Economic Evaluation of Nutrition-Sensitive Agricultural Interventions to Increase Maternal and Child Dietary Diversity and Nutritional Status in Rural Odisha, India

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ABSTRACT

Background: Economic evaluations of nutrition-sensitive agriculture (NSA) interventions are scarce, limiting assessment of their potential affordability and scalability.

Objectives: We conducted cost–consequence analyses of 3 participatory video-based interventions of fortnightly women’s group meetings using the following platforms: 1) NSA videos; 2) NSA and nutrition-specific videos; or 3) NSA videos with a nutrition-specific participatory learning and action (PLA) cycle.

Methods: Interventions were tested in a 32-mo, 4-arm cluster-randomized controlled trial, Upscaling Participatory Action and Videos for Agriculture and Nutrition (UPAVAN) in the Keonjhar district, Odisha, India. Impacts were evaluated in children aged 0–23 mo and their mothers. We estimated program costs using data collected prospectively from expenditure records of implementing and technical partners and societal costs using expenditure assessment data collected from households with a child aged 0–23 mo and key informant interviews. Costs were adjusted for inflation, discounted, and converted to 2019 US$.

Results: Total program costs of each intervention ranged from US$272,121 to US$386,907. Program costs per pregnant woman or mother of a child aged 0–23 mo were US$62 for NSA videos, US$84 for NSA and nutrition-specific videos, and US$78 for NSA videos with PLA (societal costs: US$125, US$143, and US$122, respectively). Substantial shares of total costs were attributable to development and delivery of the videos and PLA (52–69%) and quality assurance (25–41%). Relative to control, minimum dietary diversity was higher in the children who underwent the interventions incorporating nutrition-specific videos and PLA (adjusted RR: 1.19 and 1.27; 95% CIs: 1.03–1.37 and 1.11, 1.46, respectively). Relative to control, minimum dietary diversity in mothers was higher in those who underwent NSA video (1.21 [1.01, 1.45]) and NSA with PLA (1.30 [1.10, 1.53]) interventions.

Conclusion: NSA videos with PLA can increase both maternal and child dietary diversity and have the lowest cost per unit increase in diet diversity. Building on investments made in developing UPAVAN, cost-efficiency at scale could be increased with less intensive monitoring, reduced startup costs, and integration within existing government programs. This trial was registered at clinicaltrials.gov as ISRCTN65922679. J Nutr 2022;152:2255–2268.

Keywords: Nutrition-sensitive agriculture, Cost–consequence analysis, Participatory learning and action, Women’s groups, Dietary diversity, Maternal and child nutrition, India
Background

There is strong evidence on the impacts and cost-effectiveness of nutrition-specific interventions (1–4), particularly in settings with high undernutrition burdens, such as India. However, to achieve the Sustainable Development Goal (SDG) targets (5) to end hunger and undernutrition (SDG 2), multisectoral approaches are needed to address the underlying causes of undernutrition (6). In rural areas of low- and middle-income countries, where the burden of undernutrition is highest and smallholder farming provides a major source of nutrition and income (7), the agriculture sector could provide “nutrition-sensitive” interventions that improve both nutrition and agriculture outcomes simultaneously.

Trials of nutrition-sensitive agriculture (NSA) interventions have shown that these interventions may improve dietary outcomes, with results suggesting that the implementation of these interventions at scale may be a policy option. Of the 8 trials that tested the effects of NSA interventions on minimum dietary diversity of children, 4 trials showed a significant increase, although neither of the 2 NSA trials measuring impacts on maternal dietary diversity showed an effect (8). However, our ability to recommend upscaling of NSA interventions is constrained by a lack of data on their costs, and therefore a lack of evidence regarding their value for money (6, 9, 10). So far, the few economic evaluations (the family of evaluation types that relate costs and impacts) of NSA interventions that do exist come from sub-Saharan Africa (10–12) — none come from South Asia (13, 14). Policymakers need this evidence to prioritize and justify their investments, particularly in resource-constrained settings in South Asia. Additionally, economic evaluations may be more needed for multisectoral interventions such as NSA, to garner support from the multiple (traditionally separate) sectors involved and justify the efforts required to enable collaboration (15).

One reason for the lack of NSA economic evaluations is that traditional methods developed for single-sector interventions are unsuitable for multisectoral interventions. Cost–benefit analyses (which give cost per economic value of aggregate benefits) rely on too many assumptions to compute the economic value of dietary and agricultural outcomes. Cost-effectiveness analyses (which estimate costs per natural unit of an outcome or a composite health measure) give misleadingly high estimates (16). For interventions designed to affect a range of health and non-health outcomes, assigning all intervention costs to a single outcome creates an erroneous impression that the cost per unit of improvement is prohibitively high. Cost–consequence analyses (where outcomes are reported alongside disaggregated costs) offer a transparent approach that allows policymakers to weigh the evidence for themselves. Cost–consequence analyses are recommended for multisectoral interventions with multiple health and nonhealth effects (17, 18), ideally alongside cost-effectiveness analysis.

Here, we present the economic evaluation results of the UPAVAN trial, conducted in Odisha state, India, between 2016 and 2020 (8, 19). The trial aimed to test the nutritional and agricultural impacts of 3 video-based participatory NSA interventions, each compared with a control arm. The specific objectives of the economic evaluations of the UPAVAN study were the following: 1) describe intervention coverage and participation; 2) estimate the program cost and cost efficiency (cost per participant) of implementing the interventions; 3) estimate societal costs of the interventions; 4) conduct a cost–consequence analysis to present the costs alongside the effects of the interventions and estimate cost per unit increase in outcome per intervention; 5) examine effects of uncertain parameters, assumptions, and potential scenarios on intervention costs; and 6) estimate the cost of delivering the interventions at scale and affordability of scale-up across rural Odisha.

