can lead to reduced work capacity and productivity. Intensification of agricultural work by women in economic environments that harbour ‘poverty traps’ may not lead to increased productivity or improved nutrition status.

In this paper, we examine the association of women’s greater participation in agriculture with their nutritional status, using ‘calorie adequacy’ as an indicator of nutritional status. We focus on two proximate pathways through which feminisation can influence the nutritional status of women. The first is the increased physical activity and energy demand associated with greater participation in agricultural activities. Greater participation in physically intensive agricultural activities may call for higher levels of energy expenditure by women and increase their physical activity levels. At the same time, greater participation in agriculture could also be associated with increased agricultural productivity and improved food (energy) intake. The overall impact of women’s calorie adequacy is, therefore, not clear. The nutritional status of women may not improve if higher energy expenditure is not compensated for through better nutrition intake. Although there are several references in the literature on feminisation increasing women’s work burdens and drudgery, there is very little empirical evidence on how greater participation in agriculture affects the overall energy demands of women. The second pathway runs through the effect of greater participation in agriculture on the time-use patterns of women. The impact on women’s nutritional status will depend on the nature of trade-offs involved (for example reduced time spent on domestic or self-care activities, leisure, or rest) when women devote increased time to agricultural work. We examine how women’s increased participation in agriculture affects their nutritional status, by addressing the following research questions:

1. How does increased participation in agriculture by rural women affect their overall energy demand and energy intake?
2. How does increased participation in agriculture affect women’s calorie adequacy?
3. How does increased participation in agriculture affect the time use patterns of rural women?

A simultaneous examination of energy demand and time-use impacts does not appear to have been previously attempted in the empirical literature. The use of accelerometers to derive accurate estimates of energy expenditure of members of agricultural households as they go about their daily activities is an innovative feature of this paper.

The examination of these two proximate pathways of impact provides useful insights into implications of feminisation for women’s nutritional status. Our findings show that increased participation by women in agriculture leads only to modest rises in energy demand and physical activity levels, as agricultural tasks are not much more energy intensive than the domestic/care activities that they replace. Increased energy expenditure due to more time spent on agricultural activities is generally offset by higher calorie intake, with no significant impacts on calorie adequacy levels. However, increased participation in agriculture significantly changes women’s time-use patterns, reducing time for domestic work, leisure, and sleep, which may affect nutrition and wellbeing. Impacts on nutrition and wellbeing are more likely to arise from changes in time-use patterns than from increased energy demands from agricultural work.

2. Data and methods

2.1. Data

2.1.1. Study area. This paper uses data collected for a project entitled ‘Through the Looking Glass: Applying a Gender Lens to Agricultural Transformation, Labour Intensification and Nutrition Outcomes in LMICs’ funded by the Global Challenges Research Fund (GCRF) and undertaken by the University of Reading and the International Crop Research Institute for Semi-Arid Tropics (ICRISAT). Ethical clearance for the study was granted by the Research Ethics Committee of the School of Agriculture, Policy and Development, University of

Reading, UK. As all the data collected was to be anonymised, the ethics approval permitted the provision of a combined information/consent sheet and obtaining verbal consent from survey respondents. The study was conducted in four villages, Chanduri, Komaipet, Kommuguda, and Mathadiguda villages in Adilabad district, in Telangana State in India. The dataset used for analysis in this paper is available from the Mendeley Data repository at https://doi.org/10.17632/59t4k3cdt2.1.

The region has a semi-arid climate and agriculture is principally rain-fed. However, irrigation infrastructure on farms has been increasing in the district. Currently, more than 50 per cent of cropped area is reported to have access to irrigation facilities in the district (Government of Telangana, 2021b) which indicates potential for intensification of agricultural production. About 76 per cent of the Adilabad population of 708,972 live in 508 rural villages, relying mainly on agriculture for their livelihoods (Government of Telangana, 2019). The district has 15 per cent of its population belonging to the Scheduled Castes while 32 per cent belong to the Scheduled Tribes.[2] As in many parts of India, the local economy is growing; the average per capita income (adjusted for inflation) increased from 93,254 Indian Rupees[3] in 2015/2016 to 112,152 Indian Rupees in 2017/2018 but the gross district domestic product is still below the median obtained in the state (Government of Telangana, 2019). About one-quarter of the district population participates in the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) public works. Over 70 per cent of the total 4,153 square kilometres district land area is committed to agriculture and allied services – arable farming, aquaculture, livestock, and forestry services. Crop production is expanding despite increasing fragmentation of agricultural land, and the proportion of the population in agriculture has not declined. State government reports show that between the 2019-20 to 2020-21 agricultural seasons, paddy production grew by 29.9 per cent and the area under cotton production grew by 29.4 per cent during the same period (Government of Telangana, 2021a). However, notwithstanding the impressive growth in agricultural production, the burden of stunting, wasting, severe wasting and underweight in children as well as underweight in women is substantial and among the highest in India – around 52 per cent of children are underweight, and 53.2 per cent of pregnant women are anaemic. Government reports note that this region is characterised by a relatively high, and increasing incidence of malnutrition (Christopher, Scott, Singh, Menon, & Nguyen, 2021; Government of Telangana, 2021b).

2.1.2. Data collection. The villages selected for inclusion in the study were villages where the project partner International Crop Research Institute for Semi-Arid Tropics (ICRISAT) had built a good rapport with the communities from their previous research projects including the longitudinal Village Level Studies programme undertaken since 1975 (https://vdsa.icrisat.org/vdsa-vls.aspx). A stratified sample of 30 households was selected from these villages with an equal proportion of small, medium, and large landowning households in consultation with Panchayat (Local Government) functionaries. In each household, two respondents were selected, an economically active[4] male and an economically active female in the age range of 18–64 years. In practice, the respondents selected were the head of the household and the spouse (husband wife pairs) within each household. Data was collected over three non-consecutive weeks between August 2019 and August 2020 corresponding to three agricultural seasons when sowing/weeding, harvesting, and fertiliser application activities were the principal activities carried out. While there was some attrition of households between the three rounds of data collection (with some households needing to be replaced), data was collected from 64 individuals in 32 households in each season.[5] The data collected included information on socio-demographic characteristics of the household and the respondent individuals, anthropometric measures, recall based 24-hour time use and food intake data and physical activity (energy expenditure) obtained through the worn accelerometers (see below).[6]

All the households in the sample were predominantly agricultural households cultivating cotton, turmeric, rice, sorghum, and soybeans. At the beginning of the fieldwork, respondents provided information on their health and anthropometric measurements (height and weight) were also taken. The selected male and female respondents in each household were followed for 14 days, split over three data collection rounds. This translates into four consecutive days during the first round and five consecutive days during the second and third rounds. Information on household characteristics was collected from the household head. Anthropometric data was collected only once during the first week of the survey. Time-use data were also collected at one-hour intervals from respondents based on 24-hour recall. Respondents were asked to report on primary and secondary activities done within the hour in no particular format to capture time use patterns typical of rural agricultural livelihoods (Doss, Malapit, & Comstock, 2020).

