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ORIGINAL ARTICLE

An Econometric Assessment of Food Security of South India through Fuzzy Cognitive Maps

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ABSTRACT **Context:** The food security differs at different levels, global to regional and national to household and individual level because food security is deemed to be a multidimensional phenomenon encompassing climate change, civil conflicts, natural disasters, and social norms. The article presents a methodological approach to the food security assessment, which enables one to determine food security index..

Aim: The objective of the study is to use the methods of economic and mathematical modelling to assess food security.

Methods and Material: Econometric models into the cognitive map can be developed based on membership functions and fuzzy logic. Construction, testing and debugging of a specialized software package that implements impulse modelling of the analyzed systems should be carried out according to incident matrices corresponding to cognitive maps. As a result, scenario analysis of the level of food security will be carried out using fuzzy cognitive maps.

Results: The differentiation of Indian regions, according to their sectoral specialization, determines priorities of socio-economic and agricultural policy to ensure food security and improve the living standards of the population.

Conclusions: The results of the analysis revealed several factors impeding optimal level of food security of the Indian Southern States and suggest measures for optimization. Promising directions of improving agricultural policy in the field of ensuring and maintaining an acceptable level of food security in the regions of the Indian Southern States

Keywords: Econometric models, Food security, Fuzzy logic, Cognitive maps, Food availability, accessibility, nutrition

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INTRODUCTION

The concept of food security generally defined as both physical and economic access to food that meets people's dietary needs as well as their food preferences. But food security is a complex sustainable development issue, linked to health through malnutrition. Theoretically, food security and human development are co-dependent, with nutrition outcomes at their intersecting point. This joint relationship is founded on the availability of and access to food, which is critical for achieving food security. Malnutrition is the result when these prerequisites for food security are flawed, which in turn impedes human development. Review of literature reveals that ensuring food and nutrition security is a components, viz., availability, access, and absorption (nutrition) and utilization and all the four are interconnected. Many studies have shown that improvement in nutrition is important, even for increase in productivity of workers. Thus, food security has intrinsic (for its own sake) as well as instrumental (for increasing productivity) value.

Food security is the most important component of the country's economic security, provision of which is defined as the main priority of socio-economic and agricultural policy of India Ulezko [1] and Yarkova [2] highlight some aspects of food security in context of the

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theory and practice of sustainable development of the regions of Russia. Definition and evaluation of the system of food security factors are of current importance. Several modern studies have been devoted to assessment of import substitution impact on food security and food supply in the regions of Russia Novikov [3] and Trubilin [4]. There is an independent area of study that involves research contributions on the analysis of resource provision of agro-industrial complex and evaluation of its role in food supply, including at the regional level of the economy Oganesyan *et. al* [5].

Food security is defined as access to nutritionally adequate, safe and personally acceptable foods and the ability to acquire them in a socially acceptable way at all states of lifespan, Parnell and Smith [6]. Thus, sustainable food security will have to be defined as 'physical, economic, social and ecological access to balanced diets and safe drinking water, so as to enable every individual to lead a productive and healthy life in perpetuity' Food insecurity occurs when people do not have enough food to satisfy hunger, have an insufficient and limited diet, are anxious about having enough food or need to resort to makeshift coping strategies such as begging, scavenging, or relying on emergency assistance programmers Cook and Frank [7] Food security is closely related to limited household resources, low disposable income and poor socioeconomic status Cook and Frank [7] and Rush and Rusk [8].

Theoretical and methodological foundations of modelling agro-industrial complex on regional and sectoral levels are presented in the works by Ognivtsev and Siptits [9]: models of interaction for markets of various types of agricultural and food products (grain, meat products) have been developed. Of particular interest are the models of forecasting the prices in food markets as well as economic and mathematical model to justify the program of providing the region with food.

The term "food security" has been used in nearly 200 different ways across the world (Smith et al., 1993), but the most commonly cited definition comes from the first World Food Summit (FAO, 1996) which proposed that food security "exits when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." This definition is translated into the four aspects of food security: food availability, food accessibility, food utilization, and food stability. The first dimension "food availability" refers to the physical quantities of food of an appropriate quality that is supplied and distributed through domestic production or imports (FAO, 2018). The mere presence of an adequate supply does not ensure that a person can obtain and consume food. A person or household also has access to food (FAO, 2018).