Methods

Overview of the UPAVAN trial study design

Detailed descriptions of the UPAVAN interventions, study design, and impacts are reported elsewhere (8, 19, 20). In brief, the UPAVAN trial was a 4-arm, cluster randomized controlled trial, implemented in 4 administrative blocks (Patna, Keonjhar Sadar, Harichandanpur, and Ghatgaon) in the Keonjhar district, Odisha, India. One or 2 villages and surrounding hamlets were defined as a cluster, to ensure a minimum population of 800 per cluster. Stratified block random assignment was used to allocate 148 clusters to 4 trial arms (3 intervention arms and 1 control arm), giving 37 clusters per arm. Allocation of the clusters was stratified by distance to the nearest town (<10 km or ≥10 km) and the proportion of Scheduled Tribe or Scheduled Caste [historically disadvantaged households: low: 30%, medium: 30–70%; high: >70%] (8, 19), giving 6 strata in total.

Both cluster and individual-level informed consent were obtained for participation in the trial and surveys. Ethics approval for the trial was obtained from the Odisha government’s Institutional Review Board, Research and Ethics Committee, Department of Health and Family Welfare, Government of Odisha, and the LSHTM Interventions Research Ethics Committee.

Study setting

The Keonjhar district has an estimated population of 1.8 million residents, 96% of whom reside in a rural setting (21). Of this population, 44% belonged to the Scheduled Tribes and 12% to Scheduled Castes (21) — historically the most disadvantaged socioeconomic groups in India. The prevalence of maternal and child undernutrition in Keonjhar is among the highest in India. In Keonjhar during 2015–2016, 30% of women (age 15–49 y) were overweight and 40% were anemic (13), and of children aged ≤5 y, 40% were stunted and 19% were wasted (13).
UPAVAN interventions

Interventions were implemented by the Voluntary Association for Rural Reconstruction and Appropriate Technology (VARRAT), a nongovernmental organization in Odisha, with technical support from Digital Green, Ekjut, John Snow Inc. Research and Training Institute (JSI RTI), London School of Hygiene & Tropical Medicine (LSHTM), and University College London (UCL). The trial was evaluated by LSHTM, UCL, and DCOR Consulting Pvt. Ltd.

The 3 UPAVAN interventions have been described in detail elsewhere (19, 20) and are briefly described here, with an overview in Figure 1. Each intervention included 2 main components: a fortnightly women’s group meeting (the content of which varied between interventions) and a follow-up home visit to each group member after each meeting. The interventions worked with women’s self-help groups (SHGs)—an existing platform involved in savings and credit activities. The interventions were implemented for 32 mo, from March 2017 to October 2019.

Nutrition-sensitive agriculture intervention (AGRI)

In this arm, fortnightly women’s groups viewed and discussed NSA videos, following a participatory video approach designed by Digital Green (22). The participatory video approach had 4 steps: 1) local implementers identified relevant NSA practices to include in videos, 2) local videographers filmed farmers and other community members demonstrating or discussing the practices, 3) local facilitators screened the videos in group meetings and facilitated discussions, and 4) facilitators conducted follow-up home visits to pregnant women and mothers of children aged 0–23 mo who participated in the group meetings. NSA videos covered the main themes, following UPAVAN’s theory of change (5, 19), of increasing production and diversity of nutritious or income-generating foods, increasing women’s decision-making power in agricultural activities, and reducing workloads for pregnant and breastfeeding women.

Quality assurance and monitoring were embedded in the participatory video process. Facilitators kept registers to track attendance, whether participants were pregnant or had a child aged 0–23 mo, and whether a government frontline health and nutrition care provider attended the meeting. During home visits, facilitators completed forms to record participants adoption and/or recall of practices promoted in the previous meeting.

Nutrition-sensitive and nutrition-specific agriculture intervention (AGRI-NUT)

This arm used the same participatory video approach as in the AGRI arm, but videos covered both NSA and nutrition-specific topics. The AGRI-NUT group videos received were half NSA videos shown in the AGRI arm and half nutrition-specific videos covering topics on infant and young-child feeding practices and maternal diets.

AGRI-NUT + Participatory Learning and Action.

This arm used the same participatory video approach as in the AGRI arm but integrated nutrition-specific meetings that followed a Participatory Learning and Action (PLA) approach (using half the NSA videos shown in the AGRI arm and half PLA meetings). In the PLA meetings, the groups followed a 4-phase PLA cycle in which they performed the following tasks: 1) learned about and prioritized nutrition problems; 2) discussed and prioritized the causes, effects, and locally feasible strategies to address these problems within their groups and the wider community; 3) implemented the identified strategies; and 4) informally evaluated the results of their actions and made future plans. The PLA meetings were either interactive discussions without videos (using participatory techniques such as voting, storytelling, and games), or participatory videos on nutrition-specific topics that were developed as part of the PLA process. Therefore, the nutrition-specific videos in the PLA arm were different from those in the AGRI-NUT arm.

Control

Those in the control arm (and intervention arms) received standard government services. In addition, the government frontline health and nutrition workers in all 4 arms received 2 d of training on maternal, infant, and young child nutrition.

Evaluating coverage and participation

Figure 2 describes the populations aimed for inclusion according to the interventions (intervention exposure) and benefit (intervention outcomes).

The UPAVAN interventions were primarily designed to include pregnant women and mothers of children aged 0–23 mo (primary intervention participants) and to benefit children aged 0–23 mo, their mothers, and their households. Therefore, we primarily report coverage and cost-efficiency in terms of the former, and impacts (described in the next section) on the latter.

