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Comparative Nutritional Security of Tribal Farm Women in Andhra Pradesh Using Canonical Correlation Analysis

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HIGHLIGHTS

- The study highlighted a significant multivariate relationship between socioeconomic, livelihood variables and nutritional security among Chenchu and Lambada tribal women in South Coastal Andhra Pradesh
- Annual income, economic motivation, education and the impact of major government food and nutritional security schemes were important for the first canonical function, while age and BMI were most influential for the second canonical function.
- The first two canonical functions were significant in both groups, whereas the third function was non-significant.
- There was a distinct difference in the strength of association between the two tribes, with Lambada women showing relatively stronger multivariate relationships than Chenchu women.

ARTICLE INFO

Keywords: BMI, Tribal women, Canonical correlation analysis, Food security, Nutritional security.

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ABSTRACT

The study was conducted during 2025-2026 in the Palnadu and Prakasam districts of Andhra Pradesh and examined the significant relationship between a selected set of socioeconomic, livelihood and nutritional security indicators among Chenchu and Lambada tribal women. Canonical Correlation Analysis was used to assess the connection between a set of 14 independent and 3 dependent variables, namely Body Mass Index (BMI), Food security and Nutritional security for both tribes separately. For Chenchu, the first and second canonical functions were significant at a level of 0.01 with canonical correlations of 0.775 and 0.728 respectively and were supported by eigenvalues of 2.419 and 1.128 and low Wilks'lambda values of 0.165 and 0.412 whereas the third function with a correlation of 0.351, was non-significant. The significance of the first two canonical functions of Lambada's was found to be 0.01 with canonical correlations of 0.841 and 0.810, respectively, with eigenvalues of 2.419 and 1.907, respectively and with Wilks' lambda of 0.085 and 0.292, respectively. However, the third function was insignificant with a canonical correlation of 0.389. Thus, there was a multivariate relationship between BMI, food security and nutritional security with socioeconomic and livelihood variables in both samples.

INTRODUCTION

Tribes are indigenous groups officially classified as scheduled tribes and constitute a significant part of India's population (Xaxa, 1999). They are spread across several districts of Andhra Pradesh such as Srikakulam, Vizianagaram, Visakhapatnam, East and West Godavari, Guntur, Prakasam, and Kurnool, exhibiting considerable diversity in ecological and economic settings (Subramanyam & Narayana Rao, 2023). Their livelihood security is shaped by complex socio-economic and behavioural factors (Ghosh et al., 2025)

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The major sources of food and income for such communities include forest products, small-scale farming, and subsistence agriculture (Ghosh-Jerath et al., 2025). While the consumption of these traditional foods is often kept moderate because of several socio-economic and environmental factors, the food and agricultural system plays an essential role in affecting the nutrition status of tribal communities depending on wild vegetables, root vegetables, and traditional crops (Ghosh-Jerath et al., 2016). Nevertheless, food and nutrition insecurity remain prevalent amongst tribal women since their intake of foods rich in micronutrients remains lower than dietary recommendations (Kapoor et al., 2022). Compared to the non-tribal population, the tribes show more malnutrition and mineral deficiency cases, where many women have chronic energy shortage (Kshatriya et al., 2016). Socioeconomic determinants such as wealth, education, and resources play a key role in the BMI of scheduled tribes and their nutritional security (Biswas et al., 2022). Food and nutritional security are negatively impacted by poor availability of agricultural and nutrition-related knowledge due to a lack of proper education, extension services, and limited information access (Bahubalendra et al., 2025). The use of nutrition-focused agricultural practices among farmers is significantly shaped by socioeconomic and attitudinal considerations (Mishra et al., 2025).