Accurate assessment of energy expenditure associated with agricultural and rural livelihood activities is generally not feasible using observational or lab-based (for example indirect calorimetry, double-labelled water) (Dufour & Piperata, 2008) methods. The recent advent of accelerometer technology has expanded physical activity energy expenditure measurement tools. Accelerometers are portable, motion sensor devices used in the collection of objective physical activity data in free-living populations (Troiano, McClain, Brychta, & Chen, 2014; Zanello et al., 2019). In addition to the time use questionnaires administered daily, physical activity data were collected using the accelerometer model WGT3X-BT, a research-grade device approved by the US Food and Drug Administration. The ActiGraph WGT3X-BT device is a tri-axial accelerometer that has been used extensively in research (for example Wu, Yu, Tai, Zhang, & Hao, 2023) and provides the end user with raw data on movement along the three axes. Using validated algorithms (Santos-Lozano et al., 2013; Sasaki, John, & Freedson, 2011) the movement data is translated into energy expenditure (kilocalories). Movement data was sampled at 30 Hz and downloaded at the end of each week. Participants were invited to wear the accelerometer on an elastic belt around the waist at all times, except during sleep at night or while bathing. The activity data collected daily over 24 hours from accelerometers were converted into activity energy expenditure (in kilocalories) using validated algorithms (Freedson, Melanson, & Sirard, 1998). The time use data collected using questionnaires were matched with energy expenditure data derived from accelerometers to determine activity-specific energy expenditure (Zanello et al., 2019). The 24-hour activity cycle of respondents extended from midnight to the following midnight. However, all individuals were assumed to be sleeping between 11 pm and 5 am except when a different activity was recorded. Accelerometer wear compliance was high among the respondents. The final dataset included data from 64 individuals from 32 households over 14 days. Data from one respondent in the third round of data collection (5 days) was dropped from the sample on account of more than 180 minutes of non-wear, which gave us a final data set of 891 day-level observations (64x14 – 5). For regression analysis, observations that reported zero or very low-calorie consumption (owing to fasting or ill health, and so forth) were dropped, giving a sample of 700 day-level observations.

The data provided by the accelerometers is the Activity Energy Expenditure (AEE) of the individual. AEE is the calories expended during physical activity and is the standard measure used in the economics literature to model energy expenditures in free living populations (Friedman et al., 2021). To calculate AEE in this study, raw 60-seconds epoch length physical activity data collected from the accelerometer devices were converted to kilocalories using a validated algorithm (Freedson et al., 1998). AEE plus the Basal Metabolic Rate[7] (BMR) constitutes the total energy expenditure of the individual. The Physical Activity Level (PAL) is defined as the ratio of the AEE to the Total Energy Expenditure (AEE + BMR) of the individual.

The daily calorie intake of individuals was assessed from the dietary survey data which recorded the foods consumed and portion sizes (based on standard portion bowls given to the respondents). The food intake was converted to calories consumed (KCALSCON) using the conversion factors from the National Institute of Nutrition Food Composition Tables (Longvah, Ananthan, Bhaskarachary, & Venkiah, 2017). For the local foods not listed in the NIN food composition tables, the conversion factors were provided by a group of nutritionists in ICRISAT from relevant studies in the literature. The Calorie Adequacy Ratio (CAR) for each individual was derived as the total calories consumed divided by the total energy expenditure of the individual (AEE+BMR). CAR has limitations as an indicator of nutritional status as it does not take into account dietary diversity and the quality or healthiness of diet. However, given the highly localised nature of diets in the study villages, this was the most feasible indicator of nutritional status that could be constructed from the food intake data.

The activities described by the respondents in the recall-based time-use survey were classified into activity categories, broadly following the activity categories described in the India Time Use Survey (Government of India (GoI), 2020). The activities were further grouped into the following macro-categories relevant for time use analysis in rural agricultural settings: (1) agriculture, (2) non-agricultural economic, (3) domestic and childcare, (4) social and leisure, (5) self-care, and (6) sleep (Antonopoulos & Hirway, 2009). The principal time use distinction that we are interested in for women is that between economic and non-economic activities (that is, those which yield an economic return or remuneration versus those which do not). (1) and (2) above are economic activities while (3), (4), (5), and (6) are non-economic activities. Time use surveys generally make a distinction between 'paid' and 'unpaid' work. However, in the context of rural agricultural livelihoods, this may not correspond to the distinction between economic and non-economic activities as women's agricultural and other production related work is often unpaid and is part of family labour. The activities included in each category are specified in Table 1.

The sample size used in the study (32 households in each round and 2 respondents from each household) is small and may not be representative of the rural population of Telangana. The sample size was kept small due to the intensive nature of the data collection exercise that included the collection of household and individual data, monitoring of the respondents' wearing accelerometers, downloading of data from the devices, and a recall based daily dietary and time use survey. However, it may be noted that the data collection exercise did yield 21,384 hourly observations on time use and energy expenditure (891 day-level observations) and 700 day-level observations on food intakes for analysis.[8] The dataset used for the analysis was the set of 700 day-level observations for which the data on time-use, energy expenditure, and food intake were available. The implications derived for women's energy expenditure, time use, and nutrition when they increase their participation in agricultural activities are likely to be relevant for similar rural agricultural settings in LMICs.

2.2. *Methods*

2.2.1. Women's participation in agriculture. The proportion of time-use devoted to agriculture is used as an indicator of women's participation in agriculture. When working with time use data, the issues of simultaneous activities and the presence of zero values in the time use data are two methodological issues we addressed.

Women may be performing secondary activities alongside the primary activity being undertaken in any given interval. Primary activities are the main tasks performed during an hour, while secondary activities overlap with these tasks. Typical secondary activities undertaken by women, such as childcare, can be undercounted if they are not considered in the time use data collection (Floro, 1995; Ironmonger, 2005). Therefore, each recorded activity in hourly intervals was identified as either primary or secondary. After aggregating time use data to the day level, secondary activities were reported in about a quarter of daily observations. Following Picchioni et al. (2020), observations without secondary activities were assigned a full weight of 1. When a secondary activity was reported, a weight of 0.7 was assigned to the primary activity and 0.3 to the secondary activity. Although the allocation of weights is somewhat arbitrary, compositional

Table 1. Time use categories

Categories	Activities
Agricultural activities	Includes time spent in crop production such as soil ploughing, weeding, fertiliser application, irrigation, pesticides application, harvesting and threshing, and livestock production including care and management of livestock. Other activities include forest produce collection and related travel.
Non-agricultural economic	Includes time spent in salaried employment, non-farm wage employment in construction and public work schemes, business and petty trading, and professional development training.
Domestic and care provision	Includes household maintenance, food management, cleaning and upkeep of dwelling, home repair, washing clothes and utensils, shopping and related travel, and care provision including caring for children, elderly, sick and disabled, and unpaid voluntary activities helping other households, and community services.
Social and leisure	Includes time allocated to socialising, talking, reading, watching television, and internet use.
Self-care	Includes time spent eating, bathing, brushing, exercising, and other personal care activities.
Sleep and resting time	Includes sleeping time and resting.

regression results showed no significant differences with alternative weights of 0.5:0.5, 0.6:0.4, or 0.8:0.2.

