Food security mediates the decrease in women's depressive symptoms in a participatory nutrition-sensitive agroecology intervention in rural Tanzania

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Abstract

Objective: To investigate if food security mediated the impact of a nutrition-sensitive agroecology intervention on women's depressive symptoms.
Design: We used annual longitudinal data (four time points) from a cluster-randomised effectiveness trial of a participatory nutrition-sensitive agroecology intervention, the Singida Nutrition and Agroecology Project. Structural equation modelling estimation of total, natural direct and natural indirect effects was used to investigate food security's role in the intervention's impact on women's risk of probable depression (Center for Epidemiologic Studies Depression Scale > 17) across 3 years.
Setting: Rural Singida, Tanzania.
Participants: 548 food insecure, married, smallholder women farmers with children < 1 year old at baseline.
Results: At baseline, one-third of the women in each group had probable depression (Control: 32·0 %, Intervention: 31·9 %, *P* difference = 0·97). The intervention lowered the odds of probable depression by 43 % (OR = 0·57, 95 % CI: 0·43, 0·70). Differences in food insecurity explained approximately 10 percentage points of the effects of the intervention on odds of probable depression (OR = 0·90, 95 % CI: 0·83, 0·95).
Conclusions: This is the first evidence of the strong, positive effect that lowering food insecurity has on reducing women's depressive symptoms. Nutrition-sensitive agricultural interventions can have broader impacts than previously demonstrated, i.e. improvements in mental health; changes in food security play an important causal role in this pathway. As such, these data suggest participatory nutrition-sensitive agroecology interventions have the potential to be an accessible method of improving women's well-being in farming communities.

Depression is a leading cause of disability worldwide[1]. In 2017, depressive disorders ranked as the third leading cause of disability globally and led to over 40 million years lived with disability lost in low- and middle-income countries[2]. Furthermore, the burden of depressive disorders

continues to rise globally[3,4]. The economic consequences of mental disorders are severe, and the global economy is estimated to lose over US$16 trillion between 2010 and 2030, driven partly by early onset of mental health conditions and subsequent productivity loss across the life course[3,5]. Depression is associated with poor quality of life, cognitive impairment, negative physical health

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outcomes such as cardio- and cerebrovascular diseases and higher levels of mortality[3,6,7]; it is also a point of concern for individuals with substance abuse disorders and dementia[3]. Moreover, parental depression can also impede the capacity to provide quality childcare[8–10], therefore casting negative downstream effects to children[11–14]. As such, the need to reduce mortality, morbidity and disability from mental disorders was identified as a specific target within the 2030 Sustainable Development Goals (SDGs) #3[3]. Additionally, the WHO has emphasised the importance of strengthening the prevention and treatment of mental health in their Mental Health Action Plan (2013–2020)[15].

A complicated and dynamic web of risk factors interact to cause depression. In addition to biological and developmental factors, such as serotonin and dopamine metabolism[16], socio-environmental influences have an integral and modifiable role in depression[3]. Specifically, these determinants include political and environmental factors (e.g. climate change, clean water and violence); social and cultural factors (e.g. education and social support); demographic factors (e.g. age, sex and ethnicity) and economic factors (e.g. food security, employment and assets)[3,17]. The influence and interaction of economic and demographic factors are demonstrated by the fact that the prevalence of depression is consistently higher in women than in men[1,18,19], especially in low- and middle-income countries[1,20].

Food security, defined as adequate access to the quality and quantity of food needed for an active and healthy life[21], plays a prominent role in mental health[21]. The link between food security and mental health has been found to be bidirectional[22] and is posited to operate through biological[23] and psychosocial pathways[24,25]. Biological pathways include inadequate access to nutritious foods leading to nutritional deficiencies associated with poor mental health status[23,26,27] and physical effects associated with food insecurity, such as stomach aches and headaches, which can impact mental health status[26,28]. Psychosocial pathways include inadequate access to sufficient preferred food creating stress[24,25,29–32] and experiences of stigma from not being able to fulfil social expectations of providing food for the household[33].

Empirical findings demonstrate the association between food security and women's depression. Cross-sectional observational evidence from Weaver and Hadley's systematic review[24], Pourmotabbed et al.'s systematic review[34] and Tribble et al.'s meta-analysis[35] demonstrate this relationship. Longitudinal studies from multiple countries, including Tanzania[25], India[36] and Uganda[37], strengthen this evidence since they all found that food-insecure women were more likely to experience depressive symptoms. Multiple studies, including Tribble et al. (unpublished results) and Weaver and Hadley[24], have called for the need to further explore the directionality between food security and depression in order to establish causality. The study by Huddleston-Casas et al.[22] is the only work,

to our knowledge, in which a causal link between food security and depression is stated. This conclusion was reached using data from three annual cross-sectional surveys in a high-income country (the US), analysed using structural equation modelling (SEM)[38]. As such, there is still a need for stronger, interventional evidence of a causal relationship between food security and depressive symptoms, especially in low-income countries.

Even without strong evidence that food insecurity causes depression, there is still a strong push to address food security as a depression reduction strategy. For example, in their review on global mental health literature in the context of SDG targets, the Lancet Commission on global mental health emphasised the importance of addressing social determinants of mental health by meeting various SDG[3] in addition to addressing the stigma, cost and availability barriers of psychological therapies[3,39,40]. The Commission even specifically recommends policymakers to 'reduce the prevalence of depression through improved food security'[3]. This approach to depression reduction may be important because although there are known and effective treatments for mental disorders, a significant proportion of people affected by depression in low- and middle-income countries never receive such treatments[41]. The Commission's recommendation was also echoed by the WHO Mental Health Action Plan for 2013–2020[15] and global health academics, such as Tsai[30] and Hadley[42].

Nutrition-sensitive agriculture interventions, i.e. agricultural interventions aimed to improve underlying determinants of nutrition[43,44] are one example of interventions to address food insecurity. Agroecology, a holistic approach to growing food using ecological methods, such as crop diversification and compost, and concurrently addresses the health, social and economic inequities of the food system, is another[45]. Both approaches are expected to improve food security by improving the diversity of household agricultural production, increasing household resilience in times of climatic shock and improving women's nutritional knowledge, input to and control over household and agricultural decisions[43,46]. There is evidence in support of these mechanisms. For example, a systematic review of nutrition-sensitive agriculture interventions found that they have consistently improved the dietary diversity of their participants[44]. In Zambia, a nutrition-sensitive agriculture study improved food access, one facet of food security, over 4 years of interventions[46]. A participatory nutrition-sensitive agroecology intervention in Malawi, which incorporated lessons on gender equity, nutrition and ecological approaches to agriculture, increased food security after 2 years[47].

