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Midline assessment of agroecological intervention on anaemia and diet diversity in Andhra Pradesh, India

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Abstract:
The Homestead Food Production (HSFP) program in Andhra Pradesh addresses rural food insecurity and malnutrition through natural farming and health and nutrition (H&N) interventions. This midline assessment, conducted in 2024, covered 227 villages and 23,749 participants, with 110 villages in the Andhra Pradesh Community Managed Natural Farming (APCNF) plus Health and Nutrition group and 117 villages in the Model Mandal group (control). The intervention group showed significantly lower anaemia prevalence among women of reproductive age, children under five and adolescents compared to the Model Mandal group. Dietary diversity was higher in the intervention villages, with a mean score of 5.70. Thus, continued multisectoral interventions in agriculture, nutrition education and health are needed to further reduce malnutrition among vulnerable populations.

Keywords: Community based natural farming, anemia, diet diversity, IYCF practices, homestead food production (HSFP)

Background:
India, a country with a population exceeding 1.4 billion, faces an array of socioeconomic and environmental challenges, including poverty, malnutrition and food insecurity **[1]**. Nutritional anemia, particularly iron deficiency anemia, remains a significant global health challenge that disproportionately affects women and children in low and middle-income countries **[2]**. In India, anemia affects 57% of women (15–49 years) and 67% of children under five, as per national surveys **[3]**. Agriculture supports the livelihood of over half of India's rural population, who depend on farming for income and sustenance **[4]**. Studies have demonstrated that integrating nutrition-sensitive agriculture, *i.e.,* homestead food production, significantly reduces anemia prevalence and improves micronutrient intake in vulnerable populations **[5]**. Despite the substantial progress made in the agricultural sector, the dual challenges of malnutrition and food insecurity remain pervasive **[6].** Several governmental initiatives, such as the National Project on Organic Farming (NPOF), Paramparagat Krishi Vikas Yojana (PKVY) and Zero Budget Natural Farming (ZBNF), have aimed to promote sustainable farming practices **[7-9]**. However, these initiatives have encountered several challenges, including limited scale, complex certification processes and inadequate market linkages for organic produce **[10]**. Integrating and promoting nutrition-sensitive agriculture has emerged as a sustainable solution to combat the challenges of nutrition-related deficiency diseases **[11]**. The Homestead Food Production (HSFP) program in Andhra Pradesh addresses rural food insecurity and malnutrition through natural farming practices **[8]**. Furthermore, the HSFP is specifically focused on vulnerable populations, such as women and children, who are more prone to the detrimental effects of malnutrition **[12]**. The initiative empowers women by involving them in decision-making, resource management and leadership in gardening to improve nutrition and socioeconomic status **[13]**. Few Indian studies show Nutri Garden interventions with nutrition education improve diet variety, food intake and household income **[14, 15]**. Nutrition-sensitive agriculture in Africa and South Asia boosts fruit and vegetable intake, reducing micronutrient deficiencies through homestead food production **[16, 17]**. Therefore, it is of interest to report the despite of growing recognition of the interlinkages between agriculture and nutrition, there is a dearth of comprehensive studies that evaluate the long-term impacts of integrated approaches.

Materials and Methods:
This midline assessment was conducted in rural villages of Andhra Pradesh, a state located in southern India, in 2024. Details of the villages and beneficiaries enrolled, district-wise, are given in the **(Table 1)**. All eligible participants who provided consent and, in the case of adolescents, assent, were enrolled in the study **(Figure 1).** Eligibility of mothers who have involved RySS led interventions. Andhra Pradesh's regenerative agriculture through the APCNF program addresses farmer distress by tackling soil degradation, biodiversity loss, water scarcity and the costs of chemical farming. The study evaluated health and nutrition interventions within APCNF, implemented by Rythu Sadhikara Samstha (RySS). Using natural inputs as soil