Since time-use data is compositional, the total time spent on all activities in a day sums to 1,440 minutes. An increase in time spent on one activity inevitably reduces time spent on others. In compositional regression analysis (see below) relating time-use patterns to energy expenditure, zero values are problematic for log-ratio computations (Martín-Fernández, Barceló-Vidal, & Pawlowsky-Glahn, 2003). However, time use data do have truly observed (essential) zeros or too-infrequent-to-capture (rounded) zeros. Traditional methods for handling zeros include imputing small values for rounded zeros and aggregating related variables for essential zeros (Martín-Fernández et al., 2003). We use a combination of these methods to address these zeros. For example, childcare, which often has zero values (especially for men), is combined with domestic activities (Aitchison, 1982). For activities with rounded zeros, we imputed 0.01 hours (36 seconds) per day (Aitchison, 1982; Martín-Fernández et al., 2003).

2.2.2. Modelling the effects of women's increased participation in agriculture. To examine the effects of women's increased participation in agriculture, we model AEE, KCALSCON, and CAR separately as a function of the time spent in agricultural activities, along with household and individual characteristics. Since the proportions of time spent in different activities sum to one, they constitute 'compositional' variables. Conventional OLS methods are unsuitable for these variables due to multicollinearity and adding up constraints. The OLS coefficient of a compositional variable cannot be interpreted meaningfully as the effect of a unit change in the compositional variable holding all other compositional variables constant. We, therefore, use methods from compositional data analysis (Aitchison, 1982) which are now extensively used in studying the effects of time spent in physical activity or other behaviours (Chastin, Palarea-Albaladejo, Dontje, & Skelton, 2015). Specifically, we use compositional regression with the isometric log ratio (ILR) transformation of the compositional explanatory variables. The values of the ILR transformed variables depend on the sequence of variable transformation and for our model, the proportion of time spent in agricultural activities is treated as the first compositional variable. This method allows us to consistently estimate the effect of changes in time spent on one activity while accounting for concurrent changes in other activities, maintaining the constraint that proportions add up to one (or 1,440 minutes).

Linear or logistic regression approaches assess the mean response of the outcome variable to changes in the covariates and the effect of covariates is constrained to be the same along the entire distribution of the outcome variable. We would, however, like to allow the effect of participation in agriculture to vary along the distribution of the outcome variable (for example the effect of increased participation in agriculture may be very different for a respondent who is undernourished [CAR < 1] compared with a respondent who is better nourished). We, therefore, use the quantile regression technique which allows the impact of explanatory variables to vary along the entire distribution of the outcome variables (AEE/KCALSCON/CAR).

The quantile regression model estimated was:

$$Y_{k(\tau)} = \beta_{(\tau)0} + \beta_{(\tau),\, i=1}^{D-1} z_i + \boldsymbol{\gamma\prime}_{(\tau)}\boldsymbol{I} + \boldsymbol{\delta\prime}_{(\tau)}\boldsymbol{H} + \boldsymbol{\pi\prime}_{(\tau)}\boldsymbol{C} + \varepsilon \qquad (1)$$

where Y_k denotes the outcome variables, k = AEE, KCALSCON or CAR, τ denotes the quantile, D is the number of activity categories (in this case six – agriculture, non-agriculture economic,[9] domestic and childcare, social and leisure, personal care, and sleep) and

$$z_i = \sqrt{\frac{D-j}{D-j+1}} \cdot ln\left(\frac{x_i}{\sqrt[Dj]{\prod_{j=i+1}^{D} x_j}}\right)$$

for $j = 1,2, \ldots D\text{-}1$ and x_i is the number of minutes spent in each activity category during the day and $\sum x_i = 1{,}440$ minutes. ***I*** denotes the vector of individual characteristics; ***H*** is a vector of household characteristics and endowments, ***C*** denotes the vector of control variables such as the day of the interview, seasonality, village. **γ, δ,** and **π** are vectors of coefficients and ε captures the error term. The above equations were estimated for the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} quantiles. Table 2 provides a description of all the variables used in the compositional data regression. The analysis was performed using the ILR and COMPREG, user-written Stata commands (Zanello, 2024a, 2024b). For comparison, we also present the Ordinary Least Squares (OLS) estimates of the above model alongside the quantile regression results. We also test for differences in coefficients of the quantile regression across quantiles, which serves as a check on whether the quantile regression approach is useful. Unobserved individual, household, or locality characteristics (for example health status, interest in or ability for agricultural work) may be correlated with predictor variables, especially the time spent in agriculture which is a key variable of interest. If unobserved characteristics are correlated with predictor variables, then a fixed effects specification will be appropriate. We use the Hausman test to decide whether a fixed effects or random effects model specification is appropriate for the data.

2.2.3. Relating women's participation in agriculture to patterns of time-use. We split the sample of women into five quintiles based on the time spent in a day in agricultural activities. To examine the impact of women's participation in agriculture on their overall patterns of time use, we test for significant differences in the proportion of time spent in different activities between the different quintiles (using the Bonferroni correction). The differences in the time spent in different activities across the quintiles of agricultural participation provide some insights into how women's participation in agriculture affects their activity patterns and the nature of trade-offs associated with women's greater participation in agriculture.

