Developing Global Hunger Index

A Project report submitted in partial fulfilment of requirements for the Degree of M.Sc. (Statistics) with specialization in Industrial Statistics

By

Miss. Mansi Dinesh Deshmukh

Miss. Prajakta Sanjay Satbhai

Mr. Darshan Kishor Bhadane

(NAAC Re-accredited A Grade University)

DEPARTMENT OF STATISTICS

SCHOOL OF MATHEMATICAL SCIENCES

KAVAYITRI BAHINABAI CHAUDHARI,

NORTH MAHARASHTRA UNIVERSITY

JALGAON – 425001

(2023-2024)

CERTIFICATE

This is to certify that Miss. Mansi Dinesh Deshmukh, Miss. Prajakta Sanjay Satbhai, Mr. Darshan Kishor Bhadane Motirale students of M.Sc. (Statistics) with specialization in Industrial Statistics, at kavayitri Bahinabai Chaudhari, North Maharashtra University, Jalgaon have successfully completed their project work entitled **"Developing Global Hunger Index"** as a part of M.Sc. (Statistics) program under my guidance and supervision during the academic year 2023-2024.

(Dr. R. D. Koshti)

Project Guide

ABSTRACT

Progress in combating hunger and undernutrition has been lagging for decades. Best practices to fight hunger and undernutrition have been available for a long while, but lack of political will among leaders and a lack of political power among the poor have hampered their implementation. Since indices have proven to be powerful tools for advocacy and are able to capture multifaceted phenomena, the Global Hunger Index (GHI) was developed to increase attention to the hunger problem and mobilize the political will to speed up urgently needed progress in the fight against hunger. The GHI captures three dimensions of hunger: insufficient availability of food, shortfalls in the nutritional status of children, and child mortality, which is to a large extent attributable to undernutrition. Accordingly, the index includes four indicators: the share of the population whose caloric intake is insufficient as estimated by the Food and Agriculture Organization of the United Nations (FAO), the share of children under the age of five who have low height for their age, reflecting chronic undernutrition and : the share of children under the age of five who have low weight for their height, reflecting acute undernutrition as compiled by the World Health Organization (WHO), and the under-five mortality rate as reported by the United Nations Children's Fund (UNICEF). The GHI has been calculated for 2000, 2008, 2015, and, most recently, for 2023. The latest round ranks 125 countries out of 139 countries. To identify those countries that do notably better or worse with regard to hunger and undernutrition than would be expected from their Gross National Income (GNI) per capita, a regression analysis of the GHI on GNI per capita is run.

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Place: Jalgaon

Date:

Miss. Mansi Dinesh Deshmukh

Miss. Prajakta Sanjay Satbhai

Mr. Darshan Kishor Bhadane

INDEX

CHAPTER 1: INTRODUCTION **1-2**

OVERVIEW 1

OBJECTIVE 2

SIGNIFICANCE 2

CHAPTER 2: CONCEPT OF GLOBAL HUNGER INDEX **3-5**

DEFINATION OF KEY TERMS 4

THE ADDED VALUE OF GHI 5

CHAPTER 3: DATASET **6-9**

INCLUSION CRITERIA FOR COUNTRIES 7

HOW HUNGER SEVERITY OF COUNTRIES WITH MISSING DATA 8

CHAPTER 4: EXPLORATORT DATA ANALYSIS **10-15**

DISCRIPTIVE STATISTICS 10

GRAPHICAL REPRESENTATION 11

CHAPTER 5: STATISTICAL TOOLS **16-19**

PRINCIPAL COMPONENT ANALYSIS 16

MULTIPLE LINEAR REGRESSION 17

TIME SERIES 18

REGRESSION TREE 19

CHAPTER 6: STANDARD METHOD **20-26**

CHAPTER 8: PRINCIPAL COMPONENT ANALYSIS METHOD **27-41**

STEPS TO DEVELPO THE INDEX 27

VALIDITY OF ROBUSTNESS 34

MULTIPLE LINEAR REGRESSION 36

TREE METHOD 37

RELATION BETWEEN GNI PER CAPITA AND GHI SCORE 39

CHAPTER 9: HUNGER IN INDIA **42-60**

DISCRIPTIVE STATISTICS 43

GRAPHICAL REPRESENTATION 44

PRINCIPAL COMPONENT ANALYSIS METHOD 48

VALIDITY OF ROBUSTNESS 56

MULTIPLE LINEAR REGRESSION 56
TIME SERIES ANALYSIS OF UNDER 5 CHILD MORTALITY OF INDIA 57

CHAPTER 10: STEPS TAKEN TO REDUCE HUNGER 61-66
STATUS OF HUNGER IN INDIA 61
REASON BEHIND INDIAS PERSISTENT PROBLEM OF HUNGER 62
STEPS TAKEN BY INDIAN GOVERNMENT 63
FOMO ZERO: HOW BRAZIL IS TAKLING HUNGER AND FOOD INSECURITY 65
CHAPTER 11: OVERALL CONCLUSION 67
CHAPTER 12: REFERENCE 68

CHAPTER 1: INTRODUCTION

OVERVIEW

Hunger remains a critical issue affecting populations worldwide, with significant implications for both global and national levels. The Global Hunger Index (GHI) serves as a vital tool in comprehensively measuring and tracking hunger, providing insights into the severity of food insecurity and malnutrition.

In particular, regions like South Asia and Africa South of the Sahara face the highest hunger levels, emphasizing the urgent need for targeted interventions to address food insecurity. India, as a prominent country in South Asia, grapples with significant hunger challenges, reflected in indicators such as undernourishment and child stunting. The GHI calculation, which considers factors like insufficient caloric intake, child stunting, child wasting, and child mortality, offers a multidimensional view of hunger that is crucial for understanding the complexities of food insecurity.

Moreover, in the realm of calculating the Global Hunger Index, the utilization of Principal Component Analysis (PCA) emerges as a promising alternative method that can enhance the accuracy and efficiency of GHI calculations. This methodological approach not only offers a more robust framework for assessing hunger but also opens avenues for refining policy interventions and driving impactful change in combating malnutrition and hunger worldwide.

Given the pressing nature of hunger in both the global and Indian contexts, there is a critical need to calculate the Hunger Index to assess the s severity of the issue, identify areas for improvement, and guide policy interventions. By delving into the nuances of hunger through a comprehensive index like the GHI, we can gain valuable insights into the challenges faced by populations and work towards sustainable solutions to combat food insecurity.

OBJECTIVE

The present study has the following objectives:

1. To understand and apply the traditional GHI method.
2. Explore different statistical techniques used in developing a hunger index
3. To identify regions and countries where hunger is most severe.
4. To study the Hunger Index of Indian states.
5. To provide actionable insights for policymakers and stakeholders.

The index should have a scientifically sound basis and be available for as many developing countries and countries in transition as possible. The underlying data should be released annually, so that updated rankings can be presented each year.

SIGNIFICANCE

The accurate measurement of hunger is crucial for formulating effective policies and interventions. The GHI highlights successes and failures in hunger reduction, providing insights for policymakers and stakeholders to design effective interventions. Hence to study this index which will be helpful to make policies at countries as well as state level.

CHAPTER 2: CONCEPT OF THE GLOBAL HUNGER INDEX

The Global Hunger Index (GHI) is a tool used to comprehensively measure and track hunger at global, regional, and national levels reflecting multiple dimensions of hunger over time. It provides a snapshot of the state of hunger worldwide by combining multiple indicators related to hunger and undernutrition.

The GHI is intended to raise awareness and understanding of the struggle against hunger, provide a way to compare levels of hunger between countries and regions. It calls for attention to those areas of the world where hunger levels are highest and where the need for additional efforts to eliminate hunger is greatest.

It is calculated by the International Food Policy Research Institute(IFPRI) based in Washington, D.C. It is jointly published by Concern Worldwide and Welthungerhlife annually. The GHI scores are based on four component indicators as follows and is calculated on a 100-point scale reflecting the severity of the hunger, where 0 is the best possible score (no hunger) and 100 is the worst:

- **Undernourishment:** The share of the population with insufficient caloric intake.
- **Child stunting:** The share of children under age five who have low height for their age, reflecting chronic undernutrition.
- **Child wasting:** The share of children under age five who have low weight for their height, reflecting acute undernutrition.
- **Child mortality:** The mortality rate of children under age five, which is linked to undernutrition and poor health conditions.

These indicators are chosen because they cover different dimensions of hunger and undernutrition, including both short-term and long-term effects on individuals and populations. By combining these indicators, the GHI provides a holistic view of the state of hunger globally and helps identify areas where interventions are most needed to improve food security and nutrition outcome.

By analysing these indicators, the GHI provides a comprehensive assessment of hunger levels and helps identify regions and countries where urgent action is needed to address food insecurity and malnutrition. The GHI is a valuable tool for policymakers, researchers, and organizations working in the field of food security and nutrition to understand the scope of the problem and track progress over time.