bio-stimulants, the program promotes dietary diversity and nutrition through homestead food production—Nutri-gardens, backyard poultry, small ruminants, fisheries along with Farmer Nutrition Schools and cooking demonstrations. Nutrition Farming Fellows (NFFs) promote healthy eating habits. Soil is the foundation of nutrition' underpins the H&N interventions at APCNF. While upstream activities, *i.e.,* enabling farmers to adopt natural farming, form the basis of the intervention, HN interventions aim to nudge household consumption behaviors toward natural farming. It includes ensuring that natural farming produce translates into improved food-plate diversity, which was one of the major objectives of HN activities. Operationalizing the objective of improved dietary diversity and pesticide- and fertilizer-free food consumption led to the development of a range of interventions. The baseline assessment of the Homestead Food Production (HSFP) program found improvements in dietary diversity, micronutrient intake and household food security **[15]**. However, it is critical to evaluate the sustainability and progression of these outcomes over time. The present study aims to assess the impact of the HSFP program on the prevalence of anemia among pregnant women, lactating women, children under five, adolescents and adults in rural Andhra Pradesh. Additionally, to study the dietary diversity across these population groups. Standardized procedures and calibrated equipment were used to ensure the accuracy of data collection. The process was conducted by NFFs, who received two days of training in electronic data capture using the Kobo toolbox. Data collection was carried out in collaboration with the Department of Women and Child Development and local childcare centers known as Anganwadi Centers. The collected data were utilized to calculate various health metrics, as detailed in the Data Analysis section. Households were selected for the survey based on specific criteria, including the presence of a pregnant woman, a lactating mother, a child under the age of two, a Seed-to-Seed (S-S) farmer, an adolescent aged 10 to 18 years, or a family categorized as the poorest of the poor (POP). If any of these criteria were met, all members of the household were included in the study. The survey questionnaire was pilot-tested during earlier studies to ensure its suitability. Hemoglobin (Hb) levels for women and children were assessed using the Mission® Hemoglobin system, a reliable point-of-care device designed for rapid and accurate measurement of Hb concentrations. The hemoglobin cut-offs for different age groups are given in the supplementary material **[18]**. The dietary diversity questionnaire (DDQ) was used to assess the diet quality and diversity among the study participants. The minimum Dietary Diversity for Women (MDD-W) is one of the most widely used indicators derived from the DDQ and it has recently been proposed as an indicator in the SDGs. The MDD-W is composed of 10 food groups: grains, pulses, nuts and seeds, dairy, meat and fish, eggs, dark leafy vegetables, vitamin A-rich fruits and vegetables, other vegetables and other fruits. If women of reproductive age (15-49) in low- and middle-income countries consume at least 5 of these groups, it suggests a higher likelihood of adequate micronutrient intake. The MDD-W was a binary indicator, expressed as the proportion of women meeting this dietary diversity threshold **[19, 20]**. The NCD-Protect score assessed adherence to a health-promoting diet based on 9 food groups protective against non-communicable diseases: whole grains, pulses, nuts/seeds, vitamin A-rich vegetables and fruits, dark leafy vegetables, other vegetables, citrus and other fruits. Each group was scored as 0 (not consumed) or 1 (consumed), with a total score ranging from 0 to 9. Higher scores reflected better adherence to dietary guidelines **[21, 22]**. The NCD-Risk score was based on 8 food groups associated with higher non-communicable disease risk: soft drinks, sweets, processed meats, deep-fried foods, fast foods and salty ultra-processed snacks. Each group is scored 0 (not consumed) or 1 (consumed), with a total score from 0 to 9. Higher scores reflected greater intake of unhealthy foods and a higher likelihood of exceeding recommended limits for sugar, fat, salt and red meat **[21, 22]**. The Global Dietary Recommendation (GDR) score ranges from 0 to 18 and measures adherence to dietary guidelines that address NCD risk factors. A higher score indicated a greater likelihood of meeting these guidelines. It was calculated by subtracting the NCD-Risk score from the NCD-Protect score, then adjusting the result to the positive range by adding 9. The final score represented the mean score of the population **[21, 22]**. The data analysis was carried out using STATA version 17 **[23]** and R version 4.4.1**[24]**. Categorical variables were summarized using frequencies and proportions, while continuous variables were described using the mean with standard deviation or the median with IQR, depending on the data's normality. A Pearson chi-squared test, an independent samples t-test and a Mann-Whitney test were used to compare outcomes. The study was conducted collaboratively by Rythu Sadhikara Samstha (RySS) and All India Institute of Medical Sciences (AIIMS), Mangalagiri. The study was approved by the Institute Ethics Committee of All India Institute of Medical Sciences, Mangalagiri, Andhra Pradesh, India. (AIIMS/MG/IEC/2023-2024/95, Dated 30-03-2024). Written informed consent was obtained from all participating individuals. The data collection from children and adolescents was conducted after obtaining consent from their parents/caregivers. Written assent was obtained from adolescents.

Results:

Table 1 presents the age and gender distribution of study participants across the groups. A total of 23,749 individuals were included in the study, with females accounting for the majority (56.88%). Over half of the participants were females in both arms. Children aged 5–9 years represented the smallest proportion in the intervention and Model Mandal arms. Overall, adults constituted 61.83% of the total population followed by adolescents (16.29%), children under 5 (15.58%) and children aged 5–9 years (6.31%). Approximately one-third of the participants in both the intervention and Model Mandal villages were selected based on the presence of at least one adolescent in the household. Based on the poorest-of-the-poor criteria, 25.2% of participants were recruited to the study. The selection criteria for various groups are detailed in **Table 2**. **Table 3** presents the