Table 2. Description of variables used in the regression models

	Variable description
Dependent variable(s)	
Activity energy expenditure (AEE)	Total amount of calories used to perform physical activities daily. The variable measures day-level AEE for every respondent
Kilocalories consumed (KCALSCON)	Total calories consumed in a day derived from food intake
Calorie Adequacy Ratio (CAR)	Calories consumed / Calories expended (KCALSCON/TEE)
Independent variables	
Age	Individual age in number of years
Gender	Dummy variable for gender 0= men and 1 = women
Literacy 1	Dummy variable indicating if a respondent has no education
Literacy 2	Dummy variable indicating if a respondent has primary education
Literacy 3	Dummy variable indicating if a respondent has secondary education or above
Agricultural time use	Time spent in agricultural – crop and livestock activities in a day in minutes
Non-agricultural economic time use	Time spent in non-agricultural economic activities in a day in minutes
Domestic and care time use	Time spent in domestic, care and voluntary activities in a day in minutes
Leisure time use	Time spent in leisure activities in a day in minutes
Self-care time use	Time spent in self-care activities in a day in minutes
Sleep and rest time use	Time spent in sleep and rest in a day in minutes
Number of elderly females in HH	Total number of female adults older than 64 years within the household
Number of elderly males in HH	Total number of male adults older than 64 years within the household
Number of adult females in HH	Total number of female adults aged 18–64 years within the household
Number of adult males in HH	Total number of male adults aged 18–64 years within the household
Number of children under 18 yrs in HH	Total number of children below 18 within the household
Total land cultivated (hectares)	Total area of land cultivated by household in hectares
Total livestock units	Ownership of livestock units based on the Food and Agricultural Organization 2011 guidelines (Upton, 2011)
Wealth index	Wealth index based on ownership of household assets constructed using the method of Filmer and Pritchett (2001)
Seasonal dummies	Dummy variables indicating the primary activity undertaken in agricultural cropping cycle: (1) Weeding, (2) Fertiliser application, and (3) Harvest
Day (dummy)	Day number of data collection for the individual (from 1 to 5)

3. Results

3.1. Descriptive statistics

Table 3 presents the descriptive statistics of household-level characteristics. Households consist of medium to large family sizes according to the UNESA's classification of household size, with at least three people and an average of five people in each household (United Nations Economic and Social Affairs, 2017). The average household size in our sample was 5.04 which compares with the average household size of 4 for Telangana State (Government of Telangana, 2023). The average landholding size in the sample was 2.9 hectares, which is higher than the average landholding of 1.5 hectares in Adilabad District (Government of Telangana, 2024). This may be due to the equal proportion of small, medium, and large landowning households in our sample. To calculate the total household livestock holdings, we followed the United Nations Food and Agriculture Organization (FAO) guidelines for aggregating the value of livestock from different livestock categories (FAO, 2011). The household wealth index, serving as a proxy for household income, was computed using principal components analysis based on the respondents' dwelling characteristics, ownership of farm equipment, transportation means, and consumer goods (Filmer & Pritchett, 2001).

We present individual level descriptive statistics in Table 4. The descriptive statistics are derived from 700 day-level observations for which data on time-use, energy expenditure, and food intakes were available. Respondents in our sample are young. On average, male household heads are older than female household heads by five years. Of the respondents in our sample, only 22 per cent of females can read and write compared with 44 per cent of males. The average body mass index (BMI) of 18.13 among women is below the national and World Health Organization guidelines for normal BMI range of 18.5–25 kg/m^2 (National Institute of Nutrition, 2011). BMI for men is slightly higher, but close to the lower limit of the normal BMI range. Using the WHO's BMI cut-off values, 63 per cent of women and 38 per cent of men are underweight. The proportion of women underweight in our sample is considerably higher than the proportion of women underweight in Adilabad district (27%) (POSHAN, 2022). This suggests that the sample of households in the study may be more nutritionally deprived than the population in Adilabad district. Activity Energy Expenditure (AEE) for men is considerably greater than that of women, with a significant difference of 174 calories per day. Men have a significantly higher Total Energy Expenditure (TEE) as well as Kilocalories (KCALSCON) consumed than women. However, women have a higher Calorie Adequacy Ratio (CAR) then men, which suggests a better nutritional status for women in relation to men in the sample.

We observed in our sample that very few respondents reported participating in non-agricultural economic activities, and many of the activities reported were related to agriculture (for example marketing of produce). Therefore, in the compositional regression that follows, we have grouped agricultural activities with non-agricultural economic activities into a single category designated as 'agricultural and economic activities'. Men, on average, spend significantly more time on agricultural and economic activities per day (323 minutes) compared to women (285 minutes). For domestic activities, women spend substantially more time, averaging 230 minutes daily, compared to 69 minutes for men. While there is a significant difference between men and women in time spent in personal care, the magnitude is small (13 minutes). However, men report a higher average time spent in leisure activities (264 minutes) than women (164 minutes), and this difference is also statistically significant. Lastly, the time spent on sleeping and resting activities is quite similar between genders, with men averaging 551 minutes per day and women 543 minutes, showing no significant difference.[10] A striking feature of the time use data is the sharp imbalance between men and women in the allocation of labour and household responsibilities. The time spent by women on domestic and care work is more than three times the amount spent by men and accounts for 77 per cent of the time spent in the household on domestic and care work. However, women have access to only 62 per cent of the leisure time

Table 3. Descriptive statistics of household-level variables (n = 37)

	Mean	Std. Dev.	Min	Max
Total land cultivated (hectares)	2.93	1.61	0.81	6.89
Total Livestock Unit (FAO)	1.72	1.61	0.00	7.92
Wealth Index	−0.02	2.55	−5.27	5.63
Household size	5.03	1.55	3	11
Number of adult males	1.14	0.42	1	3
Number of adult females	1.08	0.36	0	2
Number of elderly males	0.08	0.28	0	1
Number of elderly females	0.11	0.31	0	1
Under 18	2.62	1.19	1	6
Village Chanduri (per cent)	0.19	0.39	0	1
Village Kommuguda (per cent)	0.32	0.47	0	1
Village Mathadiguda (per cent)	0.49	0.51	0	1
Observations (households)	37*			

Note: * The number of households reported in this table is more than the sample size of 32 households in each round as some households dropped out after the initial round of data collection and had to be replaced for subsequent rounds.

Table 4. Individual-level socio-demographic, anthropometric, and physical activity variables (n = 74)

	Men		Women		
	Mean	SD	Mean	SD	t-test
Age (years)	37.33	7.94	32.12	6.64	5.21**
Literacy	0.44	7.67	22.35	6.29	0.22***
Body mass index (BMI)	19.85	3.11	18.13	2.70	1.72*
Underweight (per cent)	0.38	0.49	0.63	0.48	−0.25*
Normal weight (per cent)	0.55	0.50	0.33	0.46	0.22
Overweight (per cent)	0.07	0.25	0.04	0.17	0.03
Activity energy expenditure (AEE)	557.54	159.94	383.80	113.17	173.7***
Basal metabolic rate (BMR)	1344.01	145.72	1178.50	76.80	165.5***
Total energy expenditure (TEE)	1901.55	275.72	1562.30	171.65	339.3***
Physical Activity Level (PAL)	1.41	0.09	1.32	0.09	0.09***
Kilocalories consumed (KCALSCON)	2365.38	312.00	2068.33	253.18	297.1***
Calorie Adequacy Ratio (CAR)	1.26	0.21	1.48	0.23	−0.218***
Agricultural and economic activities (mins / day)	323.84	89.74	285.30	74.46	38.53*
Domestic activities (mins / day)	69.86	45.18	230.20	61.88	−160.3***
Personal care activities (mins / day)	230.15	20.50	216.99	22.63	13.16*
Leisure activities (mins / day)	264.40	84.66	164.45	64.41	99.95***
Sleeping and resting activities (mins / day)	551.75	26.64	543.06	67.22	8.69
Number of days per respondent	9.51	2.68	9.41	2.70	0.108
Number of days per season per respondent	3.95	0.23	3.95	0.23	0
Observations (number of individuals)	37		37		