Despite the plausibility of nutrition-sensitive agriculture and agroecology (in particular, because of its emphasis on equity) to improve mental health, there is a dearth of empirical evidence to support this relationship. In fact, we believe our recent finding that a participatory nutrition-sensitive agroecology intervention reduced the prevalence of probable depression is the first agricultural intervention to

report positive mental health impacts[48]. Specifically, we found that Singida Nutrition and Agroecology Project (SNAP-Tz) reduced the prevalence of probable depression among Tanzanian women farmers by 11·4 percentage points. However, the role of food security in this impact remains unclear.

We, therefore, investigated the plausible but untested potential for changes in food security to drive the decrease in the prevalence of probable depression among women smallholder farmers in SNAP-Tz. We first assessed covariate associations of probable depression at the baseline and then conducted mediation analyses modelling probable depression after 3 years, controlling for these covariates.

Methods

Study design & settings

The current study took place in the Singida rural district of Tanzania's semi-arid central region. In Tanzania, depressive disorders have increased by 35 % between 2007 and 2017 and are ranked as the third leading cause of disability[49]. While these rates may be increasing due in part to the more frequent measurement of mental health outcomes, the prevalence suggests that depressive disorders are a significant issue. Smallholder farming is the primary source of livelihood in Singida; households cultivate an average of 2·15 ha[50]. Food insecurity is also a persistent issue for the majority of smallholder households in rural Tanzania[51,52]. In 2012, 49 % of households in the Singida region had poor household dietary diversity, an indicator of food insecurity[50].

Intervention

The Singida Nutrition and Agroecology Project (SNAP-Tz; NCT02761876) was a cluster-randomised effectiveness trial that investigated the effects of a participatory, nutrition-sensitive, agroecological intervention on improving child's diet through improvements in food security, sustainable agriculture, gender equity and women's well-being[48,53,54]. In-depth details on study design are reported elsewhere[53,54]. Briefly, the intervention consisted of a male and female 'mentor farmer' leading their village peers in participatory learning about sustainable farming, legume intensification, nutrition and women's empowerment.

The study enrolled 598 households: 25–30 households from each of twenty villages, with ten villages randomised to receive the intervention and the other ten to receive the intervention at the end of the study. Village selection criteria included their village leadership's willingness to participate in the study, having more than 200 children under 5 years, and not participating in other interventions. Twenty villages were ultimately included and paired based on the number of months of food security, predominant soil type and proximity to health clinics. Household eligibility criteria included

(1) being food insecure as defined by the community; (2) having a child under one year old in Jan 2016; (3) having access to land and planning to farm in the coming year; (4) intending to reside in that village for the next 3 years and (5) being interested in experimenting with new farming techniques. From amongst these households, two 'mentor farmers' (one man, one woman) were elected by participating households in each village to facilitate participatory learning on nutrition-sensitive agriculture.

The twenty mentor farmers from the ten intervention villages were trained on nutrition-sensitive agroecology during a farmer-to-farmer learning exchange with Malawian farmers[47] and the Farming for Change curriculum[53]. The curriculum encouraged participatory learning methods, e.g. experiential-based learning and theatre, to educate smallholder farmers with limited literacy on topics of agroecology, climate change, nutrition, gender and social equity. The mentor farmers then facilitated learning exchanges on curriculum topics during monthly community meetings and regular household visits. Additionally, each participating household received a mix of legume seeds (e.g. cowpea, pigeon pea, groundnut and soya), adequate to plant 0·1 ha at the beginning of the farming season during the first 2 years of the study.

For the current analysis, we only included married women (*n* 548) from the study because the relationship of food insecurity and depression would likely greatly differ from single and widowed women[55,56].

Data collection

Four annual household surveys were conducted between 2016 and 2019 using questionnaires administered by local enumerators at the participant's residence or public village meeting place. The data collection team consisted of twenty local enumerators, and each survey took about 1 hour to administer. Survey pre-testing was performed to ensure participant comprehension and accurate outcome measurement within the questionnaire.

Key outcomes

Depressive symptoms were evaluated using the Center for Epidemiologic Studies Depression Scale (range: 0–60)[57]. The Center for Epidemiologic Studies Depression Scale is composed of 20 items that query the frequency (0 = rarely or never, 1 = sometimes and 2 = often, 3 = most of the time) with which participants have experienced various depressive symptoms, such as sadness and trouble sleeping in the past week. Probable depression was modelled as a binary outcome (Center for Epidemiologic Studies Depression Scale > 17), and this cut-off was validated among a similar population in East Africa[58].

Food security was measured using the Household Food Insecurity Access Scale (range: 0–27); higher values indicate greater insecurity[59]. Women and men were jointly asked to report their household access to food in the prior month. Household Food Insecurity Access Scale has been

used broadly to assess food security in rural Sub-Saharan Africa[60], including in Tanzania[61] and Malawi[47]. Food insecurity was modelled as a continuous variable throughout the analyses.

Covariates

A variety of sociodemographic information was collected across all time points (2016–2019). Covariates assessed for confounding include marital status (monogamous or polygamous), farming as main occupation, ethnic group (Nyaturu or other ethnic groups), religion (Muslim or other religion), years of education, years lived in village before 2016 and dependency ratio, calculated as the number of children (≤ 14) and elders (> 65) divided by number of household members between the ages of 15 and 64[62]. The indicator for household wealth was tertiles of an index derived from a principal component analysis of self-reported household asset ownership of thirty-three items in January 2016.

Indicators of social support and gender equity were also assessed as potential confounders of the relationship between food security and depressive symptoms since they have previously been found to be associated with food security and depressive symptoms[36,63–71]. Social support was indicated using an adapted version of Duke's Perceived Social Support Scale[72] (range: 0–40), where women were asked to what extent they liked the amount of help they received in ten different circumstances, such as when they are sick or during household work. Those with a mean social support score ≥ 3 were considered as having low social support, based on Antelman and colleagues' previous use of the scale in urban Tanzania[72].