Coverage was assessed as whether or not primary intervention participants attended ≥1 group meeting and received ≥1 home visit, based on monitoring data recorded by group facilitators (registered with records on 46,527 meetings and forms on 149,585 home visits). We also assessed coverage in terms of all participating women, defined as women of any age who attended ≥1 group meeting according to group registers, because all women of all ages in the intervention clusters were eligible to participate in UPAVAN interventions.
FIGURE 2  Target populations of UPAVAN interventions. UPAVAN, Upscaling Participatory Action and Videos for Agriculture and Nutrition.

the SHG platform that UPAVAN worked with includes women of all ages.

Participation is given as: total group meetings and home visits attended by primary intervention participants; group meetings attended by all women; and total "points of contact," the sum of group meeting attendance (all women) and home visits.

Evaluating consequences (trial impacts)

We had 2 primary outcomes. The first outcome was child dietary diversity, measured as the percentage of children aged 6–23 mo consuming ≥4 of 7 food groups in the previous 24 h, using the WHO-defined food groups (23). The second primary outcome was BMI (measured as kg/m²) of nonpregnant, nonpostpartum (gave birth >42 d previously) mothers of these children. Secondary outcomes were maternal dietary diversity, measured as percentage of mothers consuming ≥5 of 10 food groups in the previous 24 h using FAO-defined food groups (24), and percentage of children with a weight-for-height -score <−2 SD of the WHO growth standards median (25). The trial was powered for the 2 primary outcomes to give a target sample size of 4736 mother–child pairs (1184 per arm) at baseline and again at endline.

Other outcomes on health, women’s empowerment, food security, and agricultural production were prespecified and are given in Supplemental Material Table S1.

The impact of the interventions was evaluated on children aged 0–23 mo and their mothers (and their households for household-level indicators). The impact evaluation used randomly selected samples of eligible households from each cluster at baseline and endline. Households were eligible if they contained a child aged 0–23 mo with no disability affecting anthropometric measurements, and the child’s primary caregiver had no disability impairing their participation in the surveys and had been resident in the household for at least half a year before data collection.

Impacts were analyzed using intention-to-treat analysis. The analyses were cross-sectional, assessing outcomes in each intervention arm compared with the control arm at endline. The analyses adjusted for baseline measures by including all individuals at each timepoint linked by cluster, and outcomes were analyzed using separate generalized estimating equations to account for clustering. Adjusted analyses also included distance to the nearest town and proportion of Scheduled Tribe or Scheduled Caste households as covariates.

Results of the UPAVAN impact evaluation are reported elsewhere (8). In this paper, we have presented adjusted effects on all prespecified outcomes that were statistically significant from control; these comprise the “consequences” in our cost–consequence analysis.

Evaluating costs

The full cost methodology is presented in the economic evaluation protocol (26) and is summarized in this section and Figure 3.

Economic costs of the interventions were estimated from a program perspective (i.e., costs incurred by the implementing agencies) and a societal perspective (i.e., costs to program implementers, the government health system, and program participants). Economic costs refer to direct financial costs plus indirect costs such as value of donated items or time (opportunity) costs of participating. All direct and indirect cost types, including program and societal costs, as well as the data sources and assumptions used for calculating costs, are given in Supplemental Material Table S2.

The time horizon for cost analysis was 41 mo, including a 9-mo startup period and 32-mo intervention implementation. Activities during the startup period included recruitment and training of group
facilitators and their supervisors, community sensitization activities, and development of video content and PLA meeting plans.

**Program costs.**
A combination of activity-based costing (27), expenditure approach, and ingredient approaches (28) were used to estimate program costs. First, the intervention components and associated main activities were identified and defined as cost centers. Then, data on quantity and costs (or estimated value of resources, in case of donated items) were collected and allocated to these cost centers. To estimate the direct costs of designing and implementing the interventions, we collected financial cost data from all UPAVAN partner expenditure records or project accounts. For indirect costs, we identified donated items and volunteered time through interviews with all project staff and estimated their opportunity cost (value) using the current market value for donated items (28–30) and staff monthly salaries for volunteered time. Donated items were mainly video making and editing equipment used by the implementing partner. Volunteered time mainly included unpaid time contributed to the design and adaptation of intervention materials, as well as quality assurance by technical partners.

Cost data were collected using data capture tools (Supplemental Material—data collection tools) designed for the project. All data collected were entered into a customized excel-based costing tool, adapted from the costing tool developed by the UCL Centre for Global Health Economics (http://www.ighe.org) for analysis. The tool categorizes the costs based on the following line items: staff, materials, capital, joint costs (shared by several activities such as field travel and partner meetings), and overheads. The tool also categorizes costs based on the intervention component: AGRI, NUT, PLA, training of government frontline health and nutrition care providers, quality assurance and monitoring, or partner coordination, and implementation stage (startup or implementation). Staff costs were allocated to intervention components using data from staff time–use surveys collected through interviews with all project staff (full descriptions of line items, intervention components, and implementation phases are given in Supplemental Material Table S3). The same allocation rule was applied to allocate nonstaff joint costs to intervention components. Capital costs were annualized based on the estimated lifetime of each item, using a discount rate of 3%. We included contributions of the international technical (JSI RTI) and research partners (LSHTM and UCL) in developing and supporting interventions, but not research costs.

**Costs to government health system.**
We measured direct financial costs and indirect opportunity costs incurred by primary health centers and government frontline health and nutrition care providers [i.e., Anganwadi workers (AWWs), accredited social health activists (ASHAs), and auxiliary nurse midwives (ANMs)].

Direct costs were based on any increase in the use of health and nutrition services (in the past 6 mo), as determined by comparing percentages of households using any health or nutrition services in each intervention relative to control in the endline survey, and published data on unit cost to health centers for providing those services (31–36). We estimated the indirect costs as the opportunity costs of government frontline health and nutrition care providers participating in the interventions. This calculation was based on group attendance by government frontline health and nutrition workers (assessed from facilitator registers), mean durations of meetings and travel times to meeting locations (from the endline survey), and published monthly salaries of the government frontline health and nutrition care providers (Supplemental Material Table S2).