Hence, "food accessibility" is a measure of the ability to get food, which depends on household and individual purchasing power and food prices as well as legal entitlements, political willingness, and social structure. Further, "food utilization" is the third dimension and relates to whether or not individuals or households are able to obtain sufficient energy and nutrition from food consumption (FAO, 2021). The last dimension is "food stability" which depicts the situation in which a country, state, district, household, or individual is food secure at all times.

Economic and mathematical modelling in assessing and forecasting the level of food security allows us to develop formal, multi-criteria models for assessing food security. The modelling process includes a number of successive stages: to define the subject and purpose of the analysis; to define the object; to identify factors that affect its functioning; and to develop criteria of evaluation and optimization.

MATERIALS AND METHODS

For India, useful data on agricultural and socio-economic factors are collected from various sources like Ministry of Agriculture (GoI), Planning Commission (GoI), National Sample Survey Organization (NSSO), Reserves Bank of India (RBI), Centre for Monitoring Indian Economy (CMIE), Census (GoI), Census of Agriculture (GoI), State Departments of Agriculture for

Table 1. State wise population, Per Capital Income, Human development index, Hunger index, Income Ratio and Infant mortality rate

Sl. No	Indian States	Per Capital Income (PCI)	HDI Ranking	Hunger index	Income Ratio	IMR
1	Andra Pradesh	3398.76	11	3	0.85	52
2	Karnataka	3269.76	10	11	0.84	45
3	Kerala	5262.89	1	2	0.84	12
4	Tamil Nadu	3835.05	6	6	0.83	31
5	Maharashtra	3913.14	4	1 0	0.81	33
6	Odisha	3614.13	6	9	0.86	35
	ALL INDIA	3337.33	N/A	N/A	0.84	53

and the Central Statistical Organization (CSO). Monthly rainfall and temperature related data is collected from the respective Meteorological stations in India. Climate change related other variables are taken from Indian

Meteorological Department (IMD) (GoI), and National Remote Sensing Agency (NRSA), Hyderabad.

The states of South India are considered to create the state-wise FSI, while data is considered during 2021-2022. Following states of India are included in this study: Orissa, Maharashtra, Andhra Pradesh, Tamil Nadu, and Karnataka. Total 26 determinants of food security are segregated in three categories, such as food availability, food stability, and food accessibility. Following indicators are used to create state-wise FSI in India:

Food Availability:

Number of livestock/1000 population (in Number) Per capita food-grain availability/year (in Kg.). Per capita calorie availability/day (in Calories). Number of agricultural labour/hectare cultivated land (in Number). Per capita consumption expenditure/month (in Rs.). Government expenditure (revenue and capital) on agricultural and allied sector, rural development, and irrigation and flood control/per hectare cultivated land (in Rs.).

Stability of Food:

Food-grain yield/hectare(in Kg./Ha.). Applications of fertilizer/hectare cultivated land (in Kg./Ha.).Percentage of gross irrigated area to net sown area (in %).Cropping intensity (in %). Ratio of literate population to gross sown area (in Number).Percentage of forest area to gross sown area (in %).Storage capacity/1000 population (in Quintal).

Accessibility of Food:

Percentage of main worker to the total population (in %) Literacy rate (in %). Road length/1000 population (in Km.). Railway road length/per 1000 population (in Km.). Per capita national domestic product (in Rs.). Poverty (in %). Urbanization (in %). Gender ratio (in Number). Population density (in Number). Percentage of rural population to total population (in %). Credit Deposits Ratio (in Number). Infant Mortality Rate (in Number). Rural population/hectare arable land (in Number).

An Analysis of State Wise Food Grains Production, Per-capita Income, Percentage of Food Expenditure, Percentage of Population Below Poverty

Table 2. State wise population, food grains production, per-capita availability of food grains, per-capita income and percentage of people with safe Drinking Water (2021)

Sl. No	State	Population (million)	Food grains Production (million tonnes)	Per-capita availability of food grains in (Kilograms)	Per-capita income (in Rs)	Percentage of people with safe Drinking Water
1.	Andhra Pradesh	84.66	18.66	220	121071.96	90.5
2	Karnataka	61.13	10.86	170	125998.56	87.5
3	Kerala	33.38	5.12	150	154424.6	97.6
4	Maharashtra	112.37	10.97	100	170137.36	83.4
5	Odisha	41.94	8.01	190	78177.56	75.3
6	Tamil Nadu	72.13	5.59	080	167579.56	92.5
	All India	1215.0	257.13	2110	11634.64	85.5