The forest-dependent hill tribe Chenchu and the tanda-settled plain tribe Lambada were selected for this study due to their distinct ecology and settlement patterns that influence their availability of food, dietary diversity, and health status (Jinka Ramamurthy & Hoffman, 2023; Kishore, 2016). Studies indicated that these communities often face disproportionate food and nutritional insecurity (Webb et al., 2016). The occurrence of deficiencies of micronutrients and undernutrition is more common among Chenchu women (Rao et al., 2015; Garg et al., 2023). Similarly, in the case of Lambada women, malnutrition, anaemia, and chronic disease incidence have been linked to poverty, lack of healthcare access, and poor educational levels (Anil, 2024). Poor dietary diversity and inadequate food intake adversely affected nutritional security among tribal women (Kujur et al., 2026).

Food security and nutritional security are multidimensional and dynamic constructs encompassing food availability, access, utilization, dietary quality, health status and stability over time (Sharma, 2019). In the present study, these concepts were operationalized through validated composite indicators integrating dietary diversity, nutrient adequacy, food access and anthropometric measures. Nutritional security goes beyond food security by including food quality, utilisation, and health outcomes and is especially important for tribal and rural communities with staple based, low diversity diets (Nandi, 1999). It is hypothesised that socio-economic and agricultural variables significantly influence nutritional security among tribal women. The study applies canonical correlation analysis to examine these multivariate relationships among Chenchu and Lambada tribal farm women in South Coastal Andhra Pradesh.

METHODOLOGY

The study was conducted in Palnadu and Prakasam districts of Andhra Pradesh using an ex-post facto design. A total of 192 respondents were selected through random sampling: 96 Chenchu and 96 Lambada tribal farm women. A pre-tested interview schedule was used for data collection. Data were analysed using Canonical Correlation Analysis (CCA) in SPSS, which identified relationships between two sets of variables by maximising inter-set correlations (Keskin & Yasar, 2007; Pujitha et al., 2024). The analysis identified key variables influencing the dependent variable. Two sets of variables were considered: 14 independent variables (C) and 3 dependent Variables (D) for both tribes.

$C = c_1, c_2, \ldots\ldots c_{14}$; $D = d_1, d_2, d_3$

c_1 = Age, c_2 = Education, c_3 = Family type, c_4 = Farming experience, c_5 = Landholding, c_6 = Occupation, c_7 = Number of crops grown, c_8 = Annual income, c_9 = Livestock ownership, c_{10} = Natural capital, c_{11} = Access to basic services, c_{12} = Agricultural mass media contact, c_{13} = Economic motivation, c_{14} = Impact of major government food and nutritional security schemes and d_1 = Body Mass Index (BMI), d_2 = Food security, d_3 = Nutritional security.

Body Mass Index (BMI) was calculated as weight (kg)/height² (m²) and classified according to the WHO Expert Consultation for Asian populations: <18.5 kg/m² (underweight), 18.5–22.9 kg/m² (normal), 23.0–24.9 kg/m² (overweight at risk) and e"25.0 kg/m² (obese). This classification is considered more appropriate for Asian populations due to their increased metabolic risk at lower BMI levels (Kshatriya et al., 2016). Food security was measured using a modified 35-point composite index developed from Riley et al. (1999). The index comprised seven dimensions: household food availability, food accessibility, affordability, food utilization, food stability, dietary sufficiency, and coping strategies. Each component was assessed through multiple statements using a five-point Likert scale, where higher scores indicated better food security. The cumulative score ranged from 0-35, with higher values representing higher household food security. Nutritional security was assessed using diet diversity score, 24-hour dietary recall and Mean Adequacy Ratio from 7-day nutrient intake (MAR) (FAO, 2018; FAO & FHI 360, 2016; Gibson, 2005).

The number of canonical correlation pairs equals the number of variables in the smaller set. In the study, 3 canonical correlation pairs are estimated: (O_1, P_1); (O_2, P_2); (O_3, P_3) and (Q_1, R_1); (Q_2, R_2) and (Q_3, R_3). Linear combinations of independent and dependent variables for Chenchu and Lambada are O1 and P1; Q1 and R1, respectively, called as Canonical variates (Sahoo et al., 2024).

$O_1 = o_{11} .c_1 + \ldots\ldots\ldots + o_{1i} .c_{1i}$,

$O_2 = o_{21} .c_1 + \ldots\ldots\ldots + o_{2i} .c_{2i}$.