Gender equity indicators include measures of women's experience with and attitude towards domestic violence, the burden of household work and decision-making power. Domestic violence experience was measured by asking if participants had experiences with any emotional, financial, sexual or physical violence with any family members living inside or outside of the household over the past year (dichotomous). Attitude towards domestic violence was then measured by asking participants if physical violence was justified in seven scenarios (range: 0–7)[73]. Two additional indicators of women's burden of household work were included. One was men's involvement with seven household chores commonly perceived as 'women's work', such as fetching water, within the past month. The mean number of these activities was then calculated (range: 0–1)[74]. The other was the number of leisure hours women had in the previous 24 h[75]. Finally, women were asked if and to what extent they had decision-making power within agricultural and income allocation activities; these items came from the Women's Empowerment in Agriculture Index questions[75]. Responses were scored no/little = 0, some = 0·5 and final say = 1, and the mean of the seven responses was calculated (range: 0–1). We used linear splines to split income allocation decision-making scores

between groups (0–0·4 v. 0·41–1) because exploratory analysis indicated that the association between probable depression and income allocation decision-making power differs between the two groups (online supplementary material, Supplemental Figure S1). This difference in the nature of the association between the two groups is consistent with previous work that reported that women having more say in decision making without adequate resources was associated with dissatisfaction and social stress[76].

Data analysis

Evaluating predictors of probable depression

We first described baseline characteristics between study arms using t-tests and Pearson χ^2 tests as appropriate. Standard errors were adjusted for village-level clustering in all cases.

To assess associations of covariates with probable depression at baseline, we calculated risk ratios (RR) for all covariates, including demographics, gender equity, social support and physical health variables, using log-binomial regression models (Table 1). We then used a Poisson approximation to a log-binomial multivariable regression model due to convergence issues, including all significant variables from the bivariate risk ratio estimates (Table 1). Finally, backwards stepwise model selection[77] was used until all variables remaining in the model were significant ($P < 0.05$). We chose to keep maternal social support in the final model due to epidemiologic reasoning and previous literature demonstrating relationships between social support, food insecurity and depressive symptoms[30,33,78]. Adjusted risk ratios (aRR) were calculated from this parsimonious model (Table 1). Standard errors for all models accounted for clustering at the village level. These analyses were performed using Stata 16[79].

Mediation analysis

To understand food insecurity's role in the intervention's impact on women's depressive symptoms between 2016 and 2019, we carried out mediation analyses using structural equation modelling estimation of total, natural direct and natural indirect effects[80]. In the current analysis, the total effect is an estimate of how much odds of probable depression would change if the control group received the interventions. The natural direct effect is an estimate of the effect of the intervention on odds of probable depression as if the intervention had no impact on food security. The calculation of the natural direct effect contrasts the depression scores of the intervention group with the control group, assuming that food security values are those that participants would have had in absence of the intervention, regardless of their intervention assignment. The natural indirect effect represents the effect of the intervention that is due to the effect of the intervention on food security[81] (i.e. the proportion of the intervention effect that is mediated by food security), contrasting the food security values that participants would

Table 1 The risk of probable depression (CES-D > 17) at baseline of SNAP-Tz (January 2016) in bivariate and multivariate models. Food insecurity, domestic violence experience, men's involvement with household chores typically done by women and higher income allocation decision-making power were significantly associated with a greater likelihood of probable depression among smallholder farmers in Tanzania in log-binomial multivariable regression (*n* 548)

Variable	Risk Ratio (RR)	95 % CI	Adjust Risk Ratio (aRR)	95 % CI
Intervention	1·00	0·75, 1·32	–	–
Key outcome				
Household Food Insecurity Access Scale (0–27)	1·07*	1·05, 1·10	1·06*	1·03, 1·08
Demographics				
Farming as main occupation (ref: any other)	1·07	0·36, 3·16	–	–
Monogamous marital status (ref: polygamous)	1·57*	1·16, 2·12	–	–
Nyaturu ethnic group (ref: Nyiramba or other)	0·96	0·49, 1·86	–	–
Muslim (ref: Christian, Traditional African, none)	0·96	0·69, 1·33	–	–
Wealth Tertiles†				
Poorest	Ref	–	–	–
Middle	0·83	0·66, 1·04	–	–
Wealthiest	0·91	0·70, 1·19	–	–
Dependency ratio‡	1·08	0·92, 1·28	–	–
Age (years)	1·02*	1·01, 1·04	–	–
Years of education	0·99	0·96, 1·03	–	–
Years lived in village	1·02*	1·01, 1·03	–	–
Adequate social support§ (≥ 3 out of 4)	0·78	0·56, 1·10	0·76	0·56, 1·04
Gender equity				
Experienced any domestic violence‖	1·91*	1·47, 2·47	1·47*	1·15, 1·89)
Attitude towards domestic violence (0–7)¶	1·08*	1·02, 1·13	–	–
Leisure time (hours)	1·00	0·92, 1·08	–	–
Agricultural decision-making power (0–1)††	1·84	0·89, 3·79	–	–
Income allocation decision-making power (0–1)††	2·76*	1·48, 5·15	–	–
Low-income allocation decision-making power (0–0·4)	0·60	0·14, 2·53	–	–
High-income allocation decision-making power (0·4–1)	6·42*	3·31, 12·45	2·90*	1·79, 4·69
Men's involvement with household chores (0–1)	0·37*	0·23, 0·60	0·60**	0·40, 0·90

*$P < 0.01$; **$P < 0.05$.
†Wealth tertile is based on asset index score, developed using principal component analysis from household's ownerships of any land, metal roof, electricity, ox plow, solar panels, cell phone, radio, modern beds, mosquito net, books, bicycle and cattle.
‡Dependency ratio calculated as number of children (< 14 years) and elders (> 65 years) divided by number of adult household members (15–64 years).
§Cut-off from Antelman et al.[72].
‖In the past year.
¶World Bank indicator[73].
††Modified Women's Empowerment in Agriculture Index[75].

have had under the intervention *v.* control if all participants had undergone the intervention.

Probable depression was modelled as a binary outcome (Center for Epidemiologic Studies Depression Scale > 17) and food insecurity as a continuous mediator (assuming a normal kernel). Income allocation decision-making power, men's involvement with household chores typically done by women, domestic violence experience and social support were *a priori* identified as time-varying confounders of the mediator–outcome relationship and subsequently controlled for in mediation analyses. To ensure temporality of the mediation analysis, time-varying confounders measured during the prior year were used in models for the subsequent mediator (food insecurity scores) and subsequent outcome (probable depression). For example, the 2016 time-varying confounder data were used in models of food insecurity and probable depression in 2017, and time-varying confounder data from 2017 were used in models of food insecurity and probable depression from 2018. Moreover, as neither food insecurity nor probable depression was significantly different between groups at baseline in 2016 (online supplementary material,

Supplemental Table S1), baseline food insecurity nor probable depression status were not considered as potential confounders of the mediator–outcome relationship. Mediation analyses were performed via the 'mediation' macro in SAS 9.4[82,83].