The methodology of the GHI is designed to capture the complex nature of hunger and malnutrition, taking into account various dimensions of food insecurity. It allows for comparisons across different regions and countries, highlighting disparities and areas of improvement. The GHI plays a crucial role in raising awareness about the challenges of hunger and advocating for effective interventions to combat food insecurity on a global scale.

DEFINATION OF KEY TERMS:

Hunger: It is usually understood to refer to the distress associated with a lack of sufficient calories. The Food and Agriculture Organization of the United Nations (FAO) defines food deprivation, or undernourishment, as the habitual consumption of too few calories to provide the minimum dietary energy an individual requires to live a healthy and productive life, given that person's, age, stature and physical activity level.

Undernutrition: It goes beyond calories and signifies deficiencies in any or all of the following: energy, protein and/or essential vitamins and minerals. Undernutrition is the result of inadequate intake of food in terms of either quantity or quality, poor utilization of nutrients due to infections or other illness or a combination of these immediate causes.

Malnutrition: It refers more broadly to both undernutrition and over nutrition (problem caused by unbalanced diets that involve consuming too many calories in relation to requirement with or without low intake of micronutrient-rich foods)

Stunning: It is defined as low height-for-age. It is the result of chronic or recurrent undernutrition, usually associated with poverty, poor maternal health and nutrition. Frequent illness and /or inappropriate feeding and care in early life.

Wasting: It is defined as low weight-for-height. It often indicates recent and severe weight loss, although it can also persist for a long time. It usually occurs when a person has not had food of adequate quality and/or they have frequent or prolonged illnesses.

Mortality Rate: The term mortality refers to the total deaths that occurred particularly on a large scale such as in a population or geographical area. It is usually depicted in the form of mortality rate. According to the mortality rate definition, an index of the number of deaths in a given year or a specified time interval in a defined population is called mortality rate. It is typically expressed in

population units, such as deaths per 1,000 people for a recall period (or specified time frame).

$$Mortality\ Rate = \frac{Number\ of\ deaths}{Number\ of\ live\ births} \times 1000$$

THE ADDED VALUE OF THE GHI:

As compared to using a group of single indicators (e.g., the three components of the GHI), a composite index like the GHI has several advantages:

1. An index composed of different but related indicators is able to integrate different aspects of a multifaceted phenomenon like hunger and undernutrition.
2. The combination of indicators measured independently from each other reduces the impact of random measurement errors on the resulting index.
3. By condensing information from complementary indicators, an index is conducive to a quick overview and facilitates the use of statistics by policymakers and the public.

Indices have proven to be powerful, "eye-catching" tools for advocacy. If used in international rankings, they can foster a sense of competition among countries and thus help to promote good policies (Streeten 1994; Ryten 2000).

CHAPTER 3: DATASET

Data used in the calculation of GHI scores come from various UN and other multilateral agencies like Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO), United Nations Children's Fund (UNICEF), United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME) for the year 2022.

DATA UNDERLYING THE CALCULATION OF THE 2000, 2008, 2015, AND 2023 GLOBAL HUNGER INDEX SCORES

Country	Undernourishment (% of population)				Child wasting (% of children under five years old)				Child stunting (% of children under five years old)				Child mortality (% of children under five years old)			
	'00–'02	'07–'09	'14–'16	'20–'22	'98–'02	'06–'10	'13–'17	'18–'22	'98–'02	'06–'10	'13–'17	'18–'22	2000	2008	2015	2021
Afghanistan	46.4	25.4	21.3	30.1	10.9 *	8.4 *	9.5	3.7	50.3 *	50.8 *	40.4	44.7	12.9	9.6	7.0	5.6
Albania	4.9	7.4	4.3	4.1	7.5 *	9.6	4.2 *	1.6	32.0 *	23.2	15.7 *	11.3	2.7	1.6	1.0	0.9
Algeria	8.1	5.6	2.6	<2.5	3.1	4.1	4.1	2.7	23.6	15.4	11.7	9.8	4.2	3.0	2.5	2.2
Angola	67.8	43.6	13.5	21.6	9.2 *	8.3	4.9	6.0 *	50.4 *	29.2	37.6	29.4 *	20.5	13.8	8.8	6.9
Argentina	3.1	3.4	2.7	3.2	2.1 *	1.2	1.9 *	2.7	10.4 *	8.2	8.1 *	12.3	2.0	1.5	1.2	0.7
Armenia	25.7	5.8	<2.5	<2.5	2.5	4.1	4.4	3.3 *	17.3	20.9	9.4	10.9 *	3.1	2.1	1.4	1.1
Azerbaijan	16.8	<2.5	<2.5	<2.5	9.0	6.8	3.2	3.6 *	24.2	26.5	17.8	12.0 *	7.5	4.3	2.6	1.9
Bahrain	—	—	—	—	2.2 *	1.9 *	1.8 *	1.8 *	4.1 *	3.3 *	3.1 *	3.1 *	1.2	0.9	0.7	0.7
Bangladesh	15.6	12.9	14.8	11.2	12.5	17.5	15.6	11.0	51.1	43.2	32.7	23.6	8.6	5.5	3.8	2.7
Belarus	<2.5	<2.5	<2.5	<2.5	2.4 *	2.1 *	2.1 *	1.9 *	6.4 *	3.9 *	3.4 *	3.4 *	1.3	0.7	0.4	0.3
Benin	17.3	9.1	8.1	9.9	9.0	5.2	4.5	5.0	36.2	37.4	34.0	32.2	13.7	11.4	9.8	8.4
Bhutan	—	—	—	—	2.6	4.5	3.1 *	2.6 *	47.7	34.9	25.3 *	18.3 *	7.7	4.8	3.3	2.7
Bolivia (Plurinat. State of)	27.8	24.9	16.0	19.4	1.6	1.4	2.0	1.5 *	33.2	27.1	16.1	18.1 *	7.6	4.7	3.2	2.5
Bosnia & Herzegovina	3.4	<2.5	<2.5	<2.5	7.4	4.0	3.6 *	3.4 *	12.1	11.8	8.6 *	7.5 *	1.0	0.8	0.6	0.6
Botswana	23.8	22.3	24.1	22.9	5.9	7.3	6.0 *	5.4 *	29.1	28.9	18.9 *	16.7 *	7.4	6.9	4.5	3.5
Brazil	10.7	5.1	<2.5	4.7	2.8 *	1.8	2.1 *	3.1	10.0 *	7.0	7.1 *	7.2	3.5	2.1	1.6	1.4
Bulgaria	3.9	4.4	3.7	<2.5	4.9 *	4.7	5.9	4.2 *	11.1 *	9.2	7.0	6.5 *	1.7	1.1	0.8	0.6
Burkina Faso	22.9	15.4	13.3	16.2	15.5	11.3	10.2	10.1	41.4	35.1	30.1	22.1	17.9	13.3	10.1	8.3
Burundi	—	—	—	—	8.1	6.0 *	5.1	4.9	64.0	56.8 *	55.9	55.8	15.5	10.3	6.8	5.3
Cabo Verde	15.0	13.3	21.4	18.2	4.1 *	3.2 *	3.1 *	3.0 *	15.0 *	10.0 *	8.7 *	7.8 *	3.8	2.8	2.0	1.4
Cambodia	24.3	15.2	6.9	4.8	17.1	9.1	9.7	9.6	49.0	39.5	32.4	21.9	10.6	5.1	3.2	2.5
Cameroon	22.7	11.1	4.4	6.4	7.3	7.6	5.2	4.3	36.6	37.6	31.7	28.9	14.4	11.8	8.8	7.0
Central African Republic	38.5	32.6	49.1	48.7	10.4	12.1	6.2	5.3	44.4	43.6	38.0	40.0	16.6	13.7	11.6	10.0
Chad	38.6	40.2	26.2	31.4	13.9	16.3	13.3	8.3	38.9	38.7	39.8	28.0	18.4	15.6	12.9	10.7
Chile	3.5	3.6	3.1	2.5	0.5	0.3	0.3	0.3 *	3.0	2.0	1.8	1.9 *	1.1	0.9	0.8	0.7
China	10.1	3.9	<2.5	<2.5	2.5	2.6	1.9	1.7 *	17.8	9.8	6.5	4.8 *	3.7	1.8	1.1	0.7
Colombia	8.9	11.5	4.9	6.6	1.0	0.9	1.6	1.0 *	18.2	12.6	12.7	10.2 *	2.5	2.0	1.6	1.3
Comoros	25.2	20.0	12.4	13.5	13.3	9.2 *	10.6 *	9.9 *	46.9	39.9 *	30.2 *	28.6 *	9.6	7.8	6.1	5.0
Congo (Republic of)	27.0	36.1	27.7	33.3	9.2 *	8.0 *	8.2	7.8 *	30.8 *	26.7 *	21.2	24.0 *	11.4	6.9	5.3	4.3
Costa Rica	4.7	3.9	4.2	3.0	1.9 *	0.7	1.1 *	1.8	10.9 *	5.6	5.2 *	9.0	1.3	1.1	0.9	0.8
Côte d'Ivoire	18.2	18.9	11.9	7.7	6.9	14.3	6.1	8.4	31.2	39.0	21.6	23.4	14.3	11.4	9.0	7.5
Croatia	6.9	<2.5	<2.5	<2.5	1.3 *	1.1 *	1.1 *	1.0 *	1.3 *	0.9 *	0.9 *	0.8 *	0.8	0.6	0.5	0.5
Dem. Rep. of the Congo	27.9	28.4	30.2	35.3	15.9	10.4	8.1	6.4	44.4	45.8	42.7	41.8	16.0	12.3	9.6	7.9
Djibouti	42.1	21.3	21.3	16.8	19.4	17.0	13.9	10.6	27.1	33.0	28.0	20.9	10.1	8.1	6.6	5.4
Dominican Republic	20.6	16.2	7.4	6.3	1.5	2.3	2.4	2.2	7.7	10.1	7.1	6.7	4.0	3.6	3.5	3.3
Ecuador	21.0	21.1	9.0	13.9	2.7	2.1	1.6	3.7	27.9	25.9	23.9	23.0	3.0	2.1	1.5	1.2
Egypt	5.2	5.5	5.8	7.2	7.0	7.9	9.5	5.4 *	24.4	30.7	22.3	21.2 *	4.7	3.1	2.3	1.9
El Salvador	7.3	10.0	9.6	7.7	1.5	1.6	2.1	1.0 *	32.3	20.8	13.6	13.3 *	3.3	2.1	1.5	1.2
Equatorial Guinea	—	—	—	—	9.2	3.1 *	3.0 *	3.9 *	42.7	28.6 *	24.4 *	25.2 *	15.6	12.0	9.4	7.7
Eritrea	—	—	—	—	15.0	14.6	—	—	43.0	52.5	—	—	8.5	6.0	4.6	3.8
Estonia	3.5	<2.5	<2.5	<2.5	1.5 *	1.5 *	1.5	1.3 *	1.5 *	1.1 *	1.2	1.2 *	1.1	0.5	0.3	0.2