overall prevalence of anemia across various population subgroups. Among the "seed-to-seed farmers" across both APCNF and model mandal villages, 1,653 individuals (66.25%) were identified as anemic, with 10.5% total anemia cases in the population. Anemia was more common among females than males in both villages, whereas its prevalence was similar among adolescents and children under five. The highest prevalence of anemia was observed among lactating mothers (80.8%), with lactating mothers in the model mandal reporting the highest (82.6%). **Table 4** shows the prevalence of anemia in various populations across Model Mandal and intervention villages. It was high among lactating women (61% in the modal mandal vs. 39% in intervention, $p < 0.001$) and among the poorest of the poor (52% vs. 48%, $p < 0.001$). Among pregnant women, children under five and adolescents, anemia affected approximately half of the individuals in both groups. Seed-to-seed farmers also exhibited a considerable burden of anemia (59% vs. 41%, $p = 0.15$). **Table 5** presents anemia severity across population groups in Model Mandal and intervention villages. Among pregnant women, moderate and severe anemia were higher in the Modal Mandal group (57% and 61%) than in the intervention group (43% and 39%) ($p < 0.001$). Lactating women in the intervention village showed significantly lower severe anemia (14% vs. 86%) and moderate anemia ($p < 0.001$). **Table 6** presents an analysis of dietary diversity and quality using the Dietary Diversity Questionnaire (DDQ) calculator. Diet diversity indicators were generally higher in the Modal Mandal group. The Minimum Dietary Diversity for Women (MDD-W) was higher in the interventional group (73.61) than in the Model Mandal group (51.23) and the Dietary Diversity Score (DDS) was higher (5.70 vs. 4.94). Processed meat consumption was notably higher in the Modal Mandal group (4.79% vs. 0.30%). The Modal Mandal group reported a higher intake of salty or fried snacks (38.94% vs. 25.56%) and deep-fried foods (25.94% vs. 16.95%). The Dietary Diversity Score was comparable across genders. Females have a slightly higher proportion of consuming at least one vegetable and at least one fruit. Conversely, males report slightly higher consumption of animal-source foods and pulses **(Table 12)**. **Table 7** presents an analysis of infant and young child feeding (IYCF) practices based on the Dietary Diversity Questionnaire (DDQ) across the intervention and Model Mandal groups. Exclusive breastfeeding in the first two days was higher in the intervention group (86%) than in the Modal Mandal group (73%). No infants were reported to be exclusively breastfed for six months or longer, though 26.44% of infants were mixed milk-fed. Continued breastfeeding at 12–23 months was 66.67%. Introduction of solid foods at 6–8 months was universal in the Model Mandal group (100%) but lower in the Intervention group (87.5%). **Table 8** highlights gender disparities—females had lower MAD (6.35% vs. 18%) and higher zero vegetable/fruit consumption (54.76% vs. 47.62%). **Table 9** shows that 2,843 households had Nutri gardens; more in the Intervention group (1,753) than in the Model Mandal group (1,090). Most were started between 2022 and 2024. Leafy vegetables were widely grown (97%), followed by tubers (59%), fruits (40%), pulses (39%) and medicinal plants (24%). **Table 10** presents backyard poultry data. More households in the Intervention group (1,268) kept poultry than in the Model Mandal group (585). Egg consumption was higher in the Intervention group, with 76% consuming all their eggs, while 39% of Model Mandal households consumed half. Egg sales were minimal, with 84% in the Intervention group and 73% in the Model Mandal not selling eggs. **Table 11** presents the district-wise distribution of villages and participants, totalling 227 villages and 23,749 participants. APCNF + HN cover 110 villages with 11,619 participants, while Model Mandal includes 117 villages with 12,130 participants.

Table 1: Distribution of participant details characterized by age and gender across the intervention and model mandal villages

Arms	Age category	Gender				Total	
		Female		Male			
		n	%	n	%	n	%
APCNF + HN (Intervention)	Under 5 Children	890	48.45	947	51.55	1837	15.81
	Children (5-9y)	345	52.04	318	47.96	663	5.71
	Adolescents	1351	73.83	479	26.17	1830	15.75
	Adults	3987	54.70	3302	45.30	7289	62.73
	Total	6573	56.57	5046	43.43	11619	100.00
Model Mandal Village (Control)	Under 5 Children	936	50.27	926	49.73	1862	15.35
	Children (5-9 years)	448	53.65	387	46.35	835	6.88
	Adolescents	1371	67.27	667	32.73	2038	16.80
	Adults	4181	56.54	3214	43.46	7395	60.96
	Total	6936	57.18	5194	42.82	12130	100.00
Total	Under 5 Children	1826	49.36	1873	50.64	3699	15.58
	Children (5-9y)	793	52.94	705	47.06	1498	6.31
	Adolescents	2722	70.37	1146	29.63	3868	16.29
	Adults	8168	55.63	6516	44.37	14684	61.83
	Total	**13509**	**56.88**	**10240**	**43.12**	**23749**	**100.00**

Table 2: The selection criteria for recruiting the participants into the study

Category	Intervention		Model Mandal		Total	
	n	%	n	%	n	%
1. Pregnant woman	1001	8.423	909	7.426	1910	7.917
2. Lactating mother	811	6.824	1159	9.469	1970	8.166
3. Child under 2 years	2281	19.194	2107	17.214	4388	18.189
4. Seed to seed (S-S farmer)	1032	8.684	1424	11.634	2456	10.181

5. Adolescent (10 to 18 years)	3722	31.319	3575	29.208	7297	30.248
6. Poorest of poor (POP)	3037	25.555	3066	25.049	6103	25.298
Total	11884	100	12240	100	24124	100
Missing					76	

Table 3: Descriptive comparison of anemia across different age groups in intervention and model mandal villages