$O_x = o_{i1} .c_1 + \ldots\ldots\ldots + o_{ii} .c_i$

$P_1 = p_{11}. d_1 + p_{12}. d_2 + p_{13}. d_3$

$P_2 = p_{21}. d_1 + p_{22}. d_2 + p_{23}. d_3$

$P_3 = p_{31}. d_1 + p_{32}. d_2 + p_{33}. d_3$

$Q_1 = q_{11} .c_1 + \ldots\ldots\ldots\ldots + q_{1i} .c_{1i}$

$Q_2 = q_{21} .c_1 + \ldots\ldots\ldots\ldots + q_{2i} .c_{2i}$.

$Q_x = q_{i1} .c_1 + \ldots\ldots\ldots + q_{ii} .c_i$

$R_1 = r_{11}. d_1 + r_{12}. d_2 + r_{13}. d_3$

$R_2 = r_{21}. d_1 + r_{22}. d_2 + r_{23}. d_3$

$R_3 = r_{31}. d_1 + r_{32}. d_2 + r_{33}. d_3$

Table 1. Descriptive Nutritional Indicators of Chenchu and Lambada Tribal Farm Women

Indicator	Chenchu (Mean ± SD / %)	Lambada (Mean ± SD / %)
Body Mass Index (kg/m²)	23.35 ± 4.54	23.87 ± 3.66
Underweight (%)	20.84	5.20
Normal BMI (%)	52.08	44.79
Overweight (%)	14.58	17.72
Obese (%)	12.50	32.29
Food Security Score (0-35)	23.68 ± 1.80	24.46 ± 1.92
Dietary Diversity Score (DDS)	12.09 ± 0.99	12.26 ± 1.01
Mean Adequacy Ratio (MAR)	0.79 ± 0.05	0.81 ± 0.05
Daily Energy Intake (kcal/day)	1782.2 ± 217.41	1779.12± 172.13
Protein Intake (g/day)	47.46± 4.53	48.44 ± 4.33
Fat Intake (g/day)	20.32 ±3.00	20.75 ± 3.10
Calcium Intake (mg/day)	350.33 ± 47.73	370.60 ± 69.55
Iron Intake (mg/day)	10.45± 1.81	11.95± 2.31
Thiamine (mg/day)	1.09 ± 0.17	1.20 ± 0.24
Riboflavin (mg/day)	0.74 ± 0.10	0.80 ± 0.12
Ascorbic Acid (mg/day)	113.41 ± 20.73	118.1 ± 22.95

where i = 14 independent variables, standardised correlation coefficients for C and D are denoted as o_{11} ,....o_{1i}; p_{11}, p_{12}, p_{13}; q_{11}, ...q_{1i} and r_{11}, r_{12}, r_{13}, Canonical correlation between (O_i, P_i); (Q_i, R_i) = $\frac{cov(OiPi)}{\sqrt{var(Oi)var(Pi)}}$; $\frac{cov(QiRi)}{\sqrt{var(Qi)var(Ri)}}$

RESULTS

The canonical correlation analysis was performed using SPSS between socioeconomic and livelihood variables with BMI, food security and nutritional security among Chenchu and Lambada tribal farm women is presented in Table 2. In both groups, the first and second canonical functions were significant ($p<0.01$), whereas the third canonical function was non-significant. Among the Chenchu women, the first canonical function recorded a canonical correlation of 0.775 and the second function recorded 0.728. In the Lambada group, comparatively higher canonical correlations of 0.841 and 0.810 were observed for the first and second canonical functions, respectively. Lower Wilks' lambda values in the first two functions indicated stronger multivariate relationships between the two sets of variables in both groups.