**Costs to participants and their households.**
We estimated opportunity costs to participants of attending dissemination meetings and follow-up home visits by using data on the total number of group attendants and follow-up home visits per intervention arm (from facilitator registers and home visit forms); mean durations of group meetings and home visits, and mean travel time to the meeting location (collected in the UPAVAN endline survey); and the minimum daily wage of an agricultural worker in Odisha state (303 Indian Rupees or US$4.31) (37) (Supplemental Material Table S2).

We estimated cost to households of adopting practices promoted in UPAVAN as any differences in the following expenditures: seeking healthcare (out-of-pocket fees and transport costs paid for child and maternal healthcare from public, private, or informal healthcare providers), agricultural inputs, food costs, and nonfood costs. These...
costs were estimated as the mean differences between each intervention and the control arm, using the expenditure survey in the UPAVAN endline survey.

Analysis
Our results are presented in the form of cost–consequence analysis, by tabulating disaggregated costs and outcomes of the interventions compared with the control arm. We selected a program perspective as the base case to reflect the potential budget impact of adopting the intervention. The societal perspective presents the full costs of implementing the interventions.

All costs, including unit costs obtained from published studies, were adjusted for inflation using the Indian Consumer Price Index (38) and converted to 2019 US$, using the exchange rate of 70.42 (39) for the costs to Indian partners (in Indian Rupees), and 0.78 (39) for costs to the UK partners (in British Pounds Sterling, GBP). In addition, costs were discounted at 3% per y, as recommended by WHO-CHOICE (World Health Organization CHOosing Interventions that are Cost-Effective) (40) and the Gates/IDS Reference Case for Economic Evaluation (41). Our study follows the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) (42).

We calculated total costs and mean annual costs of the interventions. Mean annual costs enable comparisons with other interventions that run for different durations. Mean annual costs were calculated as the sum of startup and implementation costs, divided by 41 mo (the costing time horizon), and multiplied by 12, so they divide startup costs equally across each year. We decomposed the total costs of the interventions and presented these as a share of line-item (i.e., staff, materials, capital, other), intervention component (i.e., NSA videos, nutrition-specific videos, PLA, quality assurance, coordination, frontline worker training), and implementation phase (i.e., startup and implementation).

To estimate the cost-efficiency of the interventions, we calculated the total or annual costs of each intervention per primary intervention participant. We also estimated cost per total point of contact (sum of group attendees and total home visits). We also estimated cost per unit increase in maternal and child dietary diversity scores (i.e., 2 statistically significant primary and secondary outcomes) for each intervention arm, compared with the control arm. They were calculated as mean increase in outcome divided by cost per primary intervention participant.

We conducted a number of univariate sensitivity analyses that vary 1 parameter at a time, and scenarios for potential intervention costs at scale. In sensitivity analysis, we examined the impact of 2 uncertain assumptions: we altered the allocation rule for dividing the costs of the nutrition-specific component between the AGRI-NUT and AGRI-NUT + PLA arms (from a 75:25 rule to a 90:10 rule), and we varied the discount rate from 0% to 6% (40, 41). In scenario analyses, we tested impacts of 3 scenarios that we believe will be relevant when interventions are implemented at scale: reducing startup costs by 50%, reducing costs of monitoring by 25% and 50%, and replacing international staff costs with local staff costs. A detailed description of sensitivity and scenario analyses are presented in the Supplemental Material - Sensitivity and scenario analyses.

Finally, we estimated the potential cost of delivering the AGRI-NUT + PLA intervention to all rural populations in Odisha state, by dividing the total intervention cost by the total population in the intervention clusters (based on census data) and multiplying by the total rural population of Odisha.

Results
Trial coverage and participation
UPAVAN’s coverage and participation are described in Table 1. Throughout the 32-mo implementation period, the UPAVAN interventions covered a mean of 4567 primary intervention participants, and 9367 women of any age, per intervention arm. So, approximately one-half of participants were pregnant women and mothers of children aged 0–23 mo, and 17% of the total population directly participated in UPAVAN intervention activities, per arm. Assuming an average of 5 members per household (and 1 participant per household, and that household members discussed the interventions), the interventions reached a mean of 87% of the total population per arm.

Program costs and program cost efficiency
Program costs are described in Table 2 and presented by year in Supplemental Material Table S4. Total program costs of the AGRI, AGRI-NUT, and AGRI-NUT + PLA intervention arms were estimated as US$272,121, US$366,686, and US$386,907, respectively, and the mean annual costs of the intervention arms were estimated as US$79,645, US$107,323, and US$113,241, respectively. Start-up costs accounted for ∼26% of total costs, with the AGRI-NUT arm having the highest proportion of startup costs (30%) and the AGRI-NUT + PLA arm having the lowest (23%). The main reason for higher startup costs for the AGRI-NUT arm is that more staff time was spent preparing...