Missing data
Baseline missing values ranged from 0 to 6 % for all variables (online supplementary material, Supplemental Table S2), while the number of missing values for probable depression, food insecurity and covariates ranged from 0 to 13 % during follow-up (from 2017 to 2019) (online supplementary material, Supplemental Table S3). Study attrition differed by participant age, ethnic group and length of time living in the village before the study baseline, so these characteristics were included in the imputation models, along with all confounders, mediators and outcomes discussed above (online supplementary material, Supplemental Table S4). Imputation with chained equations with 20 iterations was used to impute missing values of probable depression, food insecurity and covariate data at each time point[84]. For imputed values below zero or

outside of score ranges, post-estimate rounding was used to adjust values into range. Imputation was performed using Stata 16[79].

Results

Characteristics at baseline

The majority of women enrolled in the study were married monogamously, of the Nyaturu ethnic group, and reported farming as their main occupation (online supplementary material, Supplemental Table S1). On average, they were about 30 years old. At baseline, one-third of the married women in each group had probable depression (Control (C): 32·0 %, Intervention (I): 31·9 %, *P* difference = 0·97, Table S1). More than three-quarters of participants experienced moderate to severe food insecurity (C: 86·9 %, I: 86·5 %, *P* difference = 0·63, online supplementary material, Supplemental Table S1).

Baseline covariate associations with probable depression

At baseline, probable depression was associated with food insecurity, any experience of domestic violence, high income-allocation decision-making power and lack of men's involvement with household chores typically done by women (Table 1). Women who experienced higher food insecurity were at a higher risk of probable depression (aRR = 1·06, 95 % CI: 1·03, 1·08). Measures of gender inequity were also correlated with increased risk of probable depression: married women who experienced domestic violence were at higher risk of probable depression (aRR = 1·47, 95 % CI: 1·15, 1·89, Table 1). Income allocation decision-making power scores higher than 0·4 were associated with an increased risk of probable depression (aRR = 2·90, 95 % CI: 1·79, 4·69), while scores 0–0·4 did not have any significant association with risk of probable depression (Table 1). On the other hand, women who reported men being involved with household chores typically done by women were associated with a decreased risk of probable depression (aRR = 0·60, 95 % CI: 0·40, 0·90). Notably, there were no significant associations between risk of probable depression and social support, dependency ratio, wealth tertiles, occupation, age, marital status, amount of leisure time and education. Sensitivity analyses modelling depression as a continuous variable demonstrated similar results (online supplementary material, Supplemental Table S5).

Mediation analysis

The intervention lowered the odds of probable depression by 43 % (total effect OR = 0·57, 95 % CI: 0·43, 0·70) (Fig. 1a). Differences in food insecurity explained approximately 10 percentage points of the effects of the intervention on odds of probable depression (natural indirect effect
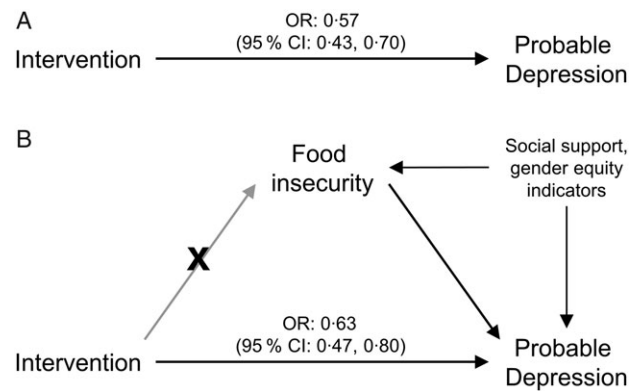

Fig. 1 Diagrams of total effect (Panel A) and natural direct effect (Panel B) estimates for mediation of food insecurity in the nutrition-sensitive agroecology intervention's impact on odds of probable depression (SNAP-Tz) (*n* 548). OR with 95 % CI shown correspond to each indicated pathway and 'X' represents the muted effect of the intervention on food insecurity in the calculation of the natural direct effect. MI, Men's involvement with household chores typically done by women; DVE, domestic violence experience; INC, income allocation decision-making power

OR = 0·90, 95 % CI: 0·83, 0·95). The total effect of the intervention on odds of probable depression was partially attenuated after accounting for differences in food security (natural direct effect OR = 0·63, 95 % CI: 0·47, 0·80) (Fig. 1b). When depression was modelled as a continuous variable, or when income-allocation decision-making power was removed as a confounder, similar results were found (online supplementary material, Supplemental Table S6).

Discussion

In a nutrition-sensitive agroecology intervention that decreased the prevalence of probable depression amongst women in rural Tanzania, food insecurity played a significant mediating role. Specifically, the intervention lowered the odds of probable depression by 43 % (OR = 0·57, 95 % CI: 0·43, 0·70), and the effect of the intervention on odds of probable depression mediated by food insecurity was approximately 10 percentage points (OR = 0·90, 95 % CI: 0·83, 0·95) (Fig. 1). As such, changes in food insecurity explained approximately 23 % of the intervention's impact on depression. This is the first evidence from a randomised control trial that lowering food insecurity has a strong effect on reducing women's depressive symptoms.

This finding is important since it contributes empirical evidence on the previously theorised interdisciplinary, synergistic work between mental health, nutrition and agriculture fields to improve the quality of life for women in low-resource settings through nutrition-sensitive agriculture interventions. It answers the call from proponents of nutrition-sensitive agriculture interventions to target and measure mental health outcomes[43]. Simultaneously, it provides evidence in support of the call by those concerned with promoting global mental

health for interventions outside of traditional cognitive therapies, such as those discussed by the Lancet Commission on global mental health[3] and others[15,30,42].

In terms of the baseline covariates of risk of probable depression, food insecurity, domestic violence experience, lack of men's involvement with household chores typically done by women and high-income allocation decision-making power scores were salient (Table 1). These findings largely correspond to existing literature: a multitude of studies have observed significant relationships between depressive symptoms and food insecurity[24,42,85,86], social support[69–71,87] and experiences of domestic violence[36,63–66] amongst women. The finding on income allocation decision-making power, however, is more nuanced. Subgroup analyses revealed positive associations only for women whose income allocation decision-making power scores were above 0·4 (*n* 237 women, 43 %). Amongst women with lower scores (0–0·4), income allocation decision-making power was not associated with elevated risk of probable depression. One possible explanation for this result is our ethnographic observations that high-income allocation decision-making power might reflect the mental burden that women bear of making decisions about child welfare without having the resources to enact them[54]. For example, in a discussion with participants about the preliminary findings about high rates of probable depression, one woman said 'husbands put all responsibilities on wives . . . you may have activities to do and children want some food which you can't afford, you just wish you could provide . . . you are depressed because you have a lot to do all alone'[74]. A similar dynamic was reported amongst Irish women: having more say in decision making without adequate resources was associated with dissatisfaction and social stress[76].