Table 1 : Dataset for the study

Here the colours shown in the table represent following categories:

: very low value of indicator,

: low value of indicator,

: medium value of indicator,

: high value of indicator,

: very high value of indicator.

They are based on threshold for the different indicator values. (Note: Threshold values for the prevalence of undernourishment are adapted from FAO (2015). Threshold values for child stunting and child wasting are from de Onis et al. (2019). Threshold values for child mortality are adapted from those shown in UN IGME (2023b) but condensed to the five categories shown.)

Category	Undernourishment	Child Wasting	Child Stunting	Child Mortality
Very Low	<5%	<2.5%	<2.5%	<1%
Low	5 - <25%	2.5 - <5%	2.5 - <10%	1 - <4%
Medium	15 - <25%	5 - <10%	10 - <20%	4 - <7%
High	25 - <35%	10 - <15%	20 - <30%	7 - <10%
Very High	>=35%	>=15%	>=30%	>=10%

Table 2 : Threshold for all the indicators

INCLUSION CRITERIA FOR COUNTRIES:

The Global Hunger Index (GHI) includes countries based on their rates of undernourishment and child mortality since 2000. A country is included if:

- At any time since 2000, at least 5% of its population was undernourished, or
- Its child mortality rate was 1% or higher.

Data on child stunting and wasting are not used to decide if a country is included because these data are not available consistently, especially for

wealthier countries. Non-independent territories and very small countries (under 500,000 people) are also excluded due to limited data.

For some countries, there isn't enough data to calculate a GHI score. However, these countries are still roughly categorized based on available information and other reports. Many of these countries face conflicts or unrest, which make data collection difficult and worsen their hunger situation. Some of these countries might actually have worse hunger issues than the Central African Republic, which currently has the highest GHI score for 2023, if more data were available.

HOW HUNGER SEVERITY IS DETERMINED FOR COUNTRIES WITH INCOMPLETE DATA:

In the 2023 Global Hunger Index (GHI) report, 136 countries were included, but 11 lacked enough data to calculate a score. To still provide an idea of hunger levels in these countries, provisional ratings were given based on:

- Available GHI indicator data
- The country's last known GHI severity rating
- The country's most recent undernourishment rate
- Undernourishment rates in the country's region
- Findings from recent Global Reports on Food Crises

Some countries lack data due to conflict or political issues, which often indicate high hunger levels. For example, Burundi, Somalia, and South Sudan are provisionally rated as having "alarming" hunger levels, but with more data, they might be rated "extremely alarming." If there was no historical data or GHI rating for a country, no provisional rating was given. For Somalia and South Sudan, despite missing data for two of the four GHI indicators, expert consultations and reports confirmed that an "alarming" rating was appropriate.

EXISTING DATA AND PROVISIONAL SEVERITY DESIGNATIONS FOR COUNTRIES WITH INCOMPLETE DATA: -

Country	2023 GHI Provisional Severity Designation	Child Stunting 2018-2022 (%)	Child Wasting 2018-2022 (%)	Child Mortality 2021 (%)	Last GHI Categorization	Last Prevalence of Undernourishment Value (%)	Sub regional Prevalence of Undernourishment (%)	Range of Prevalence of Undernourishment Values for Provisional Designation (%)
Lebanon	Low	7.0	1.4	0.8	Moderate 2022	10.9 (2022)	10.5	0.0 – 16.2
Jordan	Moderate	7.4	0.6	1.5	Moderate 2022	16.9 (2022)	10.5	15.4 – 39.4
Burundi	Alarming	55.8	4.9	5.3	Extremely Alarming 2014	67.3 (2014)	28.4	33.3 – 69.3
Somalia	Alarming	-	-	11.2	Extremely Alarming 2021	48.7 (2023)	28.4	**
South Sudan	Alarming	-	-	9.9	-	21.4 (2023)	28.4	**
Bahrain	Not	3.1*	1.8*	0.7	-	-	10.5	N/A
Bhutan	Not Designated	18.3*	2.6*	2.7	-	-	15.9	N/A
Equatorial Guinea	Not Designated	25.2	3.9	7.7	-	-	28.4	N/A
Eritrea	Not Designated	-	-	3.8	Extremely Alarming 2014	61.3 (2014)	28.4	N/A
Maldives	Not Designated	15.3	9.3	0.6	-	-	15.9	N/A
Qatar	Not Designated	1.9	1.2	0.5	-	-	10.5	N/A

Table 3 : Countries which have excluded from study

Note: Years in parentheses show when the relevant information was published in the GHI report. *Authors' estimate. **Designation based on FSIN and GNAFC (2021, 2022, 2023) and expert consultation. N/A = not applicable; — = not available.

CHAPTER 4: EXPLORATORY DATA ANALYSIS

We have already discussed the inclusion and exclusion criteria for the GHI and after excluding the countries with incomplete data we have 125 countries out of 136 countries remained. To have insights of each variable we perform EDA using different graphical methods as well as we have studied descriptive statistics for the data set.

DESCRIPTIVE STATISTICS:

Country	Undernourishment	Child wasting	Child stunting	Child mortality
Length:125	Min.: 2.50	Min.: 0.30	Min.: 0.50	Min.: 0.200
Class: character	1st Qu.: 3.00	1st Qu.: 2.30	1st Qu.: 8.50	1st Qu.: 1.100
Mode: character	Median: 7.70	Median: 4.10	Median: 17.10	Median: 2.200
	Mean: 12.96	Mean: 4.96	Mean: 18.93	Mean: 3.252
	3rd Qu.: 18.50	3rd Qu.: 6.60	3rd Qu.: 28.00	3rd Qu.: 4.700
	Max.: 51.00	Max.: 18.70	Max.: 48.70	Max.: 11.500

The undernourishment rates, spanning from 2.50% to 51.00%, demonstrate considerable variability across countries. The median (7.70%) and mean (12.96%) indicate that while undernourishment is moderate in most countries, some experience exceptionally high rates, skewing the average upward. With 50% of countries having undernourishment rates between 3.00% (1st quartile) and 18.50% (3rd quartile), it is evident that a significant number of countries have rates below the median.

Child wasting rates span from 0.30% to 18.70%, predominantly on the lower end. The proximity of the median (4.10%) to the mean (4.96%) suggests a relatively symmetrical distribution. The interquartile range, with the 1st quartile at 2.30% and the 3rd quartile at 6.60%, indicates that half of the countries fall within this range, highlighting a generally low yet significant prevalence of child wasting.

The stunting rates, ranging from 0.50% to 48.70%, highlight significant disparities in chronic malnutrition across countries. With a median of 17.10% and a mean of 18.93%, the distribution is right-skewed, indicating that a few countries

have exceptionally high stunting rates. The interquartile range of 8.50% to 28.00% shows that half of the countries fall within this range, underscoring the widespread prevalence of stunting in numerous nations.