### Table 1 Population coverage and participation in the UPAVAN interventions

| Population | AGRI | AGRI-NUT | AGRI-NUT + PLA | Mean |
|------------|------|----------|----------------|------|
| Clusters   | 37   | 37       | 37             |      |
| Pregnant women and mothers of children age < 2 y in intervention clusters | | | | |
| Total population (all ages) in intervention clusters | 51,220 | 50,094 | 60,681 | 53,998 |
| Coverage | | | | |
| Primary intervention participants | 4389 | 4347 | 4965 | 4567 |
| Number of women (any age) who participated | 9202 | 9272 | 9626 | 9367 |
| Participation | | | | |
| Average number of participants per video dissemination group | 20 (14–25) | 19 (13–25) | 18 (13–25) | 19 (13–25) |
| Total group meetings attended by primary participants | 61,446 | 60,858 | 44,685 | 55,663 |
| Total home visits to primary intervention participants | 58,482 | 57,051 | 33,052 | 49,862 |
| Total group meetings attended by all people | 389,080 | 343,864 | 298,406 | 336,517 |
| Total points of contact with all people | 427,562 | 400,115 | 331,458 | 386,378 |

1 Values are n or n (%). AGRI, nutrition-sensitive agriculture intervention; AGRI-NUT, nutrition-sensitive and nutrition-specific agriculture intervention; AGRI-NUT + PLA, nutrition-sensitive and nutrition-specific agriculture intervention using the participatory learning and action approach; PLA, participatory learning and action; UPAVAN: Upscaling Participatory Action and Videos for Agriculture and Nutrition. 2 Primary intervention participants were pregnant women and mothers of children 0–23 mo of age who attended ≥ 1 dissemination group meeting and received a follow-up home visit. 3 Facilitators aimed to conduct home visits after every video dissemination group meeting but only after some PLA meetings, when appropriate, so fewer home visits were planned in the AGRI-NUT + PLA arm. 4 Total points of contact is sum of total dissemination group meeting attendance by all people and total home visit.

### Supplemental Material Table S4

| Population | AGRI | AGRI-NUT | AGRI-NUT + PLA | Mean |
|------------|------|----------|----------------|------|
| Clusters   | 37   | 37       | 37             |      |
| Pregnant women and mothers of children age < 2 y in intervention clusters | | | | |
| Total population (all ages) in intervention clusters | 51,220 | 50,094 | 60,681 | 53,998 |
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nutrition-specific videos and training, mainly driven by inputs from international staff.

The main intervention activities of video production, group meetings, and follow-up home visits constituted the largest share of total costs (ranging from 52% in AGRI-NUT + PLA to 69% in AGRI). These activities were followed by the quality assurance and monitoring activities (ranging from 25% in the AGRI arm to 41% in the AGRI-NUT + PLA arm) (Figure 4). In the AGRI-NUT + PLA arm, more staff time was spent on the quality assurance of the PLA component from 1 partner (Ekjut).

Decomposing the total program costs to line items or inputs (as given in Table 3) shows that staff costs constituted the most costs, at ∼60% in each intervention arm, ranging from 56% in the AGRI-NUT arm to 65% in the AGRI-NUT + PLA arm. The staff costs were followed by other recurrent costs (travel costs and office overheads), varying from 29% in the AGRI-NUT + PLA arm to 39% in the AGRI-NUT arm, mainly due to the large portion of international travel by international staff (JSI RTI) in the AGRI-NUT arm. Most staff costs related to the delivery of interventions, i.e., salary for 24–26 facilitators per arm and 2–3 supervisors per arm, followed by support provided by technical assistance and research partners (Supplemental Figure 1). International staff costs were ∼33% of total staff costs, and mostly contributed to intervention development and technical support during implementation, particularly in the AGRI-NUT arm (Supplemental Figure 1).

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Table 4 gives the cost per intervention from both program and societal perspectives, followed by the cost-efficiency estimates per primary participant and per point of contact. Program costs per primary intervention participant were US$62 in the AGRI arm, US$84 in the AGRI-NUT arm, and US$78 in the AGRI-NUT + PLA arm. Program costs per point of contact were US$0.64 in AGRI, US$0.92 in AGRI-NUT, and US$1.17 in AGRI-NUT + PLA.

**Societal costs of the interventions**

Interventions slightly increased the use of maternal care services (such as delivery care, on-site feeding, and malaria testing) delivered by government frontline nutrition and health care providers, but participants did not incur significantly higher out-of-pocket expenditures. Based on the unit cost of these services, the total cost to the health system of this increased demand for health services ranged from US$1680 in the AGRI-NUT arm to US$7793 in the AGRI arm (Table 4).

Overall, government frontline nutrition and healthcare workers attended 9388 (in AGRI), 9509 (in AGRI-NUT), and 8012 (in AGRI-NUT + PLA) group meetings. Estimated total opportunity costs of their involvement ranged from US$3326 in the AGRI-NUT + PLA arm to US$4174 in the AGRI-NUT arm (Table 4).

Analyses of the endline survey data showed no evidence that the interventions increased participant household expenditures in total or on healthcare, agricultural inputs, food, or nonfood items (8). The estimated opportunity costs to the intervention participants from time spent participating ranged from US$209,433 in AGRI-NUT + PLA arm to US$266,228 in the AGRI arm.

Taken together, total societal costs of the AGRI, AGRI-NUT, and AGRI-NUT + PLA interventions were US$549,668; US$621,355; and US$604,762; respectively. Total cost efficiency (program and societal costs per pregnant woman or mother of children aged 0–23 mo) was US$125 in AGRI, US$143 in AGRI-NUT, and US$122 in AGRI-NUT + PLA. Total societal costs per point of contact were US$1.29, US$1.55, and US$1.82, respectively, (Table 4).

**Intervention consequences and cost–outcome results**

Results in Table 5 show that the AGRI-NUT and AGRI-NUT + PLA interventions increased the minimum dietary diversity of children, each compared with the control (adjusted RRs: 1.19 and 1.27; 95% CIs: 1.03, 1.37 and 1.11, 1.46, respectively. Both AGRI and AGRI-NUT + PLA increased minimum dietary diversity in mothers, each compared with the control (adjusted RR (95% CI): AGRI, 1.21 (1.01, 1.45); AGRI-NUT + PLA, 1.30 (1.10, 1.53)]. Furthermore, the AGRI intervention increased decision-making by women and the total and net annual value of agricultural production compared with...
the control arm. There was no statistically significant effect of the interventions on the other outcomes (8).