Our findings on the impacts of the intervention on mental health are consistent with previous qualitative studies on agroecology which document positive impacts on women's well-being[88–92]. Moreover, the study's participatory agroecology approach may be important for explaining the substantial impact on depressive symptoms. Hallmarks of an agroecological approach include collective action between farmers, explicit efforts to draw on local knowledge in culturally appropriate ways, attention to improving social support and gender relations, and addressing food production holistically with positive environmental, health, social, and nutrition-related outcomes[93]. All of these aspects could improve women's and men's mental health. Nutrition-sensitive agriculture interventions that are not agroecological, i.e. they do not attend to social relations or local knowledge, may not see as large of an impact. Furthermore, participatory women's groups have been proposed as a low-cost alternative intervention to address mental health, especially in settings with low numbers of specialised workers[94,95]. For example, a participatory intervention in rural India introduced women's groups discussing care-seeking behaviour and clean birth delivery methods in order to reduce maternal depression and improve birth outcomes[94]. While the current study found a significant reduction in only moderate depression cases over 3 years, participatory strategies may hold unmeasured potential in impacting women's depression on a community level compared with a clinical intervention's individual-level impact.

Future research

We encourage future nutrition-sensitive agricultural or agroecological studies to measure impacts on mental health in men[74]. In nutrition-sensitive and gender equity interventions, there are many calls for equal involvement from both men and women[44,74,96,97], but men have often not been included[74]. By not including men in interventions in order to achieve key outcomes such as gender equity and food security and by excluding them from the measurements of the impact of these interventions, the idea that only women are in charge of household responsibilities, including its food supply, is reinforced[74,97]. Furthermore, because women bear the mental and physical burden of many household responsibilities[32,98], men's involvement in household activities could help equalise that burden. Finally, it is plausible that food insecurity could mediate the effect of the intervention on depression in men the same way we observed it to do so amongst women. Insights into the possibly synergistic or cumulative effects between men and women's mental health, food security improvements and gender relations may generate further insights or recommendations for more effective interventions.

A second consideration for future research is to elucidate the role of other mediators in the relationship between nutrition-sensitive agriculture interventions and depressive symptoms. Indeed, a proportion of the intervention's impact on depressive symptoms after eliminating the effect of food insecurity was still positive and substantial (natural direct effect OR = 0·63, 95 % CI: 0·47, 0·80, Fig. 1b). It is possible that other pathways such as improved gender equity and social support also contributed to the reduction in depressive symptoms. For example, agroecology's focus on farmers' autonomy, meaningful work and social networks for learning could be a critical factor[99,100]; other studies on agroecology have found significant impacts on social capital and farmers' autonomy which could have mediating impacts on depressive symptoms[101,102].

The plausibility of there being many mediators, such as improved gender equity and social support, in this relationship is high, and often times these exposures are found together. For example, Hernandez and colleagues found that maternal depression mediated the relationship between intimate partner violence and food insecurity[103], demonstrating that there may be more dynamics at play within this complicated web. Furthermore, a study in the UK found that food insecurity within low-socio-economic status women was related to a woman's domestic violence experience

and overall burden of mental health problems (i.e. depression, psychosis spectrum disorder or alcohol/drug-related disorder)[104].

Similarly, social support could also mediate the relationship between food insecurity and women's depression. Studies in the USA[105] and sub-Saharan Africa[30,78] found a significant relationship between food insecurity, social support and depressive symptoms. On the other hand, in Nicaragua, Piperata et al. found that spousal support and maternal social support networks were not important modifiers of the link between food insecurity and mental distress. This result was speculated to be due to the fear of gossip and embarrassment about food insecurity preventing social support from being sought[33]. In contrast, in SNAP-Tz, no significant relationship between social support and risk of probable depression was found at baseline (Table 1). Since women at baseline reported very high levels of social support (C: 82·5 %, I: 76·9 %, online supplementary material, Supplemental Table S1), we believe that a ceiling effect may have masked any associations between changes in social support and depressive symptoms over time.

It is important to note that null associations may be due to the homogeneity of the current study sample. For instance, there was no significant association between baseline probable depression and wealth or years of education (Table 1). Because eligibility was based on food insecurity, the study sample was fairly homogenous. While it may appear that participants have variable wealth levels (online supplementary material, Supplemental Table S1), this variable is illusory as 83 % of the sample was severely food insecure and ownership of most high value resources was rare[54] (online supplementary material, Supplemental Table S1). Studies with samples with greater variation in socio-economic status are needed to investigate the relationship between wealth and depressive symptoms.

Strengths, limitations

Strengths of the current study include randomisation, large sample size, longitudinal analysis and robust statistical techniques. Limitations include reliance on self-reports, which makes the current analysis vulnerable to social desirability bias. This bias could have resulted in systematic underreporting of experiences with sensitive topics such as food insecurity, depressive symptoms and/or domestic violence experience. We took precautions to address this by avoiding leading questions, using different personnel for enumeration and intervention implementation and assurance of 'no wrong answers' throughout the survey. We also measured social desirability bias in July 2018 and found that it was both low and non-differential between study arms[48]. Moreover, since these measurements were recorded for each participant at multiple time points, relative changes analysed in the longitudinal mediation analyses likely mitigate this potential bias. Additionally, because income allocation

decision-making power has a more complex relationship with probable depression than other gender equity covariates (men's involvement with household chores typically done by women, experience of domestic violence, attitude towards domestic violence and leisure time, Table 1), this relationship should be looked at more carefully in studies that measure these outcomes. Another possible limitation is the study's external validity; these analyses only included food insecure, married women with a child < 1 year old at enrolment. It will be useful to know if these relationships are observed in other populations.