Table: 2 Shows State wise population, food grains production per-capita availability of food grains, per-capita income and percentage of people with safe drinking water. The food-grains production was the highest the in Andra Pradesh and lowest in Kerala Population was the highest in Maharashtra and lowest in Kerala However per-capita availability of food grains was the highest in Maharashtra and lowest in Andhra Pradesh. The percentage of people with safe drinking water facilities

Table 3. Represents state wise percentage of food expenditure in rural and urban areas. State wise percentage of food expenditure and percentage of people below poverty line in rural and Urban areas – 2021

S.No.	State	Food Expenditure			Percentage of people below poverty line		
		Rural	Urban	Total	Rural	Urban	Total
1	Andhra Pradesh	51.4	42.3	46.85	11.0	5.8	9.2
2	Karnataka	51.4	40.1	45.75	24.5	15.3	20.9
3	Kerala	43.0	37.0	40.00	9.1	5.0	7.1
4	Maharashtra	52.4	41.6	47.00	24.2	9.1	17.4
5	Odisha	57.2	45.4	51.30	35.7	17.3	32.6
6	Tamil Nadu	51.5	42.7	47.10	15.8	6.5	11.3
	All India	52.9	42.6	47.75	25.7	13.7	21.9

The comparison of state wise food expenditure reveals that percentage of food expenditure was the highest in Odisha and lowest in Kerala. The percentage of people below poverty line was the highest in Odisha and lowest in Kerala

Table 4. Affordability index for different States of India

Sl.no	State	Expenditure Index	Poverty Index	Per-capita income Index	Affordability Index
1	Andhra Pradesh	0.46	0.09	0.16	0.71
2	Karnataka	0.45	0.20	0.15	0.80
3	Kerala	0.40	0.07	1.18	0.66
4	Maharashtra	0.47	0.17	0.21	0.85
5	Odisha	0.51	0.32	0.09	0.92
6	Tamil Nadu	0.47	0.11	0.19	0.77
	All India	0.47	0.21	0.13	0.81

The study aims to calculate affordability Index based on percentage of food expenditure, percentage of people, below poverty line and per-capita income in different States of South India.The estimated affordability index was the highest in Odisha and Lowest in Kerala

Table 5. State wise per-capita Food grains availability index, Food absorption index, and estimated food security index

Sl.no	State	Per-capita food grains availability index	Food absorption index	Estimated food security index
1	Andhra Pradesh	0.10	0.89	0.61
2	Karnataka	0.06	0.85	0.43
3	Kerala	0.05	1	0.42
4	Maharashtra	0.01	0.79	0.39
5	Odisha	0.07	0.67	0.37
6	Tamil Nadu	0	0.9	0.30
	All India	1.47	0.82	0.33

The estimated per-capita availability index of food grains was the highest in Andhra Pradesh and lowest in Tamil Nadu. The estimated food absorption index was the highest in Kerala and lowest in Odisha. The estimated food security index was the highest in Andhra Pradesh and lowest in Tamil Nadu Food grains availability index was calculated based on per-capita availability of food grains. The study attempted to analyze the extent of variations indifferent components of food security index among the States by calculating in co-efficient ratio. The estimated Gini Index was 0.57 for food affordability index, 0.52 for food availability index, 0.06 for food absorption index and 0.75 for food security index

Table 6. Represents the factors extracted. The factors extracted. The factors extracted.

Component	Initial Eigen values			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
Food grains Production	3.011	75.280	75.28	3.011	75.280	75.280
Population	0.920	22.992	98.27			
Per capita income	0.065	1.633	99.90			
Area under cultivation of food grains	0.004	0.096	100.00			

Table 6 indicates that out of 4 parameters considered, food. grain production has accounted for 75.23 percentage factor influencing food security index

Table 6. Estimated principal components of factors influencing food security index

Factors	Factors loading component
Food grains Production	0.995
Population	0.449
Percapita income	0.917
Area under cultivation of food grains	0.989

The factor loading component was the highest for foodgrains production and lowest for population

KMO and Bartlett's Test :KMO and Bartlett's test as the value of test statistic is greater than 0.5 which implies that for factor analysis the selected variables were found to be appropriate

COGNITIVE ECONOMIC AND MATHEMATICAL MODELLING

In order to determine the groups of factors and the system of indicators of food security, an expert method of analysing hierarchies can be used. The obtained system of indicators forms the structure, connections and membership functions of fuzzy cognitive maps. To parameterize cognitive maps there have been constructed infological and information models; they provide justification for the relational database structure according to analysed statistical indicators.