Child mortality rates range from 0.20% to 11.50%, reflecting significant variation in child survival outcomes globally. The median rate of 2.20% is lower than the mean of 3.25%, indicating a right-skewed distribution with some countries facing exceptionally high mortality rates. The interquartile range of 1.10% to 4.70 reveals that half of the countries fall within this span, underscoring pronounced disparities in child mortality rates.

GRAPHICAL REPRESENTATION:

We will graphically represent the all four indicators i.e. Undernourishment, Child Wasting, Child Stunting and Child Mortality to obtain their interpretations visually and observe inequality regarding that variable in all countries.

1. BAR PLOT:

- Bar plot of Undernourishment (**Highest: Madagascar**)

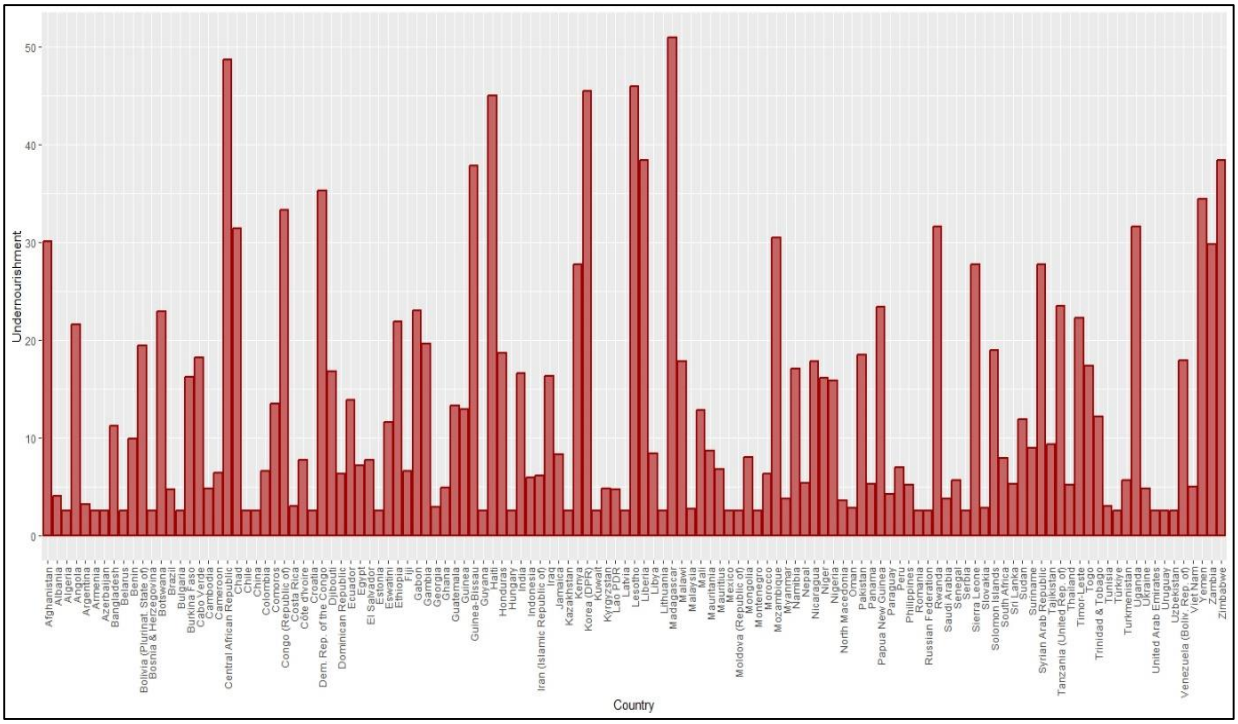


Figure 1 : Undernourishment

- Bar plot of Child Wasting (**Highest: India**)

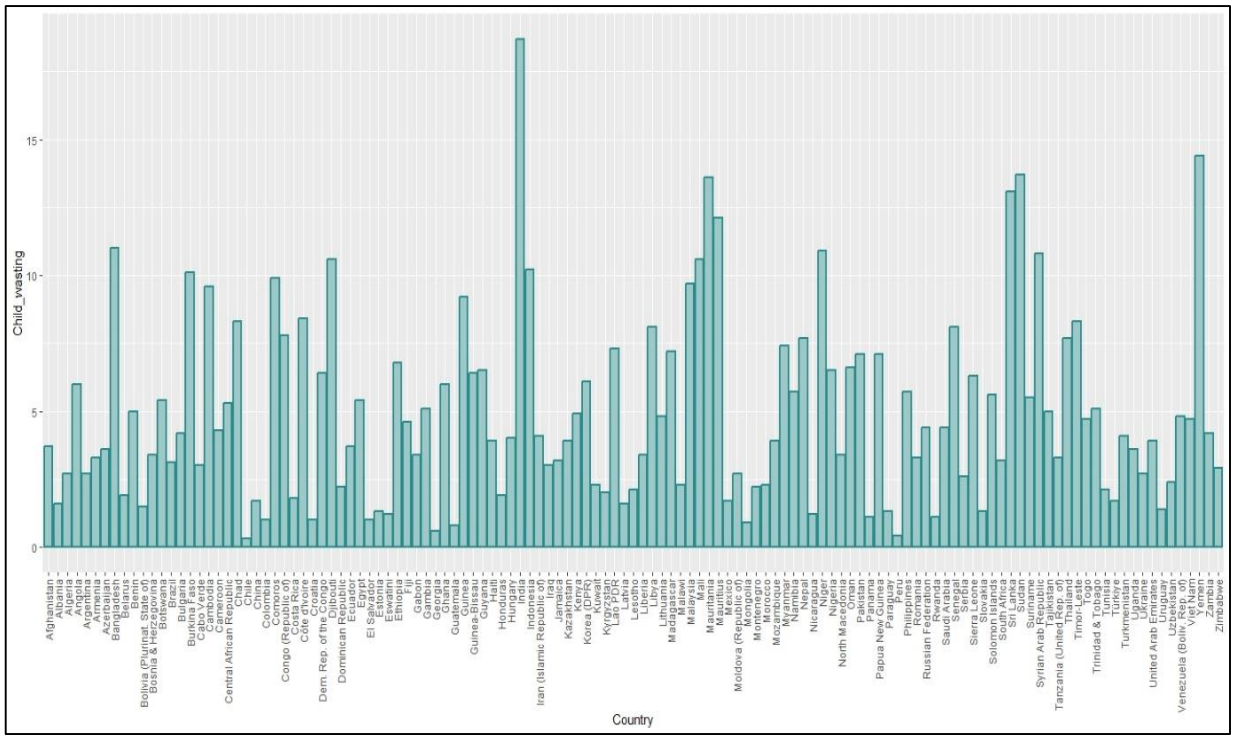


Figure 2 : Wasting

- Bar plot of Child Stunting (**Highest: Yemen**)

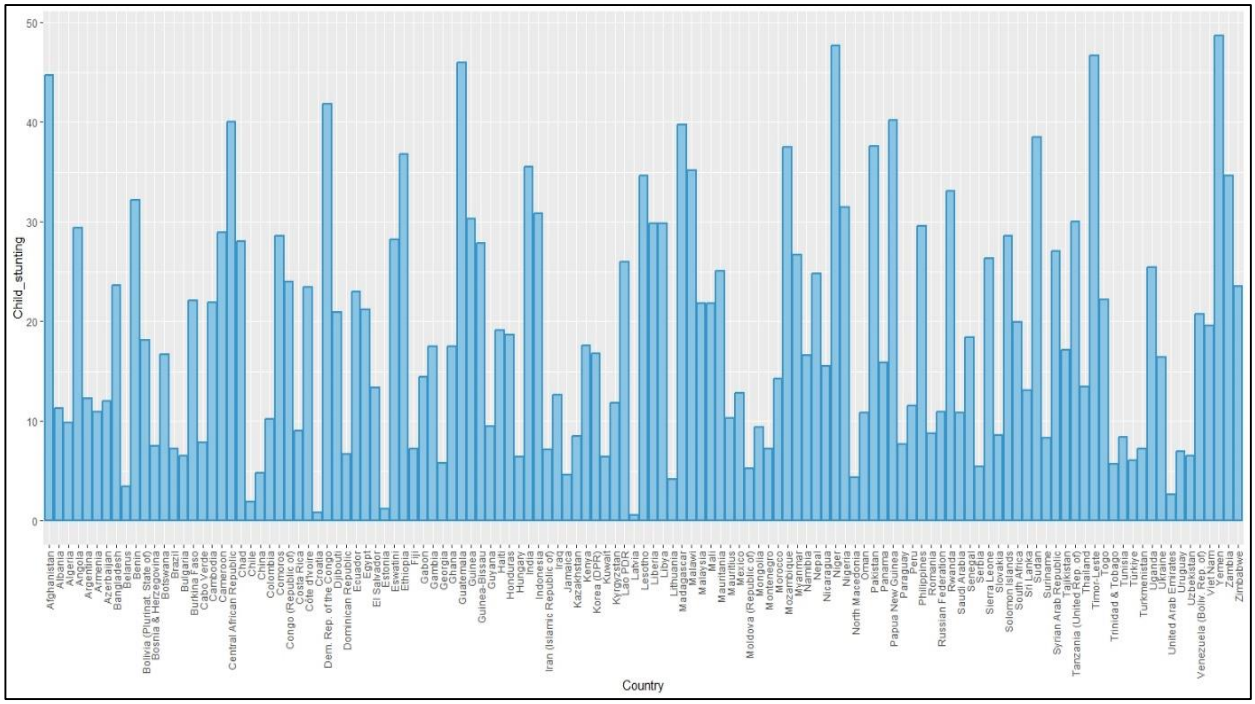


Figure 3 : Stunting

- Bar plot of Child Mortality (Highest: Niger)