Conclusions

These findings highlight that food security mediates roughly a quarter of the impact of a participatory nutrition-sensitive agroecology intervention on women's depressive symptoms. As such, these results demonstrate that nutrition-sensitive agroecology interventions can have broader impacts than previously demonstrated, i.e. they can go beyond improvements in nutrition to include improving mental health. Indeed, it seems possible that nutrition-sensitive agroecology interventions have the ability to be an accessible method of improving women's well-being in resource-poor settings, working both through changes in food security and other mediators not tested in the current analysis, such as social support, gender equity and wealth. It is therefore our hope that those working in global mental health consider the role of food insecurity in depression interventions, and that those primarily interested in nutritional outcomes consider the impacts of agricultural interventions beyond nutritional status, to include mental health.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980021001014

References

1. World Health Organization (2017) Depression and Other Common Mental Disorders: Global Health Estimates. http://www.who.int/mental_health/management/depression/prevalence_global_health_estimates/en/ (accessed June 2020).
2. James SL, Abate D, Abate KH et al. (2018) Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **392**, 1789–1858.
3. Patel V, Saxena S, Lund C et al. (2018) The Lancet Commission on global mental health and sustainable development. *Lancet* **392**, 1553–1598.
4. Institute for Health Metrics and Evaluation (2018) GBD Research Tools. http://vizhub.healthdata.org/gbd-compare (accessed May 2020).
5. Bloom, DE, Cafiero ET, Jané-Llopis E et al. (2011) *The Global Economic Burden of Non-Communicable Diseases*. Geneva: World Economic Forum.
6. Charlson FJ, Baxter AJ, Dua T et al. (2015) Excess mortality from mental, neurological and substance use disorders in the Global Burden of Disease Study 2010. *Epidemiol Psychiatr Sci* **24**, 121–140.
7. Lépine J-P & Briley M (2011) The increasing burden of depression. *Neuropsychiatr Dis Treat* **7**, 3–7.
8. McLearn KT, Minkovitz CS, Strobino DM et al. (2006) The timing of maternal depressive symptoms and mothers' parenting practices with young children: implications for pediatric practice. *Pediatrics* **118**, e174–e182.
9. Slomian J, Honvo G, Emonts P et al. (2019) Consequences of maternal postpartum depression: a systematic review of maternal and infant outcomes. *Women's Health* **15**, 1–55.
10. Butler MS, Young SL & Tuthill EL (2020) Perinatal depressive symptoms and breastfeeding behaviors: a systematic literature review and biosocial research agenda. *J Affect Disord* **283**, 441–471.
11. Rahman A, Patel V, Maselko J et al. (2008) The neglected 'm' in MCH programmes–why mental health of mothers is important for child nutrition. *Trop Med Int Health* **13**, 579–583.
12. Surkan PJ, Kennedy CE, Hurley KM et al. (2011) Maternal depression and early childhood growth in developing countries: systematic review and meta-analysis. *Bull World Health Organ* **89**, 607–615D.
13. Stewart RC (2007) Maternal depression and infant growth: a review of recent evidence. *Matern Child Nutr* **3**, 94–107.
14. Madlala SS & Kassier SM (2018) Antenatal and postpartum depression: effects on infant and young child health and feeding practices. *S Afr J Clin Nutr* **31**, 1–7.
15. WHO (2013) *Mental Health Action Plan 2013–2020*. Geneva: World Health Organization Press.
16. Syvälahti EK (1994) Biological aspects of depression. *Acta Psychiatr Scand Suppl* **377**, 11–15.
17. Lund C, Brooke-Sumner C, Baingana F et al. (2018) Social determinants of mental disorders and the Sustainable Development Goals: a systematic review of reviews. *Lancet Psychiatry* **5**, 357–369.
18. Weissman MM, Bland RC, Canino GJ et al. (1996) Cross-National epidemiology of major depression and bipolar disorder. *JAMA* **276**, 293–299.
19. Whiteford HA, Degenhardt L, Rehm J et al. (2013) Global burden of disease attributable to mental and substance use disorders: findings from the Global Burden of Disease Study 2010. *Lancet* **382**, 1575–1586.
20. Pereira B, Andrew G, Pednekar S et al. (2007) The explanatory models of depression in low income countries: listening to women in India. *J Affect Disorders* **102**, 209–218.
21. FAO, IFAD, UNICEF et al. (2019) *The State of Food Security and Nutrition in the World 2019. Safeguarding against Economic Slowdowns and Downturns*. Rome: FAO.
22. Huddleston-Casas C, Charnigo R & Simmons LA (2009) Food insecurity and maternal depression in rural, low-income families: a longitudinal investigation. *Public Health Nutr* **12**, 1133–1140.
23. Wachs TD (2009) Models linking nutritional deficiencies to maternal and child mental health. *Am J Clin Nutr* **89**, 935S–939S.
24. Weaver LJ & Hadley C (2009) Moving beyond hunger and nutrition: a systematic review of the evidence linking food insecurity and mental health in developing countries. *Ecol Food Nutr* **48**, 263–284.
25. Hadley C & Patil CL (2008) Seasonal changes in household food insecurity and symptoms of anxiety and depression. *Am J Phys Anthropol* **135**, 225–232.
26. Jebena MG, Lindstrom D, Belachew T et al. (2016) Food insecurity and common mental disorders among ethiopian youth: structural equation modeling. *PLoS One* **11**, e0165931.
27. Sparling TM, Nesbitt RC, Henschke N et al. (2017) Nutrients and perinatal depression: a systematic review. *J Nutr Sci* **6**, 1–13.
28. Heflin CM, Siefert K & Williams DR (2005) Food insufficiency and women's mental health: findings from a 3-year panel of welfare recipients. *Soc Sci Med* **61**, 1971–1982.

Public Health Nutrition

29. Cole SM & Tembo G (2011) The effect of food insecurity on mental health: panel evidence from rural Zambia. *Soc Sci Med* **73**, 1071–1079.

30. Tsai AC, Bangsberg DR, Frongillo EA *et al.* (2012) Food insecurity, depression and the modifying role of social support among people living with HIV/AIDS in rural Uganda. *Soc Sci Med* **74**, 2012–2019.

31. Sorsdahl K, Slopen N, Siefert K *et al.* (2011) Household food insufficiency and mental health in South Africa. *J Epidemiol Community Health* **65**, 426–431.

32. Hadley C & Crooks DL (2012) Coping and the biosocial consequences of food insecurity in the 21st century. *Am J Phys Anthropol* **149**, 72–94.

33. Piperata BA, Schmeer KK, Rodrigues AH *et al.* (2016) Food insecurity and maternal mental health in León, Nicaragua: potential limitations on the moderating role of social support. *Soc Sci Med* **171**, 9–17.

34. Pourmotabbed A, Moradi S, Babaei A *et al.* (2020) Food insecurity and mental health: a systematic review and meta-analysis. *Public Health Nutr* **23**, 1778–1790.

35. Tribble AG, Maxfield A, Hadley C *et al.* (2020) *Food Insecurity and Mental Health: A Meta-Analysis.* Rochester, NY: Social Science Research Network.

36. Patel V, Rodrigues M & DeSouza N (2002) Gender, poverty, and postnatal depression: a study of mothers in Goa, India. *Am J Psychiatr* **159**, 43–47.

37. Palar K, Wagner G, Ghosh-Dastidar B *et al.* (2012) Role of antiretroviral therapy in improving food security among patients initiating HIV treatment and care. *AIDS* **26**, 2375–2381.