Table 6 presents results from our estimates for cost per mean change in maternal and child dietary diversity scores. The results show that, with US$287, the AGRI-NUT + PLA arm has the lowest cost per unit of improvement, reflecting the larger improvements in both maternal and child dietary diversity in the AGRI-NUT + PLA arm than in the AGRI and AGRI-NUT arms, both compared with the control arm.

Sensitivity and scenario analysis
Table 7 shows that replacing international staff costs with local staff costs and reducing monitoring and startup costs had a large impact on the results. Replacing international staff costs with local staff costs reduced total costs by between 24% in the AGRI-NUT + PLA arm to 40% in the AGRI-NUT arm. Reducing costs of the monitoring information system by 50% (25%) reduced the total costs by between 13% (6%) in the AGRI arm to 21% (10%) in the AGRI-NUT + PLA arm. Reducing startup costs by 50% reduced the total costs and cost per primary intervention participant (pregnant women and mothers of children 0–23 mo of age) between 12% in the AGRI-NUT + PLA arm to 15% in the AGRI-NUT arm. Varying the discount rate or changing the allocation rule for the nutrition-specific component had a modest effect on the results, ranging from −10 to +10%.

Cost and affordability of scaleup
Given that AGRI-NUT + PLA was the only intervention to increase both maternal and child dietary diversity, we modeled the potential cost of scaling up the AGRI-NUT + PLA intervention to all rural districts in Odisha. The cost would

![FIGURE 4](image_url) Composition of total program costs by UPAVAN intervention arm. AGRI, nutrition-sensitive agriculture intervention; AGRI-NUT, nutrition-sensitive and nutrition-specific agriculture intervention; AGRI-NUT + PLA, nutrition-sensitive and nutrition-specific agriculture intervention using the participatory learning and action approach; NSA, nutrition-sensitive agriculture; PLA, participatory learning and action; UPAVAN, Upscaling Participatory Action and Videos for Agriculture and Nutrition.

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**TABLE 3** Total economic program costs from program perspective, by line item and UPAVAN intervention arm

| Expenses         | AGRI      |          | AGRI-NUT   |          | AGRI-NUT + PLA |          |
|------------------|-----------|----------|------------|----------|----------------|----------|
|                  | US$¹      | %        | US$²       | %        | 2019 US$³      | %        |
| Staff            | 162,153   | 60%      | 203,805    | 56%      | 249,794        | 65%      |
| Materials        | 2848      | 1%       | 3445       | 1%       | 3159           | 1%       |
| Capital          | 10,836    | 4%       | 16,539     | 5%       | 23,438         | 6%       |
| Other recurrent  | 96,284    | 35%      | 142,897    | 39%      | 110,516        | 29%      |
| Total            | 272,121   |          | 386,686    |          | 386,907        |          |

¹AGRI, nutrition-sensitive agriculture intervention; AGRI-NUT, nutrition-sensitive and nutrition-specific agriculture intervention; AGRI-NUT + PLA, nutrition-sensitive and nutrition-specific agriculture intervention using participatory learning and action approach; PLA, participatory learning and action; UPAVAN, Upscaling Participatory Action and Videos for Agriculture and Nutrition

²2019 US$. An annual discount rate of 3% has been applied.
be ~US$65 million per y, based on a cost of US$1.9 per person (total population in the AGRI-NUT + PLA intervention clusters). This is ~5% of the proposed state health budget for 2021–2022 (~US$1.3 billion per y) or 1.7% of the combined health and agriculture budget (43). However, unit costs might be lower due to potential economies of scale. In addition, given the investments already made in developing the UPAVAN interventions, it is expected that monitoring and evaluation, startup, and coordination activities will be less intensive at scale, reducing implementation costs significantly, as shown in the sensitivity and scenario analyses.

### Discussion

This study contributes to the limited economic evaluation evidence on multisectoral nutrition interventions and is to our knowledge the first economic evaluation of a nutrition-sensitive agriculture intervention in South Asia. We found that participatory NSA interventions, with different combinations of nutrition-specific behavior change or PLA components, can increase child and maternal minimum dietary diversity. The total costs of designing and implementing the UPAVAN interventions ranged from US$271,121 to US$386,907, and annual costs ranged from US$79,645 to US$113,241. Throughout the 32 mo of implementation, the interventions covered a mean of 4,567 pregnant women and mothers of children 0–23 mo of age per intervention, and the cost per pregnant woman or mother (the primary intervention participant) ranged from US$62 in the AGRI arm to US$84 in the AGRI-NUT arm.

Making comparison between UPAVAN and other NSA interventions is challenging due to differences in intervention components, delivery platforms, scales, outcomes assessed, and costing approaches. However, 2 interventions share some similarities with the UPAVAN interventions: NEEP-IE (Nutrition Embedded Evaluation Programme Impact Evaluation) in Malawi (11, 12, 44), and Mama SASHA (Sweetpotato Action for Security and Health in Africa) in Kenya (10). NEEP-IE integrated NSA with nutrition-specific training and used community-based early childhood development centers and parenting group platforms (44, 45). Mama SASHA promoted production and consumption of orange-fleshed sweet potato and integrated nutrition-specific and health components, delivered through health facilities, community health workers, and extension officers (46). UPAVAN, NEEP-IE, and Mama SASHA had similar cost efficiency, at US$62 to US$84 per participant in UPAVAN, US$160 per preschool child covered in NEEP-IE (11), and US$110 per woman and child covered in Mama SASHA (10). In all 3 programs, staff and travel costs constituted major shares (UPA V AN: 56–60%; NEEP-IE: 40%; Mama SASHA: 25%). Comparing point estimates, we found that, for child dietary diversity, AGRI and AGRI-NUT were less cost-effective than NEEP-IE and Mama SASHA, but AGRI-NUT + PLA was more cost-effective (AGRI had no effect; cost per food group increase for AGRI-NUT: US$603; NEEP-IE: US$444; Mama SASHA: US$305; and AGRI-NUT + PLA US$278). Similarly, AGRI and AGRI-NUT were less cost-effective than Mama SASHA at improving maternal diet diversity, but AGRI-NUT + PLA was more cost-effective (cost per food group increase for: AGRI US$517; AGRI-NUT US$603; Mama SASHA US$324; AGRI-NUT + PLA US$325) (47). For NEEP-IE, effects on maternal diet diversity were not reported.