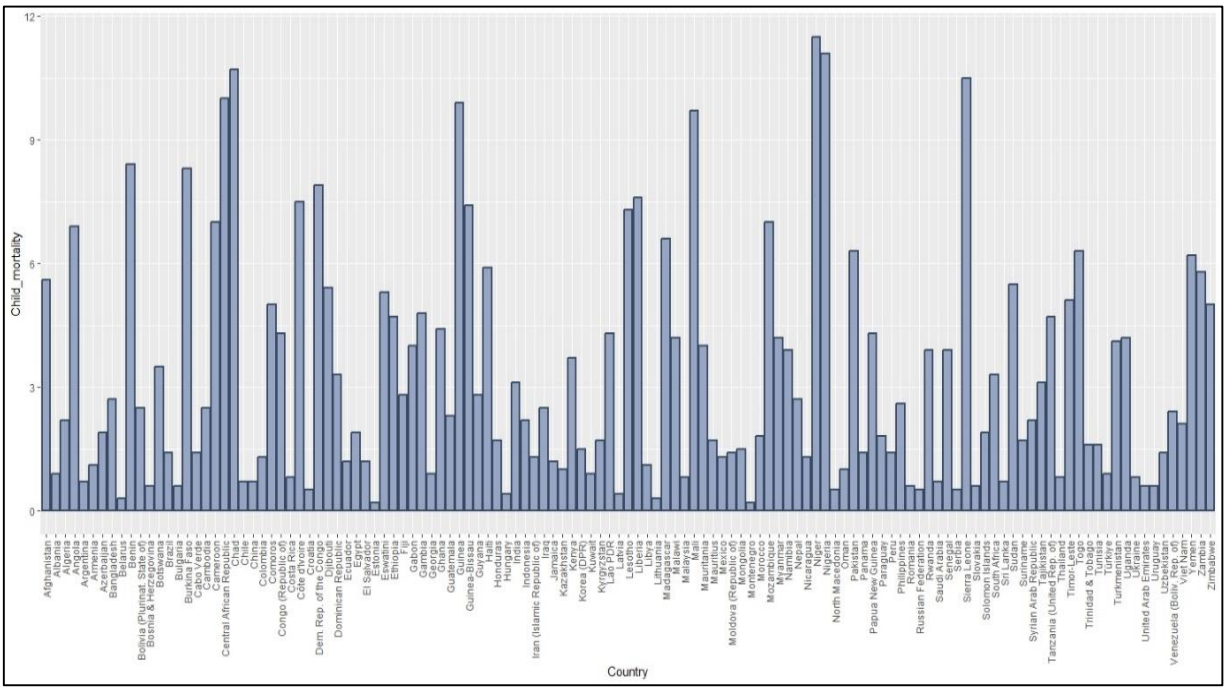


Figure 4 : Mortality

2. PAIR PLOT:

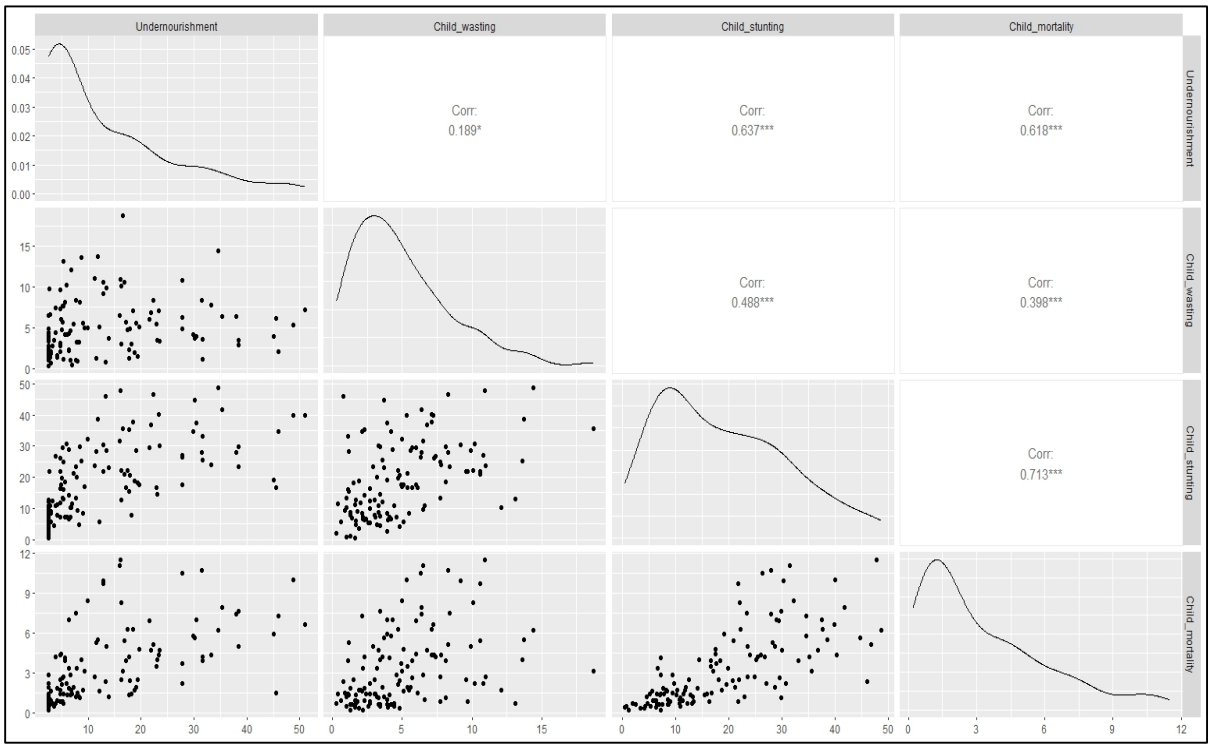


Figure 5 : Pair plot

Using Pair plot the relationship and patterns between the pairs of variables is visualized. It displays scatter plots for numerical variables and histograms for each variable's distribution along the diagonal. Pair plots help identify correlations, explore data distributions, detect outliers, and aid in variable selection for further analysis.

Interpretation:

- **Diagonal** – Kernel Density plot of Undernourishment, Child Wasting, Child Stunting and Child Mortality shows these four variables exhibits a right-skewed distribution indicating that most of the data points are concentrated at the lower end of scale with less frequent occurrences of higher values.

- **Off-Diagonal** - Undernourishment is strongly correlated with both child stunting (0.637) and child mortality (0.618), and to a lesser extent, with child wasting (0.189). Child wasting is moderately correlated with both child stunting (0.488) and child mortality (0.398). Child stunting has the strongest correlation with child mortality (0.713) among the variables.

- **The density plots** highlight that all four variables are right-skewed, indicating that most countries have low to moderate levels of undernourishment, child wasting, child stunting, and child mortality, but a few countries have very high levels. The correlations and scatter plots emphasize the significant positive relationships between these indicators, suggesting that improvements in one area (e.g., reducing undernourishment) could potentially lead to improvements in other areas (e.g., reducing child stunting and mortality).