38. Pearl J (2012) *The Causal Foundations of Structural Equation Modeling. Handbook of Structural Equation Modeling.* New York: Guilford Press.

39. Singla DR, Kohrt BA, Murray LK *et al.* (2017) Psychological treatments for the world: lessons from low- and middle-income countries. *Annu Rev Clin Psychol* **13**, 149–181.

40. van Ginneken N, Tharyan P, Lewin S *et al.* (2013) Non-specialist health worker interventions for the care of mental, neurological and substance-abuse disorders in low- and middle-income countries. *Cochrane Database Syst Rev* CD009149. doi: 10.1002/14651858.CD009149.pub2.

41. Araya R, Zitko P, Markkula N *et al.* (2018) Determinants of access to health care for depression in 49 countries: a multilevel analysis. *J Affect Disord* **234**, 80–88.

42. Hadley C, Tegegn A, Tessema F *et al.* (2008) Food insecurity, stressful life events and symptoms of anxiety and depression in east Africa: evidence from the Gilgel Gibe growth and development study. *J Epidemiol Community Health* **62**, 980–986.

43. Ruel MT & Alderman H (2013) Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? *Lancet* **382**, 536–551.

44. Ruel MT, Quisumbing AR & Balagamwala M (2018) Nutrition-sensitive agriculture: What have we learned so far? *Glob Food Sec* **17**, 128–153.

45. Gliessman SR (2007) *Agroecology: The Ecology of Sustainable Food Systems.* 2nd ed. Boca Raton, USA: CRC Press.

46. Rosenberg AM, Maluccio JA, Harris J *et al.* (2018) Nutrition-sensitive agricultural interventions, agricultural diversity, food access and child dietary diversity: evidence from rural Zambia. *Food Policy* **80**, 10–23.

47. Kangmennaang J, Bezner Kerr R, Lupafya E *et al.* (2017) Impact of a participatory agroecological development project on household wealth and food security in Malawi. *Food Sec* **9**, 561–576.

48. Santoso MV, Bezner Kerr R, Kassim N *et al.* (2021) A nutrition-sensitive agroecology intervention in rural Tanzania increases children's dietary diversity and household food security but does not change child anthropometry: results from a cluster-randomized trial. *J Nutr.* doi: 10.1093/jn/nxab052.

49. Institute for Health Metrics and Evaluation (2015) Tanzania. http://www.healthdata.org/tanzania (accessed March 2020).

50. Tanzania National Bureau of Statistics (2016) Singida Regional Profile. https://www.nbs.go.tz/nbs/takwimu/census2012/RegProfiles/13_Singida_Regional_Profile.zip (accessed October 2018).

51. Leyna GH, Mmbaga EJ, Mnyika KS *et al.* (2010) Food insecurity is associated with food consumption patterns and anthropometric measures but not serum micronutrient levels in adults in rural Tanzania. *Public Health Nutr* **13**, 1438.

52. Wandel M, Holmboe-Ottesen G & Manu A (1992) Seasonal work, energy intake and nutritional stress: a case study from Tanzania. *Nutr Res* **12**, 1–16.

53. Bezner Kerr R, Young SL, Young C *et al.* (2019) Farming for change: developing a participatory curriculum on agroecology, nutrition, climate change and social equity in Malawi and Tanzania. *Agric Hum Values* **36**, 549–566.

54. Santoso MV (2019) Evaluating the impact of a participatory nutrition-sensitive agriculture intervention on women's empowerment and child's diet in singida. PhD Dissertation, Cornell University.

55. Kornblith E, Green R-J, Casey S *et al.* (2016) Marital status, social support, and depressive symptoms among lesbian and heterosexual women. *J Lesbian Stud* **20**, 157–173.

56. Islam JCS (2004) *Marital Relationship Status, Social Support, and Psychological Well-Being among Rural, Low-Income Mothers.* College Park, MD: University of Maryland.

57. Radloff LS (1977) The CES-D scale: a self-report depression scale for research in the general population. *Appl Psychol Meas* **1**, 385–401.

58. Natamba BK, Achan J, Arbach A *et al.* (2014) Reliability and validity of the center for epidemiologic studies-depression scale in screening for depression among HIV-infected and -uninfected pregnant women attending antenatal services in northern Uganda: a cross-sectional study. *BMC Psychiatr* **14**, 303.

59. Coates J, Swindale A & Bilinsky P (2007) *Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide.* Washington, DC: Food and Nutrition Technical Assistance Project, Academy for Educational Development.

60. Jones AD, Ngure FM, Pelto G *et al.* (2013) What are we assessing when we measure food security? A compendium and review of current metrics. *Adv Nutr* **4**, 481–505.

61. Knueppel D, Demment M & Kaiser L (2010) Validation of the household food insecurity access scale in rural Tanzania. *Public Health Nutr* **13**, 360–367.

62. United Nations, Department of Economic and Social Affairs, Population Division (2011) World Population Prospects: The 2010 Revision, Volume I: Comprehensive Tables. https://www.un.org/en/development/desa/population/publications/pdf/trends/WPP2010/WPP2010_Volume-I_Comprehensive-Tables.pdf (accessed May 2020).

63. Nasreen HE, Kabir ZN, Forsell Y *et al.* (2011) Prevalence and associated factors of depressive and anxiety symptoms during pregnancy: a population based study in rural Bangladesh. *BMC Women's Health* **11**, 22.

64. Adamu AF & Adinew YM (2018) Domestic violence as a risk factor for postpartum depression among Ethiopian women: facility based study. *Clin Pract Epidemiol Ment Health* **14**, 109–119.

65. Abebe A, Tesfaw G, Mulat H *et al.* (2019) Postpartum depression and associated factors among mothers in Bahir Dar Town, Northwest Ethiopia. *Ann Gen Psychiatry* **18**, 19.

66. Rogathi JJ, Manongi R, Mushi D *et al.* (2017) Postpartum depression among women who have experienced intimate

partner violence: a prospective cohort study at Moshi, Tanzania. *J Affect Disord* **218**, 238–245.

67. Hammarström A & Phillips SP (2012) Gender inequity needs to be regarded as a social determinant of depressive symptoms: results from the Northern Swedish cohort. *Scand J Public Health* **40**, 746–752.

68. Jenkins R, Mbatia J, Singleton N *et al.* (2010) Common mental disorders and risk factors in Urban Tanzania. *Int J Environ Res Public Health* **7**, 2543–2558.

69. Getinet W, Amare T, Boru B *et al.* (2018) Prevalence and risk factors for antenatal depression in Ethiopia: systematic review. *Depress Res Treat* **2018**, 12.