Arms	Category	Anemia										
		No		**Mild**		**Moderate**		**Severe**		**Total**		**P value**
Intervention Village	seed to seed (S-S farmer)	372	35.36	326	30.99	330	31.37	24	2.28	1052	9.05	0.908
	Total	4073	35.05	3682	31.69	3627	31.22	237	2.04	11619	48.92	
Model Mandal Village	seed to seed (S-S farmer)	470	32.57	347	24.05	583	40.40	43	2.98	1443	11.90	<0.001
	Total	3382	27.88	3152	25.99	5246	43.25	350	2.89	12130	51.08	
Total	seed to seed (S-S farmer)	842	33.75	673	26.97	913	36.59	67	2.69	2495	0.11	0.029
	Total	7455	31.39	6834	28.78	8873	37.36	587	2.47	23749	100.00	
Intervention Village	Poorest of poor	1050	32.91	989	30.99	1091	34.19	61	1.91	3191	27.46	<0.001
	Total	4073	35.05	3682	31.69	3627	31.22	237	2.04	11619	48.92	
Model Mandal Village	Poorest of poor	785	25.15	723	23.17	1491	47.77	122	3.91	3121	25.73	<0.001
	Total	3382	27.88	3152	25.99	5246	43.25	350	2.89	12130	51.08	
Total	Poorest of poor	1835	29.07	1712	27.12	2582	40.91	183	2.90	6312	26.58	<0.001
	Total	7455	31.39	6834	28.78	8873	37.36	587	2.47	23749	100.00	
Intervention Village	Female	1900	28.91	1807	27.49	2682	40.80	184	2.80	6573	48.66	<0.001
	Male	2173	43.06	1875	37.16	945	18.73	53	1.05	5046	49.28	
Model Mandal Village	Female	1577	22.74	1437	20.72	3680	53.06	242	3.49	6936	51.34	<0.001
	Male	1805	34.75	1715	33.02	1566	30.15	108	2.08	5194	50.72	
Total	Female	3477	25.74	3244	24.01	6362	47.09	426	3.15	13509	56.88	<0.001
	Male	3978	38.85	3590	35.06	2511	24.52	161	1.57	10240	43.12	
Intervention Village	under-five	659	35.87	728	39.63	442	24.06	8	0.44	1837	49.66	<0.001
	primary	165	24.89	99	14.93	368	55.51	31	4.68	663	44.26	
	Adolescent	564	30.82	461	25.19	743	40.60	62	3.39	1830	47.31	
	Adult	2685	36.84	2394	32.84	2074	28.45	136	1.87	7289	49.64	
Model Mandal Village	under-five	445	23.90	540	29.00	860	46.19	17	0.91	1862	50.34	<0.001
	primary	172	20.60	84	10.06	536	64.19	43	5.15	835	55.74	
	Adolescent	511	25.07	414	20.31	1032	50.64	81	3.97	2038	52.69	
	Adult	2254	30.48	2114	28.59	2818	38.11	209	2.83	7395	50.36	
Total	under-five	1104	29.85	1268	34.28	1302	35.20	25	0.68	3699	15.58	<0.001
	primary	337	22.50	183	12.22	904	60.35	74	4.94	1498	6.31	
	Adolescent	1075	27.79	875	22.62	1775	45.89	143	3.70	3868	16.29	
	Adult	4939	33.64	4508	30.70	4892	33.32	345	2.35	14684	61.83	
Intervention Village	Lactating mother	73	21.53	94	27.73	168	49.56	4	1.18	339	8.53	0.001
	Total	1134	28.54	1038	26.12	1679	42.25	123	3.10	3974	48.83	
Model Mandal Village	Lactating mother	76	17.31	63	14.35	277	63.10	23	5.24	439	10.54	<0.001
	Total	972	23.34	836	20.07	2207	52.99	150	3.60	4165	51.17	
Total	Lactating mother	149	19.15	157	20.18	445	57.20	27	3.47	778	9.56	<0.001
	Total	2106	25.88	1874	23.02	3886	47.75	273	3.35	8139	100.00	
Intervention Village	Pregnant women	194	52.57	113	30.62	62	16.80	0	0.00	369	53.48	0.011
Model Mandal Village	Pregnant women	148	46.11	89	27.73	84	26.17	0	0.00	321	46.52	
Total	Total	342	49.57	202	29.28	146	21.16	0	0.00	690	100.00	

Table 4: Showing the comparison of anaemia status in different population groups in Model Mandal and intervention villages

Anaemia status	Model mandal n (%)	Intervention village n (%)	p-value*
Pregnant women	**n = 968**	**n = 1,059**	
Anaemia	614 (50%)	616 (50%)	0.015
No anaemia	354 (44%)	443 (56%)	
Hb (g%) Mean ± SD	11.17 ± 1.65	11.43 ± 1.63	<0.001
Lactating women	**n = 1,564**	**n = 1,113**	
Anaemia	1,158 (61%)	732 (39%)	<0.001
No anaemia	406 (52%)	381 (48%)	
Hb (g%) Mean ± SD	10.65 ± 1.88	11.22 ± 1.69	<0.001
Children under 5 years	**n = 2,908**	**n = 3,217**	
Anaemia	2,052 (50%)	2,077 (50%)	<0.001
No anaemia	856 (43%)	1,140 (57%)	
Hb (g%) Mean ± SD	10.80 ± 2.26	11.16 ± 2.00	<0.001
Adolescents	**n = 3,582**	**n = 3,741**	
Anaemia	2,608 (52%)	2,419 (48%)	<0.001
No anaemia	984 (43%)	1,322 (57%)	
Hb (g%) Mean ± SD	11.04 ± 1.73	11.48 ± 1.76	<0.001
Seed-to-seed farmer	**n = 1,443**	**n = 1,052**	
Anaemia	973 (59%)	680 (41%)	0.15
No anaemia	470 (56%)	372 (44%)	
Hb (g%) Mean ± SD	11.26 ± 1.89	11.49 ± 1.73	<0.001
Poorest of the poor	**n = 3,121**	**n = 3,191**	