3. BOXPLOT OF THE ALL FOUR INDICATORS OF THE GHI:

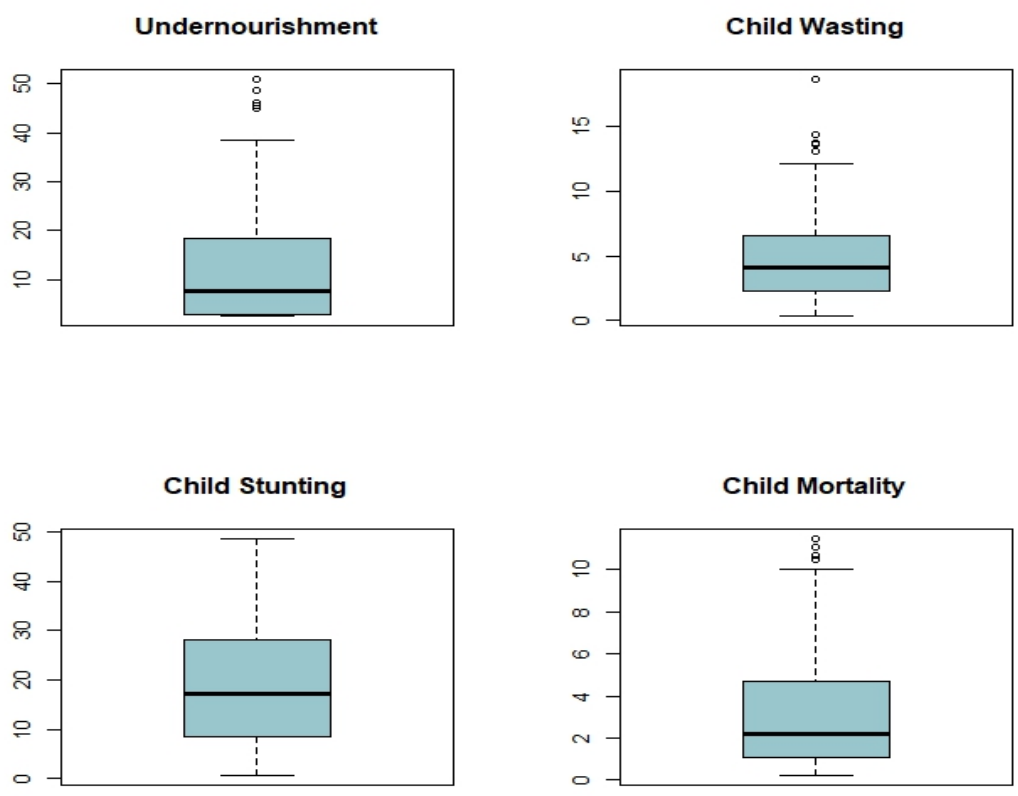


Figure 6 :Boxplot of all four indicators

Interpretation:

1. Undernourishment and Child Stunting have broader distributions, indicating significant variability in these indicators across different countries.
2. Child Wasting and Child Mortality have smaller IQRs, but the presence of outliers suggests that certain countries experience extremely high rates compared to the median.
3. The presence of outliers across all indicators highlights the disparity in hunger and malnutrition issues globally, with some countries facing much more severe challenges than others.

CHAPTER 5: STATISTICAL TOOLS

1. PRINCIPAL COMPONENT ANALYSIS (PCA):

Principal Component Analysis (PCA) is a widely used technique for dimensionality reduction and data analysis. It is used to identify patterns and structures in high dimensional data by transforming the original variables into a new set of uncorrelated variables called principal components.

The main objective of PCA is to reduce the dimensionality of the data while retaining as much information as possible. The principal components are ordered in such a way that the first component captures the maximum amount of variance in the data, followed by the second component capturing the next highest amount of variance, and so on.

Here's an overview of the PCA process:

1. Standardize the data: PCA requires the data to be standardized so that each variable has zero mean and unit variance. This is done to ensure that variables with larger scales do not dominate the analysis.
2. Compute the covariance matrix or correlation matrix: PCA analyses the relationships between variables. The covariance matrix measures the covariance's between pairs of variables, while the correlation matrix measures the correlations between pairs of variables. The choice between covariance and correlation depends on the nature of the data and the objective of the analysis.
3. Compute the eigenvectors and Eigen values: The eigenvectors and Eigen values of the covariance or correlation matrix provide information about the principal components. The eigenvectors represent the directions or axes in the original feature space, while the Eigen values indicate the amount of variance explained by each eigenvector.
4. Sort the Eigen values and select the principal components: Sort the Eigen values in descending order. The eigenvector corresponding to the largest Eigen value represents the first principal component, the one with the second largest Eigen value represents the second principal component, and so on. Typically, you would select a subset of the principal components that capture a significant amount of variance, aiming to retain most of the information.

5. Transform the data: Multiply the original data by the eigenvectors of the selected principal components. This transformation maps the data from the original feature space to the new feature space defined by the principal components. PCA has various applications in fields such as data analysis, image processing, signal processing, and feature extraction. It is a powerful tool for understanding and analysing complex datasets and is often used as a pre-processing step in machine learning tasks.

2. MULTIPLE LINEAR REGRESSION:

Multiple Linear Regression is a statistical technique used to model the relationship between a dependent variable and multiple independent variables n multiple linear regression, the goal is to estimate the coefficients (slope) of the independent variables to determine their impact on the dependent variable, while accounting for their collective effects. The model assumes a linear relationship between the dependent variable and the independent variables.

Here's an overview of the multiple linear regression process:

1. Formulate the research question: Clearly define the research question and identify the dependent variable and the independent variables to be included in the model.
2. Collect and prepare the data.
3. Specify the model: Define the mathematical equation that represents the multiple linear regression model. The equation takes the form:
$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \varepsilon$$
where Y is the dependent variable, β_0 is the intercept term, $\beta_1, \beta_2, \ldots, \beta_k$ are the coefficients of the independent variables $X_1, X_2, \ldots, X_k$, and ε is the error term representing the unexplained variation.
4. Estimate the model coefficients: Use a suitable method, such as ordinary least squares (OLS), to estimate the coefficients of the model. The estimation process aims to find the best-fitting line that minimizes the sum of squared differences between the observed values and the predicted values.

3. TIME SERIES:

Time series analysis is a statistical technique used to analyse time-ordered data points. This method is essential for understanding the underlying patterns, trends, and seasonal variations in data that are collected sequentially over time.

Time Series Data points indexed in time order, often collected at regular intervals (e.g., daily, monthly, yearly). Different components of Time Series are as follows,

- Trend: The long-term progression or direction of the data.
- Seasonality: Regular, repeating patterns or cycles in data related to time of year, month, week, etc.
- Cyclic Patterns: Long-term oscillations or fluctuations not tied to a fixed period, typically influenced by economic or other macro-level factors.
- Irregular Component (Noise): Random variation or residuals that do not follow a predictable pattern.

Objectives of Time Series Analysis is to summarizing historical data to identify patterns and significant changes over time, Forecasting (Predicting future data points based on past trends and patterns and examining the relationship between variables over time. Different techniques are used in Time Series Analysis such as Moving Average, Exponential Smoothing, Autoregressive Integrated Moving Average (ARIMA), Seasonal Autoregressive Integrated Moving Average (SARIMA), Spectral Analysis.

AUTOREGRESSIVE INTEGRATED MOVING AVERAGE (ARIMA):

- p (order of Autoregressive component): It represents the number of lagged values of the time series that are considered for predicting the current value.
- d (order of Differencing component): It indicates the number of differencing operations applied to the time series to make it stationary.
- q (order of Moving Average component): It represents the number of lagged forecast errors (residuals) that are considered for predicting the current value.

By combining these three components (AR, I, MA), ARIMA models can capture a wide range of time series patterns. The order values (p, d, q) are determined

based on the characteristics of the specific time series being modelled. These values can be estimated through methods such as autocorrelation function (ACF) and partial autocorrelation function (PACF) analysis. It's important to note that ARIMA models assume that the underlying time series is stationary, meaning its statistical properties, such as mean and variance, do not change over time. They provide a flexible framework for analysing and forecasting time series data.

4. REGRESSION TREE:

A regression tree is a type of decision tree used for predicting continuous values. It works by recursively splitting the data into subsets based on the value of input features, creating a tree-like model of decisions. Each internal node represents a decision based on a feature value, and each leaf node represents a predicted continuous value.

The primary purposes of regression trees include Predicting Continuous Outcomes, Handling Non-Linearity and Interaction's, Interpretable models Feature selection. Regression trees offer advantages such as simplicity and interpretability, not requiring data normalization, and the ability to handle non-linear relationships. However, they are prone to overfitting, instability, and the bias-variance trade-off.

To improve regression trees, ensemble methods like bagging and boosting can be employed. Bagging involves building multiple trees on different subsets of data and averaging their predictions, as seen in Random Forests. Boosting, on the other hand, sequentially builds trees, with each subsequent tree aiming to correct the errors of the previous ones, as exemplified by Gradient Boosting Machines. These techniques help mitigate overfitting and enhance predictive performance.

CHAPTER 6: STANDARD METHOD

Each country's GHI score is calculated based on a formula that combines four indicators Undernourishment, Child Stunning, Child Wasting and Child Mortality that together capture the multidimensional nature of hunger. Previously, underweight in children under five was used to measure child nutrition, but it can hide cases where children are normal weight or overweight but still stunted. Reducing underweight might increase obesity without solving stunting. Now, stunting is preferred because it better shows long-term impacts on children's health. So, newer indicators like child wasting, child stunting, undernourishment, and child mortality are now used in calculation of GHI.