Specific indicators for food groups enable construction and verification of a family of predictive econometric models. Methods for integrating the obtained econometric models into the cognitive map can be developed based on membership functions and fuzzy logic. Construction, testing and debugging of a specialized software package that implements impulse modelling of the analyzed systems should be carried out according to incident matrices corresponding to cognitive maps. As a result, scenario analysis of the level of food security will be carried out using fuzzy cognitive maps.

A software package is needed to support numerical research and scenario analysis using the developed cognitive maps Rogachev [10]. Such software package should include a computer program, a database to construct functions of factor membership and a statistical database for the research, using an intelligent system to assess and predict the integral level of food security.

To create an intelligent system of multi-criteria assessment and forecasting of the level of food security of the state and specific regions on the basis of fuzzy cognitive approach it is necessary:

1. to specify theoretical and methodological basis of the integrated assessment of food security level;
2. to form a system of indicators and methodology for construction of fuzzy production cognitive maps to assess the forecast of food security provision, considering the sphere of production, consumption, reservation and import;
3. to develop methodology and build membershipfunctions for factors of food security relevant for production cognitive maps;
4. to build a system of fuzzy cognitive maps to assess level of food security at the level of the state and specific regions;
5. to model self-development and controlled development of food security system with the help of cognitive maps for subjects at different levels;
6. to develop a software package for monitoring, assessing the level of food security and forecasting its dynamics.

These subtasks will solve the problem of objective integrated assessment of food security level on the basis of intellectual cognitive system, as well as will assess the dynamics of its change, taking into account public authorities management.

EMPIRICAL MODEL OF FOOD SECURITY ASSESSMENT

To assess food security, it is proposed to use a methodology that involves the use of statistical indicators and analysis of: level of food self-sufficiency; degree of satisfaction of physiological needs of the population in food; level of economic access to food Antamoshkina [11].

Food self-sufficiency for certain types of agricultural products is determined on the basis of self-sufficiency coefficients $\mathcal{F}_s$ the indicators are calculated as the ratio of factual production volumes to the necessary volumes of food production in accordance with rational consumption rate. Using these coefficients, it is possible to determine to what extent in the region the population needs are met based on domestic regional food production. Satisfaction degree of physiological needs of the population in food is estimated using the coefficients of factual food consumption $\mathcal{F}_{fc}$ the factual volume of consumption is compared with rational rate

The level of economic access to food is determined by the ability of the population to buy food. Its characteristics should take into account the level of monetary income of the population and food price. Calculation of economic availability is based on a system of indicators Antamoshkina [12]: Poverty rate $\mathcal{F}_p$ share of the population with incomes below the subsistence minimum; consumption ratio $\mathcal{F}_c$ share of food expenditure in the structure of consumption expenditure; Gini coefficient $\mathcal{F}_G$.

To assess the level of food security, it is necessary to determine an integral indicator the food security index I_{fs}:

$$I_{fs} := \mathcal{F}_s+\mathcal{F}_{fc}+\mathcal{F}_p+\mathcal{F}_c+\mathcal{F}_G \quad (1)$$

as sum of values in points for each of the analyzed indicators and then to correlate the obtained value with criteria of food security (see table 5).

Gini coefficient $\mathcal{F}_G$ was calculated to find out the extent of State wise variations in affordability, availability, food absorption and food Security index using the formula

$$\mathcal{F}_G = \frac{N+1}{N-1} - \frac{2U}{N(N+1)} \sum_{i=1}^{n} P_i X_i$$

P_i = The Rank assigned to the selected States.

X_i = Actual value assigned to the selected States.

U = Actual value assigned to the selected States /Number of selected States.

N = Number of selected States

Table 8. Criteria and level of food security.

Points	Level of food security
> 9	Optimal
5-8	permissible
< 5	low

The proposed model allows us using official statistics to assess the achieved level of food security in context of certain regions of the States of South India, to compare them and to determine the degree of differentiation in food supply

RESULTS

The differentiation of Indian regions, according to their sectoral specialization, determines priorities of socio-economic and agricultural policy to ensure food security and improve the living standards of the population. The States of South India is traditionally one of the regions specializing in agriculture, its resource potential of agriculture and climatic features create favorable conditions for providing the population of the region with food products in amounts not lower than the established rational consumption rates. Data on the branches of agriculture in the States of South India demonstrate higher growth rates in crop production sphere, compared with the results obtained in livestock products manufacturing. We can determine the level of self-sufficiency for food products in the subjects of the States of South India in 2021 (table 2).