The standardised and unstandardised canonical correlation coefficients of independent and dependent variables are presented in Table 3. In the Chenchu group, the first canonical function showed relatively higher coefficients for economic motivation, annual income, education and the impact of major government food and nutritional security schemes. Among the dependent variables, BMI, food security and nutritional security recorded comparatively higher coefficients. In the second canonical function, age showed the highest coefficient among the independent variables, whereas BMI recorded the highest coefficient among the dependent variables. In

Table 2. Canonical correlation analysis of Chenchu and Lambada tribal farm women with nutritional security variables

Pair of canonical variates		Canonical correlation		Square of correlation		Eigenvalue		Wilks statistic		Significance	
Chenchu	Lambada	Chenchu	Lambada	Chenchu	Lambada	Chenchu	Lambada	Chenchu	Lambada	Chenchu	Lambada
O_1, P_1	Q_1,R_1	0.775	0.841	0.601	0.707	2.419	2.419	0.165	0.085	0.000	0.000
O_2, P_2	Q_2, R_2	0.728	0.810	0.530	0.656	1.128	1.907	0.412	0.292	0.000	0.000
O_3, P_3	Q_3, R_3	0.351	0.389	0.123	0.151	0.140	0.178	0.877	0.849	0.505	0.296

Table 3. Standardised and unstandardised canonical correlation coefficients analysis, Chenchu and Lambada tribal farm women

IndependentVariables	Standardised Canonical Correlation Coefficient				Unstandardized Canonical Correlation Coefficient			
	Chenchu		Lambada		Chenchu		Lambada	
	O1	O2	Q1	Q2	P1	P2	R1	R2
Age	-.374	.963	.227	-.781	-.025	.065	.018	-.063
Education	-.331	-.131	-.025	-.083	-.332	-.132	-.020	-.068
Family Type	-.047	-.209	-.043	.167	-.093	-.416	-.090	.353
Farming Experience	-.001	-.170	.005	-.227	.000	-.017	.001	-.028
Land Holding	.063	-.195	.074	.198	.085	-.264	.095	.255
Occupation	-.058	-.097	-.006	-.128	-.056	-.093	-.005	-.105
Crops Grown	.067	-.161	-.018	-.044	.055	-.133	-.014	-.033
Annual Income	-.331	-.235	-.426	-.105	.000	.000	.000	.000
Livestock Ownership	-.206	-.167	-.103	-.162	-.468	-.379	-.243	-.383
Natural Capital	.039	-.211	-.069	.091	.089	-.484	-.089	.117
Access to Basic Services	.028	.106	-.132	-.125	.271	1.043	-1.289	-1.222
Agricultural Mass Media Contact	.054	-.168	-.117	.060	.055	-.170	-.088	.045
Economic Motivation	-.424	.103	-.327	.079	-.209	.051	-.090	.022
Impact of Major Government Food and Nutritional Security Schemes	-.324	-.056	-.427	.061	-.760	-.130	-1.113	.159
Body Mass Index (BMI)	-.405	1.100	.020	-1.030	-.089	.242	.006	-.281
Food Security	-.378	-.225	-.295	.108	-.210	-.125	-.153	.056
Nutritional Security	-.392	-.786	-.759	.122	-6.885	-13.790	-12.980	2.082

Table 4. Sample correlation between the original variable and the canonical variables

Independent Variables	Loadings				Cross loading			
	Chenchu		Lambada		Chenchu		Lambada	
	O1	O2	Q1	Q2	P1	P2	R1	R2
Age	-.363	.867	.145	-.922	-.281	.632	.122	-.747
Education	-.329	-.503	-.432	.151	-.255	-.366	-.363	.122
Family Type	.019	-.183	-.319	.124	.015	-.133	-.268	.100
Farming Experience	-.460	.685	-.236	-.681	-.356	.499	-.198	-.552
Land Holding	-.048	-.318	-.172	.167	-.037	-.232	-.145	.135
Occupation	-.096	.040	-.361	-.026	-.074	.029	-.304	-.021
Crops Grown	-.280	-.062	-.283	.159	-.217	-.045	-.238	.129
Annual Income	-.617	-.103	-.690	-.322	-.478	-.075	-.581	-.261
Livestock Ownership	-.467	-.269	-.410	-.145	-.362	-.196	-.345	-.118
Natural Capital	-.056	-.088	-.082	.058	-.043	-.064	-.069	.047
Access to Basic Services	-.188	-.094	-.305	-.128	-.146	-.069	-.257	-.104
Agricultural Mass Media Contact	.045	-.209	-.336	.322	.035	-.152	-.283	.260
Economic Motivation	-.684	-.128	-.653	.073	-.530	-.094	-.549	.059
Impact of Major Government Food and Nutritional Security Schemes	-.577	-.154	-.738	-.255	-.447	-.112	-.621	-.207
Body Mass Index (BMI)	-.803	.583	-.208	-.978	-.623	.425	-.175	-.792
Food Security	-.879	-.216	-.874	-.067	-.681	-.157	-.736	-.054
Nutritional Security	-.873	-.394	-.983	.000	-.677	-.287	-.827	.000