Taken together, our findings show broadly similar cost profiles, cost-efficiency, and cost-effectiveness for UPAVAN, NEEP-IE, and Mama SASHA. Although the UPAVAN trial was not designed to detect differences between intervention arms, we note that the higher cost-effectiveness in the AGRI-NUT + PLA

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TABLE 4 UPAVAN intervention costs and cost-efficiency by intervention arm

| Description                                      | AGRI   | AGRI-NUT | AGRI-NUT + PLA |
|--------------------------------------------------|--------|----------|----------------|
| Program costs and program cost-efficiency (US$)²  |        |          |                |
| Total cost                                       | 272,121| 366,686  | 386,907        |
| Total cost per primary intervention participant³ | 62     | 84       | 78             |
| Annual cost per primary intervention participant⁴| 18     | 25       | 23             |
| Total cost per point of contact⁵                 | 0.64   | 0.92     | 1.17           |
| Societal costs, US$                              |        |          |                |
| Total costs to the public healthcare providers   | 6125   | 4735     | 5025           |
| Costs of increase in use of services             | 7793   | 1680     | 5096           |
| Opportunity costs of involvement of frontline workers in interventions | 3527 | 4174 | 3326 |
| Total opportunity costs to the participants of attending the dissemination group meetings and home visits⁶ | 266,228 | 248,814 | 209,433 |
| Total societal costs and cost efficiency, US$    |        |          |                |
| Program + provider costs                         | 283,441| 372,541  | 395,329        |
| Societal costs (program + provider + participant)| 549,668| 621,355  | 604,762        |
| Total societal cost per primary intervention participant | 125 | 143     | 122            |
| Total societal cost per points of contact        | 1.29   | 1.55     | 1.82           |

1 AGRI, nutrition-sensitive agriculture intervention; AGRI-NUT, nutrition-sensitive and nutrition-specific agriculture intervention; AGRI-NUT + PLA, nutrition sensitive and nutrition-specific agriculture intervention using participatory learning and action approach; PLA, participatory learning and action; UPAVAN, Upscaling Participatory Action and Videos for Agriculture and Nutrition
2 2019 US$
3 Primary intervention participants were pregnant women and mothers of children 0–23 mo of age who attended ≥1 dissemination group meeting and received a follow-up home visit.
4 Mean annual total costs over a time horizon of 41 mo.
5 Total points of contact is sum of total dissemination meeting attendance and total home visits.
6 Included costs incurred by primary intervention participants and all other women who attended ≥1 dissemination group meeting.
Table 5: UPAVAN intervention consequences, measured as effects on trial outcomes among trial participants included in the endline survey.

| Outcome Measure | Control AGRI vs. Control AGRI-NUT vs. Control AGRI-NUT+PLA | AGRI-NUT + PLA vs. Control | n | aRR (95% CI) | n | aRR (95% CI) | n | aRR (95% CI) |
|-----------------|---------------------------------------------------------------|-----------------------------|----|-------------|----|-------------|----|-------------|
| Child minimum diet diversity (age ≥ 4 food groups) | 757 1.06 (0.91, 1.23) 822 1.19 (1.03, 1.37) 2 863 1.27 (1.11, 1.46) 2 | 997 1.21 (1.01, 1.45) 1 1055 1.16 (0.98, 1.38) 1139 1.30 (1.10, 1.53) 2 | 767 1.04 (0.90, 1.20) 757 1.04 (0.90, 1.20) 997 1.06 (0.90, 1.22) 1 1055 1.05 (0.90, 1.21) 1139 1.02 (0.90, 1.15) 2 | |
| Maternal minimum diet diversity (age ≥ 5 food groups) | 997 1.21 (1.01, 1.45) 1 1055 1.16 (0.98, 1.38) 1139 1.30 (1.10, 1.53) 2 | 997 1.21 (1.01, 1.45) 1 1055 1.16 (0.98, 1.38) 1139 1.30 (1.10, 1.53) 2 | 767 1.04 (0.90, 1.20) 757 1.04 (0.90, 1.20) 997 1.06 (0.90, 1.22) 1 1055 1.05 (0.90, 1.21) 1139 1.02 (0.90, 1.15) 2 | |
| Child minimum acceptable diet | 790 1.01 (0.86, 1.19) 829 1.19 (1.02, 1.41) 2 895 1.30 (1.12, 1.52) | 790 1.01 (0.86, 1.19) 829 1.19 (1.02, 1.41) 2 895 1.30 (1.12, 1.52) | 767 1.04 (0.90, 1.20) 757 1.04 (0.90, 1.20) 997 1.06 (0.90, 1.22) 1 1055 1.05 (0.90, 1.21) 1139 1.02 (0.90, 1.15) 2 | |
| Women made ≥ 2 decisions in agriculture or health | 997 1.05 (1.00, 1.11) 1 1055 1.05 (0.99, 1.10) 1139 1.02 (0.96, 1.07) 2 | 997 1.05 (1.00, 1.11) 1 1055 1.05 (0.99, 1.10) 1139 1.02 (0.96, 1.07) 2 | 767 1.04 (0.90, 1.20) 757 1.04 (0.90, 1.20) 997 1.06 (0.90, 1.22) 1 1055 1.05 (0.90, 1.21) 1139 1.02 (0.90, 1.15) 2 | |
| Total value of agricultural production over 1 yr, US$ | 996 108 (31, 231) 1 1053 74 (12, 196) 2 | 996 108 (31, 231) 1 1053 74 (12, 196) 2 | 767 97 (25, 219) 757 97 (25, 219) 997 97 (25, 219) 1 1053 97 (25, 219) 1139 97 (25, 219) 2 | |
| Net value (total value minus input costs) of agricultural production over 1 yr, US$ | 996 108 (31, 231) 1 1053 74 (12, 196) 2 | 996 108 (31, 231) 1 1053 74 (12, 196) 2 | 767 97 (25, 219) 757 97 (25, 219) 997 97 (25, 219) 1 1053 97 (25, 219) 1139 97 (25, 219) 2 | |