Notes: Asterisks indicate levels of significance. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$, based on the t-test for differences between men and women. SD = standard deviation.

that men have. The gender imbalance in the division of household responsibilities may reflect deeply embedded patriarchal socio-cultural norms but it does suggest that the nature of trade-offs involved in greater participation in agricultural or other economic activities could be very different for men and women. Figure 1 shows the proportions of activity energy expenditure and time use per day, disaggregated by men and women.

The pattern of time use among respondents is largely consistent with the literature on time use among farming households in Telangana, India (Padmaja et al., 2019), where a high

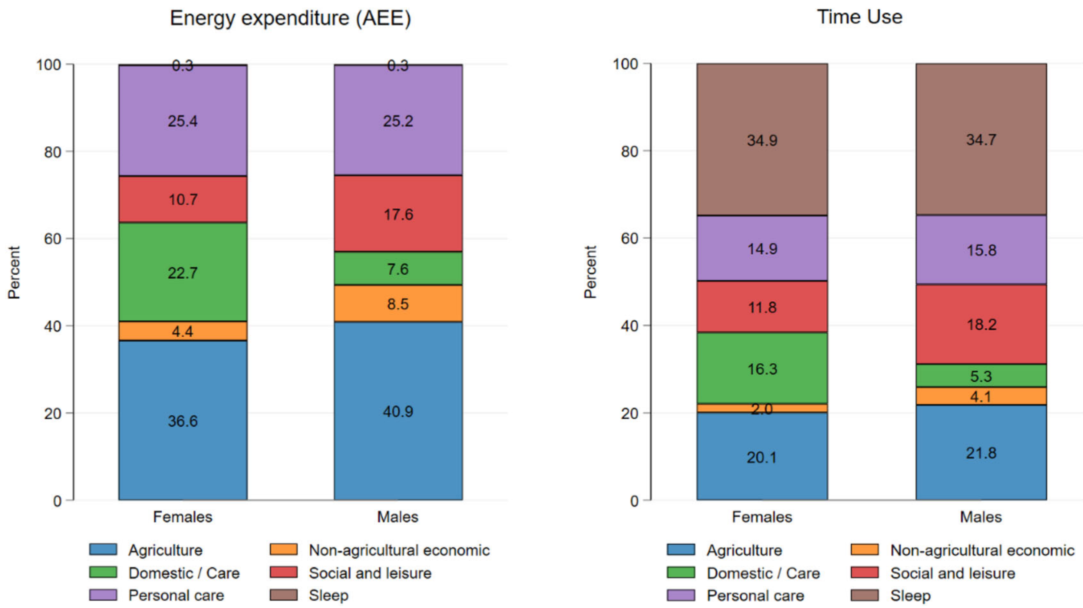

Figure 1. Proportions of energy expenditure (left) and time (right) per day, by gender on different activities.

proportion of waking hours is spent in agriculture-related activities. Men have a significantly higher Physical Activity Level (PAL) than women. Men spend almost half of their daily AEE in agriculture and non-agricultural economic activities, compared to 41% for women. This is associated with a greater time investment for men (26% versus 22% for women). Domestic activities are both more time-consuming and energy-intensive for women. They spend a significantly higher proportion of AEE (23%, nearly triple that of men) as well as time (16% versus 5% for men). For leisure activities, both the proportion of AEE and time allocation are higher for men than for women. This is consistent with previous findings (Picchioni et al., 2020) and it could reflect a difference in the type or intensity of leisure activities pursued by each gender. Energy and time involved in personal care activities and sleeping and resting are very similar for men and women.

Table 5 shows the energy intensity of activities at the major category level for men and women across three agricultural seasons (where the principal activity is respectively, fertiliser application/maintenance, harvesting, sowing/weeding). Detailed data on the energy intensity of specific activities for men and women across three seasons is presented in Supplementary Materials Appendix 1. Agricultural activities are the most energy intensive and they are closely matched by non-agricultural economic activities. Wage employment and work in public work programmes are in fact more energy intensive than agricultural activities on the farm (See Supplementary Materials Appendix 1). Women have lower energy intensity relative to men for all activities and we do not observe much variation in energy intensity of activities across the three seasons. For women, the energy intensity of domestic and care activities is only a third less than that of open-field agricultural activities, which highlights the drudgery of domestic and care activities faced by women. An interesting feature of the data is the high energy intensity of personal care and social and leisure activities relative to domestic and care activities. This may reflect the nature of these activities in rural LMIC settings. For instance, personal care activities such as bathing may be performed away from the homestead due to limited availability of sanitation and water supply infrastructure. Similarly, social and leisure activities such as participation in local festivals and community events may involve substantial physical activity.

Table 5. Energy intensity (kcals/hour) of different activities for men and women by agricultural season (S1–S3)

	Men			Women		
	S1	S2	S3	S1	S2	S3
Agriculture	44.81	47.01	43.24	30.34	30.81	29.66
Non-Agriculture economic	37.93	47.99	45.68	26.66	27.09	25.47
Domestic and care activity	33.86	33.25	25.58	21.30	19.73	21.10
Social and leisure	24.77	23.22	21.25	18.89	18.12	14.74
Personal care	30.48	30.65	28.47	21.82	21.82	20.89
Sleep	0.97	0.74	0.92	0.69	0.65	0.76

Note: Season S1, S2, and S3 capture fertiliser application, harvesting, and sowing/weeding respectively.