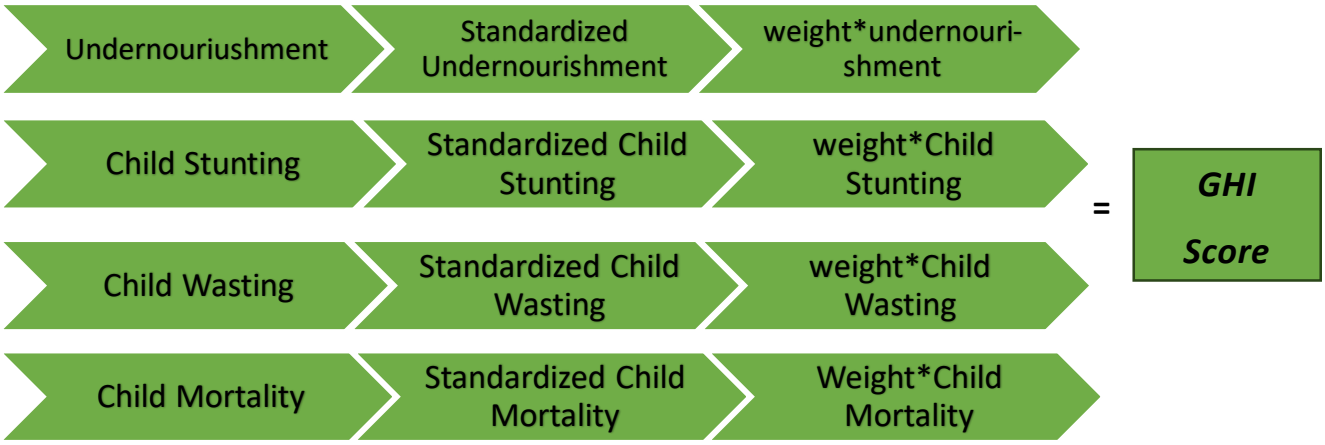
Using this combination of indicators to measure hunger offers several advantages (Figure 7). The indicators included in the GHI formula reflect caloric deficiencies as well as poor nutrition. The undernourishment indicator captures the food access situation of the population as a whole, while the indicators specific to children reflect the nutrition status within a particularly vulnerable subset of the population for whom a lack of dietary energy, protein, and/or micronutrients (essential vitamins and minerals) leads to a high risk of illness, poor physical and cognitive development, and death. The inclusion of both child wasting and child stunting allows the GHI to document both acute and chronic undernutrition. By combining multiple indicators, the index minimizes the effects of random measurement errors. These four indicators are all part of the indicator set used to measure progress toward the United Nations Sustainable Development Goals (SDGs).

HOW THE FOUR INDICATORS UNDERLYING THE GHI CAPTURE THE MULTIDIMENSIONAL NATURE OF HUNGER

Undernourishment	Child stunting	Child wasting	Child mortality
• Measures inadequate food access, an important indicator of hunger • Refers to the entire population, both children and adults • Is used as a lead indicator for international hunger reduction targets, including Sustainable Development Goal 2 (Zero Hunger)	• Go beyond calorie availability, consider aspects of diet quality and utilization • Reflect children's particular vulnerability to nutritional deficiencies • Are sensitive to uneven distribution of food within the household • Are used as nutrition indicators for SDG 2 (Zero Hunger)		• Reflects that death is the most serious consequence of hunger, and children are the most vulnerable • Improves the GHI's ability to reflect deficiencies of essential vitamins and minerals • Complements stunting and wasting, which only partially capture the mortality risk of under-nutrition

Table 4: Four Indicators of GHI capture multidimensional nature of GHI

METHODOLOGY OF INDEX:



STEPS TO DEVELOP THE INDEX:

GHI scores are calculated using a three-step process:

Step 1: Values are determined for the four component indicators for each country, drawing on the latest published data available from internationally recognized sources.

Step 2: The parameters we have are measured in different units. So to get every parameter in one unit we standardized the given parameters.

Each of the four component indicators is given a standardized score based on thresholds set slightly above the highest country level values observed worldwide for that indicator since 1988.

- the threshold for undernourishment is 80, based on the observed maximum of 76.5 percent.
- the threshold for child wasting is 30, based on the observed maximum of 26.0 percent.
- the threshold for child stunting is 70, based on the observed maximum of 68.2 percent
- the threshold for child mortality is 35, based on the observed maximum of 32.6 percent.

$$\frac{Prevalence\ of\ Undernourishment}{80} \times 100 = standardized\ undernourishment\ value$$

$$\frac{Child\ stunting\ rate}{70} \times 100 = standardized\ child\ stunting\ value$$

$$\frac{Child\ wasting\ rate}{30} \times 100 = standardized\ child\ wasting\ value$$

$$\frac{Child\ mortality\ rate}{35} \times 100 = standardized\ child\ mortality\ value$$

Step 3: The standardized scores are aggregated to calculate the GHI score for each country. Undernourishment and child mortality each contribute one-third of the GHI score, while child stunting and child wasting each contribute one-sixth of the score. Thus, the formula for GHI Score as follows:

$$\frac{\textbf{Undernourishment}}{3} + \frac{\textbf{Child Stunting}}{6} + \frac{\textbf{Child Wasting}}{6} + \frac{\textbf{Child Mortality}}{3} = \textbf{GHI Score}$$

This calculation results in GHI scores on a 100-point scale, where 0 is the best score (no hunger) and 100 is the worst. In practice, neither of these extremes is reached. A value of 100 would signify that a country's undernourishment, child wasting, child stunting, and child mortality levels each exactly meets the thresholds set slightly above the highest levels observed worldwide in recent decades. A value of 0 would mean that a country had no undernourished people in the population, no children younger than five who were wasted or stunted, and no children who died before their fifth birthday.

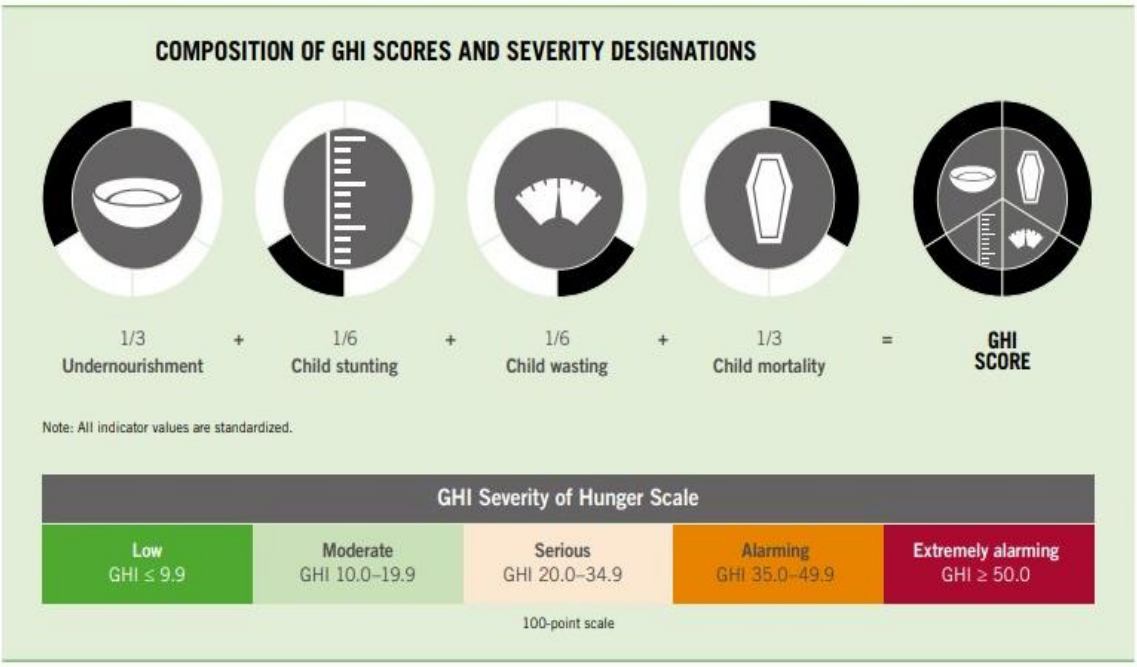


Figure 7: Composition of Indicators

This is the table showing GHI Score for each country based on standardized value of respective parameters.