AGRI, nutrition-sensitive agriculture intervention; AGRI-NUT, nutrition-sensitive and nutrition-specific agriculture intervention; AGRI-NUT+PLA, nutrition-sensitive and nutrition-specific agriculture intervention using participatory learning and action approach; PLA, participatory learning and action; UPAVAN, Upscaling Participatory Action and Videos for Agriculture and Nutrition; vs., versus.

Significantly different from the control arm, \(< P < 0.05\).
TABLE 6 Cost outcome results from UPAVAN interventions, by intervention arm1

|                      | AGRI      | AGRI–NUT | AGRI–NUT + PLA |
|----------------------|-----------|----------|---------------|
| Total program cost, US$ | 272,121   | 386,686  | 386,907       |
| Primary intervention participants covered, n | 4389      | 4347     | 4965          |
| Mean child DDS1      | 0.0 [−0.15, 0.16] | 0.13 [−0.04, 0.30] | 0.28 [0.13, 0.44] |
| Mean maternal DDS2   | 0.12 [−0.06, 0.30] | 0.14 [−0.03, 0.31] | 0.24 [0.08, 0.41] |
| Cost per primary intervention participants, US$ | 62        | 84       | 78            |
| Cost outcome, child DDS | —         | 603      | 278           |
| Cost outcome, maternal DDS | 517     | 603      | 325           |

1AGRI, nutrition-sensitive agriculture intervention; AGRI–NUT, nutrition-sensitive and nutrition-specific agriculture intervention; AGRI–NUT + PLA, nutrition-sensitive and nutrition-specific agriculture intervention using participatory learning and action approach; DDS, dietary diversity score; PLA, participatory learning and action; UPAVAN, Upscaling Participatory Action and Videos for Agriculture and Nutrition.

2Primary intervention participants (pregnant women and mothers of children <2 y of age who attended ≥1 women’s group meeting).

TABLE 7 Results from sensitivity and scenario analyses by UPAVAN intervention arm1.

| Scenarios/parameters | Cost per primary intervention participant | Cost per primary intervention participant | Cost per primary intervention participant |
|----------------------|-------------------------------------------|-------------------------------------------|-------------------------------------------|
|                      | Total costs                               | Total costs                               | Total costs                               |
| Base-case scenario   | 272,121 62                                 | 386,907 78                                |                                           |
| Allocation rule      |                                           |                                           |                                           |
| Nutrition-specific component | 272,121 62 | 386,907 78 |                                           |
| Alternative allocation rule: 90% vs. 10% | 403,726 93 | 349,867 70 |                                           |
| Discount rate         |                                           |                                           |                                           |
| Base-case 3%          | 264,880 65                                 | 405,884 82                                |                                           |
| Discount rate 6%      | 260,470 59                                 | 395,612 74                                |                                           |
| Startup costs         |                                           |                                           |                                           |
| Base-case 100%        | 236,533 54                                 | 341,955 69                                |                                           |
| MIS costs             |                                           |                                           |                                           |
| Base-case 100%        | 254,860 58                                 | 346,872 70                                |                                           |
| Replacing international costs with local staff | 182,849 42 | 294,963 59 |                                           |

1All values in 2019 US$. AGRI, nutrition-sensitive agriculture intervention; AGRI–NUT, nutrition-sensitive and nutrition-specific agriculture intervention; AGRI–NUT + PLA, nutrition-sensitive and nutrition-specific agriculture intervention using participatory learning and action approach; MIS, monitoring information system; PLA, participatory learning and action; UPAVAN, Upscaling Participatory Action and Videos for Agriculture and Nutrition; vs., versus.

2Program costs.

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in other outcomes, such as household food expenditures and healthcare seeking or utilization may have been due to lack of statistical power rather than lack of effect. Finally, we do not report cost-effectiveness in terms of outcomes commonly used in cost-effectiveness analyses of nutrition interventions (such as DALYs or life-years saved), which limits comparisons with other nutrition interventions. The outcomes that the interventions aimed to change cannot be easily translated to DALYs or other common outcomes for.

Conclusions

In this study we estimated the cost of designing and implementing 3 participatory NSA interventions in rural India, responding to the gap in evidence on the costs of multisectoral NSA interventions and providing useful data to inform their potential scaleup. Our findings show that the costs per primary intervention participant of implementing the interventions are comparable with the results from a limited set of evaluated multisectoral NSA interventions. Considering that a substantial investment has already been made to develop the UPAVAN interventions, costs at scale could be decreased with a less intensive information monitoring system, reduced startup costs, integration within existing programs, and possible economies of scale. We recommend scaleup of AGRI-NUT + PLA, which had the lowest cost per unit increase in dietary diversity. This scaleup should be feasible, given that participatory videos on agriculture, nutrition, and PLA groups are already being implemented at scale in several settings, and because the intervention approach is designed to be responsive to local contexts.

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Data Availability

Aggregated cost data are provided in the tables within paper and in supplemental tables. Trial outcome data will be available from the LSHTM Data Compass, an open-assess institutional research data repository, at https://datacompass.lshtm.ac.uk/.

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