70. Hou F, Cerulli C, Wittink MN *et al.* (2015) Depression, social support and associated factors among women living in rural China: a cross-sectional study. *BMC Women's Health* **15**, 1–9.

71. Rudkoski AK (2017) *Social Support and Maternal Mental Health in Rural Nicaragua*. Calgary: University of Calgary.

72. Antelman G, Fawzi MCS, Kaaya S *et al.* (2001) Predictors of HIV-1 serostatus disclosure: a prospective study among HIV-infected pregnant women in Dar es Salaam, Tanzania. *AIDS* **15**, 1865–1874.

73. World Bank (2018) Women who believe a husband is justified in beating his wife when she burns the food (%). https://data.worldbank.org/indicator/SG.VAW.BURN.ZS (accessed December 2018).

74. Santoso MV, Bezner Kerr R, Hoddinott J *et al.* (2019) Role of women's empowerment in child nutrition outcomes: a systematic review. *Adv Nutr* **10**, 1138–1151.

75. Malapit HJ, Pinkstaff C, Sproule K *et al.* (2017) *The Abbreviated Women's Empowerment in Agriculture Index (A-WEAI)*. Washington, DC: International Food Policy Research Institute (IFPRI).

76. Hutton M (2015) Consuming stress: exploring hidden dimensions of consumption-related strain at the intersection of gender and poverty. *Mark Manag* **31**, 1695–1717.

77. Hosmer DW, Lemeshow S & Sturdivant RX (2013) *Applied Logistic Regression*, 3rd ed. Hoboken, NJ: John Wiley & Son, Inc.

78. Na M, Miller M, Ballard T *et al.* (2019) Does social support modify the relationship between food insecurity and poor mental health? Evidence from thirty-nine sub-Saharan African countries. *Public Health Nutr* **22**, 874–881.

79. StataCorp (2019) *Stata Statistical Software: Release 16*. College Station, TX: StataCorp LLC.

80. Petersen ML, Sinisi SE & van der Laan MJ (2006) Estimation of direct causal effects. *Epidemiology* **17**, 276–284.

81. Hafeman DM (2009) "Proportion explained": a causal interpretation for standard measures of indirect effect? *Am J Epidemiol* **170**, 1443–1448.

82. VanderWeele TJ (2010) Bias formulas for sensitivity analysis for direct and indirect effects. *Epidemiology* **21**, 540–551.

83. SAS Institute Inc (2014) *SAS*. Cary, NC: SAS Institute Inc.

84. Royston P & White IR (2011) Multiple Imputation by Chained Equations (MICE): implementation in Stata. *J Stat Software* **45**, 1–20.

85. Hadley C & Patil CL (2006) Food insecurity in rural Tanzania is associated with maternal anxiety and depression. *Am J Hum Biol* **18**, 359–368.

86. Tsai I, Krumdieck NR, Collins S *et al.* (2016) Food insecurity is associated with depression and stress among a cohort of pregnant Kenyan women of mixed HIV status. *FASEB J* **30**, 273.4.

87. Prachakul W, Grant JS & Keltner NL (2007) Relationships among functional social support, hiv-related stigma, social problem solving, and depressive symptoms in people living with hiv: a pilot study. *J Assoc Nurses AIDS Care* **18**, 67–76.

88. Bezner Kerr R, Hickey C, Lupafya E *et al.* (2019) Repairing rifts or reproducing inequalities? Agroecology, food

89. Oliver B (2016) "The earth gives us so much": agroecology and rural women's leadership in Uruguay. *Cult Agric Food Environ* **38**, 38–47.

90. Sylvester O & Little M (2020) "I came all this way to receive training, am I really going to be taught by a woman?" Factors that support and hinder women's participation in agroecology in Costa Rica. *Agroecol Sustain Food Syst* 1–24.

91. Carvalho LM & Bógus CM (2020) Gender and social justice in urban agriculture: the network of agroecological and peripheral female urban farmers from São Paulo. *Soc Sci* **9**, 127.

92. Calderón CI, Jerónimo C, Praun A *et al.* (2018) Agroecology-based farming provides grounds for more resilient livelihoods among smallholders in Western Guatemala. *Agroecol Sustain Food Syst* **42**, 1128–1169.

93. Wezel A, Herren BG, Kerr RB *et al.* (2020) Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. *Agron Sustain Dev* **40**, 40.

94. Tripathy P, Nair N, Barnett S *et al.* (2010) Effect of a participatory intervention with women's groups on birth outcomes and maternal depression in Jharkhand and Orissa, India: a cluster-randomised controlled trial. *Lancet* **375**, 1182–1192.

95. Patel V & Kirkwood B (2008) Perinatal depression treated by community health workers. *Lancet* **372**, 868–869.

96. Wyatt AJ, Yount KM, Null C *et al.* (2015) Dairy intensification, mothers and children: an exploration of infant and young child feeding practices among rural dairy farmers in Kenya. *Matern Child Nutr* **11**, 88–103.

97. Barker GT, Ricardo C, Nascimento M *et al.* (2010) Engaging Men and Boys in Changing Gender-based Inequity in Health: evidence from Programme Interventions. https://www.who.int/gender/documents/Engaging_men_boys.pdf (accessed April 2020).

98. Johnston D, Stevano S, Malapit HJ *et al.* (2018) Review: time use as an explanation for the agri-nutrition disconnect: evidence from rural areas in low and middle-income countries. *Food Policy* **76**, 8–18.

99. Timmermann C & Felix GF (2015) Agroecology as a vehicle for contributive justice. *Agric Hum Values* **32**, 523–538.

100. HLPE (2019) Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. Rome: A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. http://www.healthdata.org/tanzania (accessed June 2020).

101. Deaconu A, Mercille G & Batal M (2019) The agroecological farmer's pathways from agriculture to nutrition: a practice-based case from Ecuador's Highlands. *Ecol Food Nutr* **58**, 142–165.

102. Kansanga MM, Luginaah I, Bezner Kerr R *et al.* (2020) Beyond ecological synergies: examining the impact of participatory agroecology on social capital in smallholder farming communities. *Int J Sustain Dev World Ecol* **27**, 1–14.

103. Hernandez DC, Marshall A & Mineo C (2014) Maternal depression mediates the association between intimate partner violence and food insecurity. *J Womens Health* **23**, 29–37.

104. Melchior M, Caspi A, Howard LM *et al.* (2009) Mental health context of food insecurity: a representative cohort of families with young children. *Pediatrics* **124**, e564–e572.

105. Kollannoor-Samuel G, Wagner J, Damio G *et al.* (2011) Social support modifies the association between household food insecurity and depression among latinos with uncontrolled type 2 diabetes. *J Immigr Minor Health* **13**, 982–989.