Anaemia	2,336 (52%)	2,141 (48%)	<0.001
No anaemia	785 (43%)	1,050 (57%)	
Hb (g%) Mean ± SD	10.89 ± 1.82	11.42 ± 3.26	<0.001

Table 5: Showing the comparison of the severity of anaemia in different population groups in Model Mandal and intervention villages

Severity of Anaemia	Model mandal	Intervention village	p-value*
	n (%)	n (%)	
Pregnant women	**n = 968**	**n = 1,059**	
No anaemia	354 (44%)	443 (56%)	<0.001
Mild anaemia	320 (45%)	394 (55%)	
Moderate anaemia	277 (57%)	211 (43%)	
Severe anaemia	17 (61%)	11 (39%)	
Lactating women	**n = 1,564**	**n = 1,113**	
No anaemia	406 (52%)	381 (48%)	<0.001
Mild anaemia	411 (51%)	398 (49%)	
Moderate anaemia	704 (68%)	327 (32%)	
Severe anaemia	43 (86%)	7 (14%)	
Children under 5 years	**n = 2,908**	**n = 3,217**	
No anaemia	856 (43%)	1,140 (57%)	<0.001m
Mild anaemia	789 (42%)	1,095 (58%)	
Moderate anaemia	1,204 (56%)	929 (44%)	
Severe anaemia	59 (53%)	53 (47%)	
Adolescents	**n = 3,582**	**n = 3,741**	
No anaemia	984 (43%)	1,322 (57%)	<0.001
Mild anaemia	869 (46%)	1,013 (54%)	
Moderate anaemia	1,622 (55%)	1,304 (45%)	
Severe anaemia	117 (53%)	102 (47%)	
Seed-to-seed farmer	**n = 1,443**	**n = 1,052**	
No anaemia	470 (56%)	372 (44%)	<0.001
Mild anaemia	347 (52%)	326 (48%)	
Moderate anaemia	583 (64%)	330 (36%)	
Severe anaemia	43 (64%)	24 (36%)	
Poorest of the poor	**n = 3,121**	**n = 3,191**	
No anaemia	470 (56%)	372 (44%)	<0.001
Mild anaemia	347 (52%)	326 (48%)	
Moderate anaemia	583 (64%)	330 (36%)	
Severe anaemia	43 (64%)	24 (36%)	

Table 6: Comparison of diet diversity based on Diet-quality questionnaire (DQQ) between intervention and Model Mandal groups

Indicator	Intervention	Model Mandal	Total
DDQ			
All-5	0.50	0.34	0.42
MDD-W	73.61	51.23	62.25
Dietary Diversity Score (DDS)	5.70	4.94	5.31
NCD-Protect	3.66	3.24	3.44
NCD-Risk	1.01	1.10	1.06
Global dietary recommendation (GDR) Score	11.65	11.13	11.38
At least one vegetable	87.16	84.86	85.98
At least one fruit	66.81	51.48	58.95
At least one pulse, nut, or seed	78.74	72.27	75.42
At least one animal-source food	90.78	80.27	85.39
At least one starchy staple	99.17	99.79	99.49
Zero vegetable or fruit consumption	7.63	10.15	8.92
At least one vegetable or fruit	92.37	89.85	91.08
Pulse consumption	71.97	67.28	69.57
Nuts or seeds consumption	24.45	15.40	19.81
Whole grain consumption	43.73	41.38	42.53
Processed meat consumption	4.79	0.30	2.49
Salty or fried snack consumption	25.56	38.94	32.41
Deep fried food	16.95	25.94	21.56
Sweet foods consumption	36.45	36.18	36.31
Soft drinks (sodas, energy drinks, sports drinks)	0.00	0.00	0.00

Table 7: Comparison of infant and young child feeding (IYCF) practices based on the Dietary Diversity Questionnaire (DDQ) across the intervention and Model Mandal groups

Indicator	n	Intervention	Model Mandal	Total
Ever breastfed	318	82	92	87
Early initiation of breastfeeding	318	0.00	0.00	0.00
Exclusively breastfed for the first two days after birth	318	86	73	79
Exclusive breastfeeding under six months	87	0.00	0.00	0.00

Mixed milk feeding under six months	87	23	30	26
Continued breastfeeding 12-23 months	141	0.64	0.69	0.67
Introduction of solid, semi-solid, or soft foods 6-8 months	32	100.00	78.95	87.50
Minimum dietary diversity 6-23 months	231	48.98	41.35	44.59
Minimum meal frequency 6-23 months	163	25.76	21.65	23.31
Minimum milk feeding frequency for non-breastfed children 6-23 months	76	40.54	41.03	40.79
Minimum acceptable diet 6-23 months	163	16.67	11.34	13.50
Egg and/or flesh food consumption 6-23 months	231	31.63	30.08	30.74
Sweet beverage consumption 6-23 months	231	38.78	22.56	29.44
Unhealthy food consumption 6-23 months	231	46.94	39.10	42.42
Sweet food consumption 6-23 months	231	40.82	37.59	38.96
Savory and fried snack consumption 6-23 months	231	20.41	8.27	13.42
Zero vegetable or fruit consumption 6-23 months	231	44.90	54.14	50.22
Bottle feeding 0-23 months	318	0.34	0.31	0.32
All-5 6-23 months	231	25.51	15.79	19.91
Whole grain consumption 6-23 months	231	4.08	2.26	3.03
Processed meat consumption 6-23 months	231	0.00	2.26	1.30