the Lambada group, the first canonical function recorded relatively higher coefficients for annual income, the impact of major government food and nutritional security schemes and economic motivation. Among the dependent variables, nutritional security and food security showed comparatively higher coefficients. In the second canonical function, age, landholding and family type recorded relatively higher coefficients among the independent variables, whereas BMI recorded the highest coefficient among the dependent variables. The third canonical function was non-significant in both groups and therefore was not interpreted further.

The sample correlations between the original variables and canonical variables are presented in Table 4. In the Chenchu group, the first canonical function showed relatively higher loadings for economic motivation, annual income, impact of major government food and nutritional security schemes, livestock ownership and farming experience. Among the dependent variables, food security, nutritional security and BMI recorded comparatively higher loadings. In the second canonical function, age and farming experience showed relatively higher loadings among the independent variables, whereas BMI recorded the highest loading among the dependent variables.

In the Lambada group, the first canonical function recorded relatively higher loadings for the impact of major government food and nutritional security schemes, annual income, economic motivation, education and livestock ownership. Among the dependent variables, nutritional security and food security showed comparatively higher loadings. In the second canonical function, age and farming experience showed relatively higher loadings among the independent variables, whereas BMI recorded the highest loading among the dependent variables. The third canonical function was non-significant in both groups and therefore was not interpreted further.

The proportion of variance explained by the canonical variables is presented in Table 5. In both groups, the first canonical function accounted for the highest proportion of explained variance compared with the second and third canonical functions. Among the Chenchu farm women, the first canonical function explained higher variance in Set 2 by self (0.727) compared with Set 1 by self (0.141). Similarly, in the Lambada farm women, the first canonical function explained higher variance in Set 2 by self (0.591) than in Set 1 by self (0.174). The second canonical function explained comparatively lower variance, whereas the third canonical function contributed minimal variance in both groups.

The socioeconomic and livelihood variables were significantly associated with the BMI of the Chenchu and Lambada tribal farm women in multivariate relationship and food security and nutritional security with both the tribal farm women groups. Some variables such as annual income, economic motivation, livestock ownership and the impact of significant government food and nutrition security programs had higher values of the loading and coefficient for the first canonical function. The results are consistent with previous

Table 5. Proportion of Variance for both Chenchu and Lambada farm women

Canonical Variable	Proportion of Variance Explained							
	Chenchu				Lambada			
	Set 1 by Self	Set 1 by Set 2	Set 2 by Self	Set 2 by Set 1	Set 1 by Self	Set 1 by Set 2	Set 2 by Self	Set 2 by Set 1
1	.141	.085	.727	.437	.174	.123	.591	.418
2	.129	.068	.181	.096	.123	.081	.320	.210
3	.037	.004	.092	.011	.078	.012	.089	.013

research which found that livelihood resources, household income and institutional support have a significant impact on food and nutritional security of rural households (Jairu et al., 2023). The present study also confirmed the significant association that were found between BMI, food security and nutrition security, which is consistent with previous studies that suggests the socioeconomic factors and food access plays a significant role in nutrition status and food consumption among rural women (Kumbhare et al., 2023).