The value of the coefficient of self-sufficiency $\mathcal{F}_s$ for the analyzed types of food products was 1.18, which corresponds to the optimal level and while assessing the food security index can be estimated in 2 points for macro-region of the States of South India.

DISCUSSION

Analysis of food consumption in the States of South India(SSI) in 2021 allowed us to establish that on average in the South Indian states the volume of consumption of Agro-products (this category includes flour, cereals, rice, pasta and legumes) exceeded the rational consumption rate by 23.9%. In 2021, in the South Indian states the volume of consumption of meat and meat products on average exceeded the established rational consumption rate (73 kg/year) by 2 kg. At the same time, in 2021, in the subjects of the South Indian states the situation with the consumption of poultry products was inhomogeneous. The situation with milk and dairy products consumption is still quite complicated. With the specified rational consumption rate of 325 kg per year, in 2021, in the South Indian states the volume of consumption on average amounted to 216 kg, which is only 66.5% of the recommended rational consumption rate such a significant excess of sugar consumption in comparison with the specified sustainable rates of consumption also indicates an imbalance in food diet of the population of the States of South India. In 2021, the volume of vegetable oil consumption by the population of the States of South India amounted to 14.6 kg, which slightly exceeded specified sustainable level of consumption - 12kg. With the help of the obtained values ($\mathcal{F}_{fc}$) average value is calculated and value of the indicator toform food security index is determined, in 2021, for the regions of the States of South India the value corresponded to 2 points.

Among negative trends in the South Indian states it is worth noting high degree of polarization of the population in terms of income and high proportion of the population with incomes below the subsistence minimum Shlevkova *et.al* [13]. Analysis of poverty ratio ($\mathcal{F}_p$) showed that in 2021,the population with incomes below the subsistence minimum in the States of South India amounted to 16.1 1% Ovcharuk [14] The value $\mathcal{F}_p$ for determining the integral index of food security index of the States of South India corresponds to 2 points.

Share of food expenditures in the structure of household expenditures of the South Indian states amounted to 37.9% in 2021. Some regions of the States of South India experience rather unfavorable situation in terms of consumer spending structure. In India about half of household expenditure is spent on food. Value of consumption ratio $\mathcal{F}_c$ in the calculation of food security index I_{fs} . In 2021, the Gini coefficient $\mathcal{F}_G$ for the States of South India was equal 0.362 Shlevkova *et.al* [13], when calculating food security index of the South Indian states, value of this indicator corresponds to 1 point.

We define an integral indicator: index of food security of the states of south India:

$I_{fs} := \mathcal{F}_s + \mathcal{F}_{fc} + \mathcal{F}_p + \mathcal{F}_c + \mathcal{F}_G = 2 + 2 + 2 + 1 + 1 = 8$ points.

In 2021, food security index of the states of South India did not correspond to the optimal level that was due to a significant degree of income differentiation in the region and sub-optimal structure of the consumer basket, in which a significant part of the expenditure is spent on food.

CONCLUSION

The results of the analysis revealed several factors impeding optimal level of food security of the South Indian states and suggest measures for optimization. Promising directions of improving agricultural policy in the field of ensuring and maintaining an acceptable level of food security in the regions of the South Indian states could include: measures to increase the level of self. Sufficiency in Agro products and meat products; economic availability of food for the population, which requires action plan to ensure the growth of incomes of the population in the South Indian states. This evaluation model enables us to analyze food security based on real statistical data, to select measures to optimize agricultural policy in order to ensure an acceptable level of food security in the regions of India.

Among the States, affordability index was the highest in Odisha and lowest in Kerala, food grains availability index was the highest in Maharashtra and lowest in Andhra Pradesh while food absorption index was the highest in Kerala and lowest in Odisha. The overall food security index was the highest in Andhra Pradesh and lowest in Tamil Nadu and the significant factors influencing food security index were food grains production and population

Recommendations

The availability of food grains at the ration shops should be provided at subsidized rate and PDS should be strengthened. Purchasing power of the people should be increased by providing them employment through various Government schemes. The Community Grain Banks can be sustained with locally procured grains, wherever feasible. The Banks could function under the overall umbrella of the Gram Shaba and can be operated by local self-help groups of women and men

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Conflict of Interest

The authors declare that this research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflicts of interest aka, for providing an opportunity to carry out research.

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