3.2. Effect of participation in agriculture on energy expenditure

The full results of the OLS and quantile regression modelling of AEE, KCALSCON, and CAR as a function of the ILR-transformed time use variables and household, individual, and other control variables are presented in Supplementary Materials Appendix 2. The results of the Hausman test used to decide the fixed effects versus random effects specification are presented in Supplementary Materials Appendix 3. The results show that unobserved individual characteristics are not correlated with the predictor variables. Hence the random effects model was chosen for the estimations. The main variable of interest in the compositional regressions is the ILR1 variable which has the time spent on agricultural activities as the 'lead' component (that is, it appears in the numerator). The coefficient of the ILR1 variable shows the effect on AEE/KCALSCON/CAR of an increase in the ratio of the daily time spent on agricultural activities to the geometric mean of the daily time spent on all other activities. Supplementary Materials Appendix 4 presents the results of the test of differences of the quantile regression coefficient of the ILR1 variable across quantiles for the three sets of regressions with AEE, KALSCON, and CAR as the dependent variables. The tests show that there are significant differences in the coefficients of the ILR 1 variable for some pairs of quantiles for AEE and CAR, but not for KCALSCON. For AEE, the ILR1 coefficients in the 75th quantile are significantly different from ILR1 coefficients of the 10th, 25th, and 50th quantiles. For CAR, the ILR1 coefficients of the 90th quantile are significantly different from those of the 10th, 25th, 50th, and 75th quantiles. These results suggest that there is limited variation in the effects of increased participation in agriculture over the conditional quantiles of AEE and CAR, although the magnitude of the differences is small. The coefficients of the ILR1 variable at different quantiles of the outcome variables are summarised in the Table 6 below.

The quantile regression plots of the ILR1 variable and their confidence intervals are presented in Figure 2.

The coefficient of the ILR1 variable is positive and significant for both AEE and KALSCON across all the quantiles. However, the coefficient of the ILR1 variable is not significant for CAR (except in the 90th quantile). These results suggest that an increase in the time spent on agricultural activities relative to that on all other activities is associated with an increase in energy demand and calorie intake. However, the increased energy demand due to increased participation in agriculture may be offset by increased calorie intake, leaving the CAR status of the individual largely unchanged. We discuss below the other significant variables in the regression results presented in Supplementary Materials Appendix 2.

Female gender is negatively associated with AEE and KALSCON across all quantiles, which reflects the lower energy intensity of activities taken up by women, including agricultural activities relative to men and the lower levels of calorie consumption of women relative to men.

Table 6. Ordinary least squares (OLS) and quantile regression estimates of the effects of time spent in agriculture on AEE, KCALSCON, and CAR across different quantiles (Q10 to Q90)

Dep. variable		OLS (RE)	Q10	Q25	Q50	Q75	Q90
AEE	Coefficient of ILR 1 variable	30.892*** (3.726)	19.908*** (3.632)	21.881*** (3.186)	24.042*** (4.379)	36.229*** (5.154)	37.805*** (11.750)
KCALSCON	Coefficient of ILR 1 variable	42.304*** (13.852)	60.937*** (14.882)	46.445*** (10.576)	35.968*** (12.569)	34.813 (22.335)	52.919*** (14.813)
CAR	Coefficient of ILR 1 variable	0.007 (0.009)	−0.002 (0.012)	0.004 (0.008)	0.005 (0.011)	0.010 (0.006)	0.028*** (0.009)

Notes: The **ILR1** variable is the isometric log transformed variable with the time spent in agriculture as the first component. With 5 categories of activities, $ILR1 = \sqrt{\frac{4}{5}} \cdot \ln \frac{\textit{time spent in agriculture}}{\textit{geometric mean of time spent in all other activities}}$. Q10, Q25, Q50, Q75, and Q90 represent 10th, 25th, 50th, 75th, and 90th quantiles respectively. Standard errors in parentheses. Asterisks indicate level of significance (*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$).

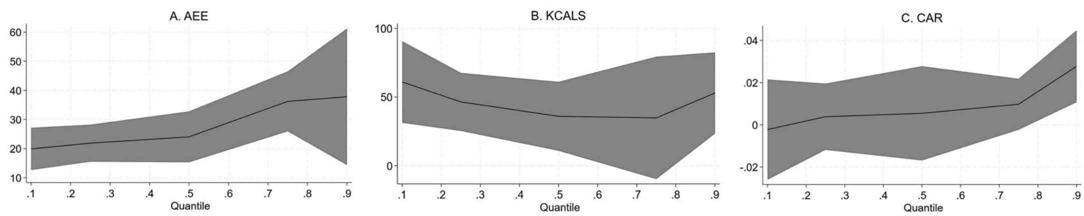

Figure 2. Quantile regression plots of ILR1 variable.

However, female gender has a positive association with CAR. This suggests that improvements in CAR following greater participation in agricultural activities are greater for women than for men, that is the offsetting effects of larger calorie intake on increased energy expenditure are greater for women. Age of respondents has negative association with both AEE and KALSCON in most quantiles suggesting decreasing energy intensity of activities and lower calorie consumption as age increases. However, age has no significant effect on CAR in any quantile. One of the village dummies (Mathadiguda village) is significant and has a negative association with AEE and a positive association with CAR across all quantiles. This may reflect better infrastructure (for example transport or access to markets) or mechanisation in relation to the base village leading to lower AEE and improved CAR with similar levels of calorie intake. The presence of a larger number adult and elderly women in the household appears to lower AEE for the respondents although the effects are significant only in some quantiles. This may reflect the sharing of domestic and care activities in a household when more adult or elderly women are present. The presence of a larger number of elderly and adult men, however, appears to increase the AEE for respondents in some quantiles. The presence of a larger number of elderly men has a negative effect on KCALSCON and CAR for the respondents in some quantiles which may reflect the larger burden of care for elderly men. The seasonal dummies are significant and positively associated across quantiles with KALSCON and CAR but not with AEE. This may reflect the better availability of food in the harvesting season and at the start of the sowing season relative to the season when maintenance activities such as fertiliser application, weeding, and irrigation are taken up.

The coefficients of the ILR1 variable cannot be interpreted as the change in AEE/KCALSCON/CAR for a unit change (1 minute) in the time devoted to agriculture. To estimate the average marginal effect of a 60-minute increase in agricultural activities, and a corresponding decrease in a specific activity (for example domestic and care activities), we use the following procedure. Using the compositional regression estimated, we predict the AEE and

KCALSCON values for a modified data set in which the time allocated to agriculture is increased by 60 minutes and time allocated to another specific activity is decreased by 60 minutes for each observation. The mean of the differences in the predicted values of AEE from the modified data set and the original data set is taken as the average marginal effect of a 60 minutes increase in agricultural activity with a 60-minute reduction in another specific activity. We do this exercise for a 60-minute increase in agricultural activity and a corresponding decrease in the time devoted to (1) domestic and care activities, (2) social and leisure activities, (3) personal care, and (4) sleep, separately. Table 7 summarises the change in AEE and KCALSCON when the time devoted to agriculture increases 60 minutes for different quantiles of the outcome variable.