DISCUSSION

The findings indicate significant multivariate relationships between socioeconomic and livelihood variables with BMI, food security and nutritional security among both Chenchu and Lambada farm women. The significance of the first and second canonical functions in both groups indicates that the selected independent variables collectively contribute to variations in nutritional outcomes. Comparatively higher canonical correlations among the Lambada farm women indicate relatively stronger multivariate relationships between socioeconomic and livelihood characteristics with nutritional security variables than among the Chenchu farm women. The lower Wilks' lambda values observed in the first two functions further indicate the existence of stronger associations between the two variable sets.

The higher coefficients and loadings observed for annual income, education, economic motivation, livestock ownership, farming experience and the impact of major government food and nutritional security schemes indicate the importance of socioeconomic and livelihood conditions in relation to BMI, food security and nutritional security among tribal farm women. The stronger contribution of annual income and livestock ownership suggests the importance of livelihood resources in improving food access and nutritional outcomes. Similarly, education and economic motivation appear to influence awareness, decision-making ability and utilisation of nutrition-related resources. The higher loadings of food security and nutritional security in the first canonical function in both groups further indicate that nutritional outcomes among tribal women are multidimensional and influenced by several interrelated socioeconomic and agricultural factors. The stronger association of government food and nutritional security schemes with the canonical functions in both tribal groups indicates the importance of public welfare interventions in improving food and nutritional conditions among vulnerable populations. Access to basic services and agricultural mass media contact also contributed to the canonical relationships, indicating the role of information access and institutional support in nutritional improvement. The contribution of farming experience and number of crops grown further suggests the importance of agricultural livelihood diversification in maintaining food availability and dietary adequacy among tribal households.

The findings are in conformity with earlier studies reporting that socioeconomic resources, livelihood conditions and access to services significantly influence food and nutritional security among tribal communities (Biswas et al., 2022) and the need for integrated policies addressing economic participation, education access, and community engagement to dismantle systemic barriers (Kujur et al., 2026). The observed relationships also support earlier findings that nutrition-sensitive agricultural practices and livelihood-related factors contribute to nutritional security among rural and tribal populations (Mishra et al., 2025). Earlier studies also reported that poor education, limited information access and inadequate livelihood opportunities adversely affect food and nutritional security among tribal households (Bahubalendra et al., 2025). The present findings further support earlier observations that tribal women often experience nutritional vulnerability because of interconnected socioeconomic and livelihood constraints (Kapoor et al., 2022; Kshatriya et al., 2016).

CONCLUSION

The current study shows that a complex interaction of socioeconomic, livelihood, and institutional factors, rather than a single driver, affects nutritional security among tribal farm women. The Chenchu and Lambada populations' nutritional outcomes were found to be significantly influenced by household income, education, livelihood assets, economic incentive, and access to government food and nutrition security programs. Food availability, accessibility, consumption, dietary quality, nutrient adequacy, and health status are all included in the dynamic and multifaceted concepts of food security and nutritional security. Canonical Correlation Analysis was used in this work to analyze these constructs after they were operationalized using approved composite indicators. Consequently, rather than being direct indicators of food or nutritional security, the canonical coefficients should be seen as markers of multivariate correlations. The results emphasize the necessity of comprehensive interventions that combine livelihood improvement, nutrition education, nutrition-sensitive agriculture, and efficient public welfare program execution. To provide a more thorough picture of nutritional security among indigenous populations, future research should include biochemical indicators and longitudinal approaches.

DECLARATIONS

Ethics approval and informed consent: The study was conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Ethical approval was waived by the Divisional Ethics Committee, Extension Division of Centurion University of Technology and Management, Paralakhemundi, Odisha, India. Throughout the study, the respondents were asked for their informed consent.

Conflict of interest: The research was carried out without any financial or commercial ties that might be seen as a potential conflict of interest, according to the authors. The authors affirm that they carefully examined, amended and edited the content as necessary when preparing this work. The final content of this publication is entirely the authors' responsibility.

Data availability Statement: Data is available upon reasonable request from the first author as well as corresponding author.

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