Table 8: Comparison of infant and young child feeding (IYCF) practices based on the Dietary Diversity Questionnaire (DDQ) across gender

Indicator	n	Female	Male	Total
Ever breastfed	318	0.89	0.86	0.87
Early initiation of breastfeeding	318	0	0	0
Exclusively breastfed for the first two days after birth	318	0.81	0.77	0.79
Exclusive breastfeeding under six months	87	0	0	0
Mixed milk feeding under six months	87	0.29	0.24	0.26
Continued breastfeeding 12-23 months	141	0.76	0.62	0.67
Introduction of solid, semi-solid, or soft foods 6-8 months	32	91.67	85	87.5
Minimum dietary diversity 6-23 months	231	40.48	46.94	44.59
Minimum meal frequency 6-23 months	163	22.22	24	23.31
Minimum milk feeding frequency for non-breastfed children 6-23 months	76	45.83	38.46	40.79
Minimum acceptable diet 6-23 months	163	6.35	18	13.5
Egg and/or flesh food consumption 6-23 months	231	29.76	31.29	30.74
Sweet beverage consumption 6-23 months	231	26.19	31.29	29.44
Unhealthy food consumption 6-23 months	231	41.67	42.86	42.42
Sweet food consumption 6-23 months	231	36.9	40.14	38.96
Savory and fried snack consumption 6-23 months	231	15.48	12.24	13.42
Zero vegetable or fruit consumption 6-23 months	231	54.76	47.62	50.22
Bottle feeding 0-23 months	318	0.27	0.36	0.32
All-5 6-23 months	231	23.81	17.69	19.91
Whole grain consumption 6-23 months	231	3.57	2.72	3.03
Processed meat consumption 6-23 months	231	2.38	0.68	1.3

Table 9: Characteristics of the Nutrition Garden across intervention and Model Mandal groups

Characteristics		Intervention	Model Mandal	Total	p-value
Household have a Nutri-Garden or Kitchen Garden	Yes	1753	1090	2843	
Year of start of Nutrigarden	Before 2018	100	48	148	<0.001
	2018	69	35	104	
	2019	129	23	152	
	2020	120	38	158	
	2021	235	106	341	
	2022	397	169	566	
	2023	490	454	944	
	2024	213	217	430	
Leaf Vegetables are grown in Nutrition Graden/Kitchen Garden	No	17	66	83	<0.001
	Yes	1736	1024	2760	
Other Vegetables	No	49	25	74	0.41
	Yes	1704	1065	2769	
Tubers	No	711	655	1366	<0.001
	Yes	1042	435	1477	
Fruits	No	1059	733	1792	<0.001
	Yes	694	357	1051	
Pulses and Legume	No	1071	885	1956	<0.001
	Yes	682	205	887	
Medicinal Plants	No	1333	961	2294	<0.001
	Yes	420	129	549	

Table 10: Characteristics of the Backyard Poultry across intervention and Model Mandal groups

Characteristics		Intervention	Model Mandal	Total	p-value
Backyard poultry	No	2706	3580	6286	<0.001
	Yes	1268	585	1853	

Eggs produced in backyard poultry is consumed by your family per month	All	380	125	505	<0.001
	Half	242	200	442	
	None	496	184	680	
	One fourth	118	40	158	
	Three fourth	32	36	68	
Eggs produced in your backyard poultry are sold	All	21	11	32	<0.001
	Half	148	103	251	
	None	1067	430	1497	
	One fourth	16	36	52	
	Three fourth	16	5	21	

Table 11: Distribution of the number of villages and participants district-wise

District Name	APCNF + HN		Model Mandal		Total	
	Number of Villages	Participants	Number of Villages	Participants	Number of Villages	Participants
Allurisitharamaraju	10	542	0	0	10	542
Anakapalli	0	0	9	447	9	447
Anantapur	5	408	3	3	8	411
Annamayya	11	1003	6	590	17	1593
Bapatla	5	904	6	1002	11	1906
Chittoor	0	0	6	878	6	878
East Godavari	0	0	5	958	5	958
Eluru	6	396	1	273	7	669
Guntur	7	1346	7	867	14	2213
Kakinada	4	502	1	1	5	503
Konaseema	0	0	5	856	5	856
Krishna	0	0	7	874	7	874
Kurnool	2	2	8	1282	10	1284
Nandyala	12	1476	6	484	18	1960
NTR	1	1	5	102	6	103
Palnadu	1	3	6	436	7	439
Parvathipuram Manyam	13	753	0	0	13	753
Prakasam	5	1175	0	0	5	1175
SPR Nellore	5	296	6	85	11	381
Srikakulam	1	1	6	346	7	347
Srisathyasai	0	0	7	390	7	390
Thirupathi	10	1480	2	143	12	1623
Visakhapatnam	0	0	5	963	5	963
Vizianagaram	1	1	0	0	1	1
West Godavari	0	0	5	666	5	666
YSR Kadapa	11	1330	5	484	16	1814
Total	110	11619	117	12130	227	23749

Table 12: Comparison of diet diversity based on Diet-quality questionnaire (DQQ) between males and females