In interpreting the figures for changes in AEE for a 60-minute increase in agricultural activity when substituted for other activities, we need to keep in mind the compositional nature of the time use variable, that is a 60-minute increase in agricultural activity always accompanied by a 60-minute decrease in some other activity. The change in AEE, therefore, depends on the relative energy intensity of agricultural activity and the activity which is substituted. While we would generally expect the increase in AEE to be the largest when agricultural activity substitutes for sleep (where AEE = 0), this may not always be the case, for example when very low intensity social activity is substituted with very high intensity agricultural activity. In Table 7, the largest increases in AEE occur when agricultural activity replaces sleep or social activity. The next largest increases occur when agricultural activity replaces domestic and care activities. A 60-minute increase in agricultural activity increases AEE across quantiles by 25–38 calories when replacing social and leisure activities, 8–44 calories when replacing domestic and care activities. The negative values for changes in AEE when agriculture substitutes personal care activities are somewhat counterintuitive. However, they may reflect the relative energy intensity of personal care activities and agricultural activities in different quantiles of AEE. The changes in AEE associated with a 60-minute increase in agricultural activity highlight the high energy intensity of non-agricultural activities relative to agriculture. The high energy intensity of domestic and care activities and personal care activities may reflect the nature of these activities in rural LMICs settings. The relatively high energy intensity of these activities may account for the modest increase in AEE with increased agricultural participation, despite the high energy intensity of agricultural work. Table 7 also shows that with the exception of personal care, in all quantiles, the increased energy expenditure associated with women's greater participation in agriculture is generally more than offset by the increased calorie consumption. Therefore, increased AEE due to greater participation in agriculture is unlikely to significantly impact calorie adequacy for women in these settings. Personal care activities include the time devoted to eating and personal upkeep. The reduction in calories consumed when agriculture substitutes for personal care activities suggest that calorie intake may be adversely affected when participation in agriculture is at the expense of personal care including time spent in eating.

3.3. Effect of participation in agriculture on time-use

Figure 3 shows the proportion of time spent by women on different activities across the quintiles of proportion of daily time spent on agricultural activities. In the bottom quintile, women do not spend any time on agricultural activities while in the top quintile women spend more than a third of their daily time on such activities. Table 8 shows the results of the Bonferroni multiple comparisons test of differences in the proportion of time spent on six major categories of activities between the five different quintiles.

Figure 3 provides a visual representation of changes in the patterns of time use of women as the proportion of time devoted to agriculture increases. An increase in the proportion of time spent on agricultural activities is associated with a decrease in the proportion of time spent on domestic and child care activities, leisure, and sleep. A comparison of the top and bottom

Table 7. Change in activity energy expenditure (AEE) and total calorie consumption (KCALSCON) for a 60-minute increase in agricultural activity replacing other specific activities across quintiles (Q10–Q90)

	AEE					KCALS				
	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90
Domestic and care activity	8***	12***	19***	33***	44***	8***	12***	19***	33***	44***
Social and leisure activity	28***	30***	26***	38***	25***	28***	30***	26***	38***	25***
Personal care activity	−4***	−2	3*	27***	27***	−4***	−2	3*	27***	27***
Sleep	25***	26***	27***	33***	35***	25***	26***	27***	33***	35***

Notes: Q10, Q25, Q50, Q75, and Q90 represent 10th, 25th, 50th, 75th, and 90th quantiles respectively. Asterisks indicate level of significance (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

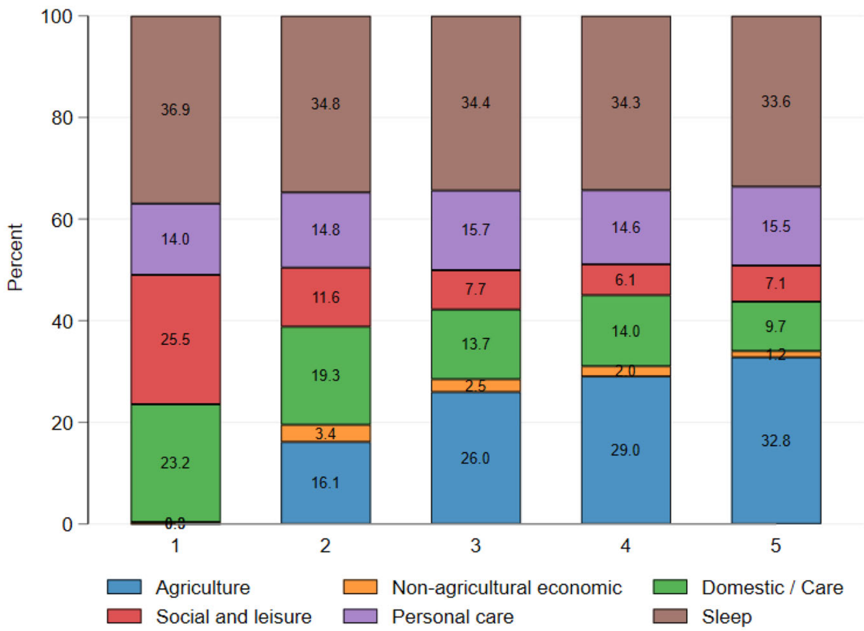

Figure 3. Time use patterns of women by quantiles of proportion of time spent on agricultural activities. *Note*: Figures computed from 700 day level observations for which data were available on time-use, energy expenditure, and food consumption.

quintiles shows that women who spend the highest proportion of time on agricultural activities spend significantly less time on domestic and child care activities (−13.5 percentage points), leisure (−18.4 percentage points), and sleep (−3.3% percentage points[11]). The Bonferroni multiple comparisons test shows that the differences in the proportion of time spent on domestic and child care activities, leisure, and sleep across agricultural time use quintiles are significant (except across the top quintiles). The changes in the patterns of time use across the quintiles illustrate the nature of trade-offs faced by women when they increase their participation in agriculture. The decline in the proportion of time spent in domestic and child care activities can have implications for women's own nutritional status and also the nutritional status of children and other household members (for example via the time spent for food preparation, feeding children, care for the elderly, and so forth). Greater participation in agriculture also appears to involve a large sacrifice of women's leisure time with implications for their wellbeing.

Table 8. Test of differences of proportion of time spent on different activities between quintiles of daily time devoted to agricultural activities by women

Quintiles being compared	Agriculture	Non-Agriculture economic	Domestic and child care	Leisure	Personal care	Sleeping and sleeping
1–2	0.161***	0.030***	−0.039**	−0.138***	0.007	−0.022*
1–3	0.259***	0.022***	−0.095***	−0.178***	0.017**	−0.026**
1–4	0.290***	0.017***	−0.092***	−0.194***	0.005	−0.026**
1–5	**0.328*****	**0.009**	**−0.135*****	**−0.184*****	**0.015**	**−0.033*****
2–3	0.098***	−0.009	−0.056***	−0.039***	0.009	−0.004
2–4	0.129***	−0.014**	−0.053***	−0.055***	−0.002	−0.004
2–5	0.167***	−0.022***	−0.096***	−0.045***	0.007	−0.011
3–4	0.031***	−0.005	0.003	−0.016	−0.011	0.000
3–5	0.068***	−0.013*	−0.040**	−0.006	−0.002	−0.007
4–5	0.038***	−0.008	−0.043**	0.01	0.01	−0.007

Notes: Differences are captured with a one-way analysis of variance (Bonferroni multiple-comparison test). *** 1 per cent significant, ** 5 per cent significant.

4. Discussion

Participation in agriculture in rural LMIC settings is generally associated with physically demanding, strenuous work with high energy intensity. Greater participation by women in agricultural work could, therefore, be expected to substantially increase the energy demands on women. Our results suggest that greater participation of women in agricultural work is associated with increases in the overall energy demands placed on women. However, the increases in energy expenditure are relatively modest, notwithstanding the high energy intensity of agricultural activities observed in the data. This counterintuitive finding is attributable to the relatively high energy intensity of domestic and care activities that are substituted by agricultural work. As seen from Table 4, for women several domestic and care activities are nearly as energy intensive as agricultural activities. It is the arduous and physically demanding nature of domestic and care activities and even personal care activities in rural LMIC settings that accounts for the very modest increases in the overall energy demands when women devote more time to agriculture. Women's greater participation in agriculture is also associated with higher calorie consumption, which may offset the increased energy demands, leaving women's nutritional status in terms of calorie adequacy unchanged. An interesting implication is that reduction in the energy intensity of agricultural work (through mechanisation, improved implements, and practices) may not substantially reduce the overall energy expenditures of women. The reduction in energy intensity of domestic and care activities – through appliances for domestic chores, infrastructure for provision of fuel, water, and so forth– may offer a more important route to reducing women's work burdens and improving their nutrition.

Our results also suggest that changes in the time-use patterns of women associated with the feminisation process – especially the trade-off against domestic work and care activities – may have a larger influence on women's nutritional status than the energy demand pathway. While our results suggest that greater participation in agriculture has no significant effect on women's own calorie adequacy, changes in the time use patterns may still affect women's own and the household's dietary quality and diversity. The effects on dietary quality and diversity may arise on account of the reduced time available for cooking, procuring food, and for childcare. In a study with evidence from Bangladesh, Nepal, Cambodia, Ghana, and Mozambique, Komatsu, Malapit, and Theis (2018) find that women's time spent in domestic work and cooking time are positively correlated with more diverse diets and long hours spent in agriculture may be negatively associated with dietary diversity in certain socio-economic contexts. Other impacts on women's health and wellbeing may arise from the significant sacrifice of leisure and sleep associated with increased participation in agriculture which may affect their ability to rest and recover from the rigours of agricultural work.

Agricultural development interventions aimed at productivity enhancement that call for greater participation by women need to carefully consider the implications for women's time use in specific socio-cultural contexts. If productivity enhancement is to translate into improvements in nutritional status, women need to be supported to address the issues arising from the reduced availability of time for domestic and care activities and for leisure. The nature of this support may need to extend beyond drudgery reduction on the farm through mechanisation, improved implements and practices. It may need to extend to reduction in the drudgery of domestic and care activities. It would also call for a reorganisation of domestic roles within rural households to address the sharp gender inequity in the allocation of domestic and care work and access to leisure and recuperation time within households.

5. Conclusion

Feminisation of agriculture observed in several LMICs may be driven by diverse factors ranging from economic development, agricultural intensification, productivity enhancing interventions, or agricultural stagnation and rural distress. The nutritional status outcomes for women resulting from greater participation in agriculture are still debated. We provide empirical evidence on two proximate pathways of impact of feminisation on women's nutritional status. We find that incremental energy demands on women consequent to increased participation in agriculture may be modest, principally because of the high energy intensity of domestic and care activities that are substituted when more time is devoted to agriculture. The incremental energy demands may be offset by the additional calorie intake associated with increased participation in agriculture. The nutritional impacts on women may flow more from the changes in time use patterns of women associated with greater participation in agriculture. Understanding the nutritional and wellbeing effects of feminisation requires a careful consideration of its impact on women's time allocation. For feminisation to translate into improved nutritional status, women may need to be supported both on and off the farm to address the complex trade-offs they face as they increase their participation in agriculture.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes

1. An individual's physical work capacity (PWC) is given by the maximum volume of oxygen (VO_2 max) that can be consumed in performing activity (Jackson & Palmer-Jones, 1999). This capacity reflects the maximum rate at which aerobic activity can be undertaken. Work which is below an individual's PWC can be sustained for a longer period. The effort or stress associated with physical activity depends on the intensity of work in relation to the PWC of an individual. A sustainable daily level of work is stated to be around 35 per cent of PWC (Åstrand, Rodahl, Dahl, & Stromme, 2003).
2. 'Scheduled' refers to schedules in the Indian constitution identifying socially and economically deprived/ marginalised caste groups and tribal (indigenous) groups as being entitled to affirmative actions in education, employment, and development programs.
3. 1 USD averaged 67.21 Indian Rupees in 2016 (Source: Reserve Bank of India).
4. 'Economically active' refers to individuals aged 18–64 years who are capable of undertaking agricultural or non-agricultural activities outside the household. Individuals not capable of taking up such work due to health, disability, or other constraints were excluded.
5. A total of 37 different households and 74 individuals participated in the three rounds of data collection.
6. This approach to data collection on energy expenditure, time use, and food intake has been discussed in Zanello et al. (2020).

7. The BMR is the the amount of energy (calories) an individual needs to keep the body functioning at rest. There are several different algorithms for estimating the BMR for an individual. In this paper we have used the equation for predicting the BMR developed by Mifflin et al. (1990) to calculate the BMR of the survey respondents.
8. Food intake data was available for fewer days than energy expenditure and time use data. This was because the duration of wear of the accelerometers (for obtaining energy expenditure data) was not completely synchronised with the collection of data on food intakes using 24 hour recall. Some zero or very low-calorie observations for food intakes (for example due to fasting or other reasons) were also deleted from the data set used for analysis.
9. As explained later in the paper, agriculture and non-agriculture economic activities were merged into a single category for estimations as there were very few observations related to non-agriculture economic activities.
10. The differences between men and women on the time spent on sleep may not be accurately captured by these figures owing to the assumption made in the time use survey that all respondents are asleep from 11 PM to 5 AM.
11. The differences in proportion of time spent on sleep are relatively small, but this may partly be an artefact of the data, which assumed that all individuals are asleep between 11 PM and 5 AM (unless they reported otherwise).

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