Indicator	Female	Male	Total
DQQ Scores			
All-5	0.41	0.43	0.42
MDD-W	62.25	-	62.25
Dietary Diversity Score (DDS)	5.33	5.29	5.31
NCD-Protect	3.46	3.42	3.44
NCD-Risk	1.04	1.09	1.06
GDR Score	11.42	11.33	11.38
Components of DQQ questionnaire (%)			
At least one vegetable	86.34	85.50	85.98
At least one fruit	59.60	58.07	58.95
At least one pulse, nut, or seed	75.34	75.54	75.42
At least one animal-source food	84.92	86.05	85.39
At least one starchy staple	99.81	99.04	99.49
Zero vegetable or fruit consumption	8.15	9.98	8.92
At least one vegetable or fruit	91.85	90.02	91.08
Pulse consumption	68.96	70.41	69.57
Nuts or seeds consumption	21.10	18.06	19.81
Whole grain consumption	42.67	42.34	42.53
Processed meat consumption	2.18	2.91	2.49
Salty or fried snack consumption	30.13	35.55	32.41
Deep fried food	18.93	25.17	21.56
Sweet foods consumption	37.53	34.63	36.31
Soft drinks (sodas, energy drinks, sports drinks)	0.00	0.00	0.00

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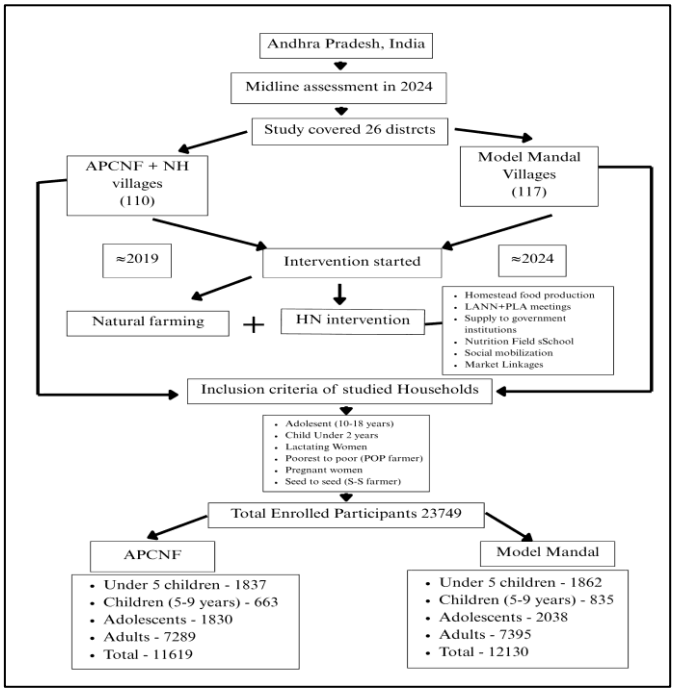

Figure 1: Showing the flow of the study

Discussion:

The current study evaluated the impact of a nutrition garden intervention on anemia and dietary diversity among pregnant women, children and adults in rural villages of Andhra Pradesh, India. Our findings suggest that the intervention significantly influenced anemia prevalence, dietary diversity and infant and young child feeding (IYCF) practices in the intervention villages compared to the Model Mandal group. In this study, the intervention group showed a lower prevalence of anemia across all demographic categories, including women of reproductive age, children under five and adolescents. For instance, among lactating mothers, anemia prevalence was 61% in the Model Mandal group compared to 39% in the intervention group. The effect of household food production strategy on anemia reduction in pregnant women and young children shows inconsistent results worldwide **[25, 26]**. However, these study findings align with recent evidence demonstrating that nutrition-sensitive agriculture can significantly reduce anemia prevalence and improve micronutrient intake in low- and middle-income countries **[5]**. The mean hemoglobin level was consistently higher in all the age groups in the intervention category, which can be attributed to increased availability and consumption of iron-rich foods, as shown in a study done in low-and middle-income countries **[25]**. Despite these improvements, high levels of moderate-to-high anemia in both groups underscore structural and systemic challenges. Factors such as helminthic infections, poor sanitation and limited access to iron supplementation programs may mitigate the full impact of dietary improvements. While agricultural interventions have the potential to address micronutrient deficiencies, their success often depends on complementary strategies such as access to health services, education and sanitation **[27]**. The data reveal that the intervention village experienced a noticeable reduction in severe anemia cases across most subgroups, suggesting the efficacy of the implemented health strategies. Reducing severe anemia improves maternal and child health boosts adult productivity and lowers healthcare costs related to anemia complications. The lower prevalence of severe anemia in the intervention village among females, adolescents and the poorest of the poor highlight the importance of tailored interventions that consider gender and socioeconomic disparities. Moreover, the higher rates of mild anemia among pregnant women in the intervention village, coupled with fewer severe cases, suggest that early anemia intervention and management could prevent progression to more severe stages. For policymakers and public health practitioners, these findings emphasize the need for continued investment in community-based health interventions that focus on nutritional education, supplementation programs and addressing the socioeconomic determinants of health. By prioritizing such initiatives, the long-term public health benefits include enhanced quality of life, reduced mortality and morbidity rates among high-risk groups and greater health equity. In conclusion, the positive outcomes observed in the intervention village serve as a testament to the power of targeted public health strategies in combating anemia and improving the overall health landscape. A key component of these interventions is the philosophy that "Soil is the foundation of nutrition," which underpins the Health and Nutrition (H&N) interventions at Andhra Pradesh Community-based Natural Farming (APCNF). This approach is holistic, focusing on enabling farmers to adopt natural farming practices while nudging household consumption behaviors towards more nutritious and diverse diets. One major objective is to ensure that natural farming practices translate into improved food-plate diversity, operationalized through various innovative interventions. The Nutrition Garden, for instance, provides a low-cost, scientifically validated model for kitchen or homestead gardens that produce a variety of nutritious vegetables, fruits and medicinal plants year-round. This not only ensures the nutritional security of marginal farming families but also empowers them towards self-sufficiency. LANN+PLA meetings are pivotal in training functionaries to develop nutrition and food security plans and encouraging households to establish homestead production, with robust community monitoring. Institutional Linkages further diversify the food basket available to beneficiaries, with a special focus on those in the critical 1000-day window of opportunity for nutritional interventions. Further, the supply to Government institutions such as AWCs, Schools and hostels also ensures that healthy and safe food is provided under supplementary nutrition in addition to what they consume at home. Dietary diversity, a critical determinant of nutritional adequacy, was significantly higher in the intervention villages. The consumption of fruits, vegetables, pulses and animal-derived foods was associated with the beneficial effects of the Nutri Garden, as indicated by a mean Dietary Diversity Score of 5.70 among households in the intervention villages. Other studies have also shown that

agricultural diversification positively impacts household dietary diversity **[4, 28 and 29]**. The Minimum Dietary Diversity for Women (MDD-W) scores were higher in the Model Mandal group than in the intervention groups, suggesting room for further better meet women's specific dietary needs. This discrepancy may be attributable to regional differences in food access or cultural dietary practices, as indicated in other studies **[30]**. In the intervention village, people consumed more vitamin A-rich foods. This supports findings from another study highlighting that targeted interventions help improve diet diversity and reduce micronutrient deficiencies **[31]**. The IYCF practices in the intervention villages showed notable improvements in key indicators, including the timely introduction of complementary foods and the achievement of minimum diversity. These findings support the importance of evidence-based nutrition interventions to improve IYCF practices **[32]**. The proportion of children meeting the minimum dietary diversity was also higher in the intervention villages, reflecting the improved maternal knowledge and access to diverse foods. Another study reported that agricultural programs that integrate nutrition education improve IYCF outcomes by addressing both supply-side and demand-side barriers **[33]**. However, gaps remain exclusive breastfeeding rates and complementary feeding practices are still suboptimal. This can be explained by socio-cultural barriers such as low health literacy and lack of maternal autonomy. It has been explored in other studies as well **[34]**. Overcoming them requires holistic strategies that educate mothers, engage communities and challenge norms. Enhancing maternal decision-making and creating enabling environments through health literacy programs, supportive policies and community involvement can drive lasting change. Culturally sensitive, integrated interventions are essential to improve child nutrition, reduce malnutrition and support early development in rural settings. The Nutrition Gardening Program empowered women as key agents of change in improving household nutrition. Previous studies have shown that women's empowerment in agriculture positively influences household food security and nutritional outcomes **[35]**. Increased adoption of Nutri gardens in intervention villages, compared to Model Mandal, reflects the program's effectiveness. Households primarily grew leafy greens rich in micronutrients, along with tubers, fruits, legumes and medicinal plants demonstrating improved dietary diversity and food security. Though women's participation was sometimes limited by time and resource constraints, their involvement proved critical. Backyard poultry further supported nutrition, with most households consuming all the eggs produced boosting intake of protein, iron and vitamin B12, vital for reducing malnutrition and anemia in children and pregnant women. The low rate of egg sales indicates a shift toward prioritizing household nutrition over income. These results highlight the potential of Nutri gardens and backyard poultry as sustainable strategies in public health nutrition. By improving access to diverse and nutritious foods, such interventions can significantly reduce malnutrition and associated health risks. Key strength of the study is its robust design, utilizing a pre-post-study comparison with both intervention and Model Mandal groups, which allowed for the assessment of the program's impact on nutrition outcomes. The inclusion of objective measures, such as hemoglobin levels, provided concrete data to assess the intervention's effect on anemia. In this study, we recruited individuals from various population groups, as well as those at high risk.

Conclusion:

We show the Homestead Food Production program in rural Andhra Pradesh, India reduces anemia and improves nutrition through gardens, dietary diversity and child feeding practices. Empowering women in homestead agriculture and poultry boosts nutrition outcomes. Thus, continued multisectoral investment combining agriculture, nutrition education and health interventions is essential to further reduce malnutrition among vulnerable groups.

Limitations:

This study is a cross-sectional midline assessment comparing intervention and model mandal villages. However, this design does not allow causal conclusions about the intervention's impact. Differences observed between groups may be influenced by baseline differences that were not accounted for. The study's short-term evaluation may not capture delayed effects or the long-term sustainability of improvements in anemia levels and dietary diversity. Additionally, although the study controlled for some confounding variables, other factors, such as seasonal variations in food availability or other health interventions, may have influenced the results. Another limitation is the potential bias in self-reported dietary diversity and food consumption. Finally, the study did not explore the socio-cultural dynamics influencing dietary habits, which could limit the generalizability of the findings outside the APCNF Program to other regions with different cultural practices or food preferences.

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