Country	GHI Score	Rank	Country	GHI Score	Rank
Estonia	2.2401	1	Iraq	13.8393	64
Croatia	2.2639	2	Ecuador	14.4663	65
Chile	2.3274	3	Philippines	14.8571	66
Latvia	2.4306	4	Honduras	14.9187	67
Belarus	3.1925	5	Cambodia	14.9286	68
Georgia	3.7798	6	Senegal	14.9702	69
China	3.7956	7	Nepal	15.0040	70
Uruguay	4.0337	8	Bolivia (Plurinat. State of)	15.6071	71
Montenegro	4.1687	9	Myanmar	16.0516	72
Serbia	4.2480	10	Libya	16.1429	73
Turkey	4.2718	11	Lao PDR	16.2996	74
United Arab Emirates	4.3988	12	Eswatini	17.2619	75
Slovakia	4.5079	13	Venezuela (Boliv. Rep. of)	17.3393	76
Kuwait	4.7004	14	Indonesia	17.5536	77
North Macedonia	4.8889	15	Namibia	17.9583	78
Lithuania	4.9702	16	Cameroon	18.6032	79
Moldova (Republic of)	5.1131	17	Gabon	18.7103	80
Costa Rica	5.1548	18	Bangladesh	18.9683	81
Hungary	5.1687	19	Guatemala	19.1290	82
Uzbekistan	5.2560	20	Solomon Islands	19.6468	83
Bosnia & Herzegovina	5.2877	21	Gambia	19.7381	84
Bulgaria	5.4940	22	Botswana	19.8512	85
Romania	5.5179	23	Côte d'Ivoire	20.5893	86
Tunisia	5.9405	24	Mauritania	20.9663	87
Paraguay	6.0198	25	Malawi	21.0754	88
Albania	6.1448	26	Togo	21.1468	89
Kazakhstan	6.1845	27	Kenya	22.0198	90
Mexico	6.2718	28	Benin	22.5694	91
Argentina	6.4286	29	Comoros	22.6964	92
Armenia	6.5179	30	Djibouti	23.0079	93
Russian Federation	6.5575	31	Tanzania (United Rep. of)	23.2440	94
Brazil	6.7282	32	Uganda	25.2143	95
Algeria	6.9702	33	Rwanda	25.3730	96
Colombia	6.9722	34	Burkina Faso	25.5278	97
Peru	7.2103	35	Mali	25.6508	98
Saudi Arabia	7.2659	36	Angola	25.9048	99
Jamaica	7.4742	37	Syrian Arab Republic	26.1071	100
Mongolia	7.5000	38	Ethiopia	26.1409	101
Kyrgyzstan	7.5397	39	Pakistan	26.6052	102
Azerbaijan	7.7083	40	Sudan	26.9742	103
Iran (Islamic Republic of)	7.7480	41	Guinea	27.1290	104
Panama	7.9385	42	Papua New Guinea	27.3611	105

Country	GHI Score	Rank	Country	GHI Score	Rank
El Salvador	8.0734	43	Korea (DPR)	27.7758	106
Ukraine	8.1667	44	Zimbabwe	27.9683	107
Oman	8.3571	45	Congo (Republic of)	28.0179	108
Dominican Republic	8.5853	46	Nigeria	28.3075	109
Morocco	8.9980	47	Zambia	28.5119	110
Guyana	9.5813	48	India	28.7103	111
Fiji	9.6865	49	Timor-Leste	29.8790	112
Turkmenistan	10.2718	50	Mozambique	30.4702	113
Thailand	10.3968	51	Afghanistan	30.5734	114
Suriname	10.4008	52	Haiti	31.0833	115
Trinidad & Tobago	10.7976	53	Sierra Leone	31.3452	116
Viet Nam	11.3611	54	Liberia	32.2222	117
Cabo Verde	12.4405	55	Guinea-Bissau	33.0377	118
Malaysia	12.4663	56	Chad	34.5516	119
Egypt	12.8571	57	Niger	35.0734	120
South Africa	12.9504	58	Lesotho	35.5238	121
Nicaragua	13.0119	59	Dem. Rep. of the Congo	35.7401	122
Sri Lanka	13.2718	60	Yemen	39.8750	123
Mauritius	13.6270	61	Madagascar	41.0119	124
Tajikistan	13.6766	62	Central African Republic	42.2837	125
Ghana	13.7321	63			

CONCLUSIONS:

The Global Hunger Index (GHI) measures and tracks hunger at global, regional, and national levels. This dataset includes the GHI scores and ranks of various countries. Here's how to interpret the key elements of this dataset.

GHI scores on a 100-point scale, where 0 is the best score (no hunger) and 100 is the worst. In practice, neither of these extremes is reached. A value of 100 would signify that a country's undernourishment, child wasting, child stunting, and child mortality levels each exactly meets the thresholds set slightly above the highest levels observed worldwide in recent decades. A value of 0 would mean that a country had no undernourished people in the population, no children younger than five who were wasted or stunted, and no children who died before their fifth birthday.

Rank:

- The rank indicates the relative position of a country compared to others in terms of its GHI score.
- A lower rank corresponds to a lower (better) GHI score.

Key Insights from the GHI:

1. Countries with Low Hunger Levels:
    - Countries with GHI scores below 5 are considered to have very low hunger levels. These countries include Estonia (2.24), Croatia (2.26), Chile (2.33), Latvia (2.43), and Belarus (3.19), among others.
    - These countries typically have effective food security policies and better overall health and nutrition statuses.
2. Countries with Moderate to Serious Hunger Levels:
    - Countries with GHI scores between 10 and 19.9 are experiencing moderate hunger. Examples include Thailand (10.40), Suriname (10.40), and Trinidad & Tobago (10.80).
    - Countries with scores between 20 and 34.9 are experiencing serious hunger. Examples include Côte d'Ivoire (20.59), Mauritania (20.97), and Malawi (21.08).
3. Countries with Alarming Hunger Levels:
    - Countries with GHI scores between 35 and 49.9 face alarming hunger. These countries require immediate and significant interventions to address hunger. Examples include Chad (34.55) and Niger (35.07).
4. Countries with Extremely Alarming Hunger Levels:
    - Countries with scores of 50 and above face extremely alarming hunger. These countries are in dire need of comprehensive and urgent action to combat hunger and malnutrition. Yemen (39.87) and the Central African Republic (42.28) are in this category.

CHAPTER 8: PRINCIPAL COMPONENT ANALYSIS METHOD

This is another method used to calculate the Global Hunger Index (GHI) using Principal Component Analysis (PCA). Instead of giving equal weights using the standard method or weights calculated from factor analysis scores, the rotation matrix, i.e., the eigenvalue matrix obtained from PCA, is used to compute weights for each variable: undernourishment, child wasting, child stunting, and child mortality. For this method, we have used the same standardization technique as in the previous factor analysis method, which is considered the best method for standardization when calculating the index. Note that the main objective here is not data reduction; we have used this method solely to obtain weights for each variable, which are then used for GHI score calculation.

STEPS TO DEVELOP THE INDEX:

This method of index calculation involves following 3 steps:

Step 1: For this method, the standardization technique is the same as that used in the factor analysis method, ensuring that the standardized data will be the same for both methods.

Step 2: To have indicators/variables as: undernourishment, child wasting, child stunting and child mortality, we used PCA to construct the Global Hunger Index by combining indicators into a single, composite index. Principal components are linear combination of variables thus we have used all four principal components to hunger index score.

The eigenvectors give the weights to be used in the linear transformation. Thus, four scores were created for each country-one for each principal component- by multiplying the respective standardized value of each indicator/variable with the proportion of the weights explained by each of the principal components. Four scores were computed in this manner. The four scores were summed to create one final score for each district. The final score for the country defines the GHI rank.

To compute scores, we use R software and obtain the output as follows:

```
Rotation Matrix:
                     PC1          PC2          PC3         PC4
S_Undernourishment 0.4910457 -0.516169407  0.62864035  0.3118566
S_Child_wasting    0.3744551  0.848124799  0.28067878  0.2483690
S_Child_stunting   0.5655091  0.002008244 -0.03123943 -0.8241477
S_Child_mortality  0.5466781 -0.119371001 -0.72460667  0.4022920


Importance of components:
                          PC1    PC2     PC3     PC4
Standard deviation     1.6015 0.9112 0.58367 0.51392
Proportion of Variance 0.6412 0.2076 0.08517 0.06603
Cumulative Proportion  0.6412 0.8488 0.93397 1.00000
```

Interpretation:

1. **Proportion of Variance:** This indicates the proportion of the total variance explained by each principal component. PC1 explains 64.12% of the variance, PC2 explains 20.76%, PC3 explains 8.52%, and PC4 explains 6.60%.
2. **The rotation matrix** indicates how much each original variable contributes to each principal component. Each value represents the correlation between the variable and the principal component.
    - PC1 captures the most variance and represents a combination of all four variables, indicating a general index of undernourishment, child wasting, child stunting, and child mortality.
    - PC2 is primarily influenced by child wasting and undernourishment, suggesting a specific pattern or dimension related to these aspects.
    - PC3 differentiates between undernourishment and child mortality, representing another dimension of variability.
    - PC4 contrasts child stunting with child mortality, showing yet another unique dimension of the data.

3. **Biplot:** The first two principal components for the standardized data. The blue country names represent the scores for the first two principal components. The red arrows indicate the first two principal component loading vectors (with axes on the top and right). For example, the loading for Child wasting on the first component is 0.37, and its loading on the second principal component 0.85 (the word Child Wasting is centred at the point (0.37, 0.85)). This figure is known as a biplot, because it displays both the principal component scores and the principal component loadings.

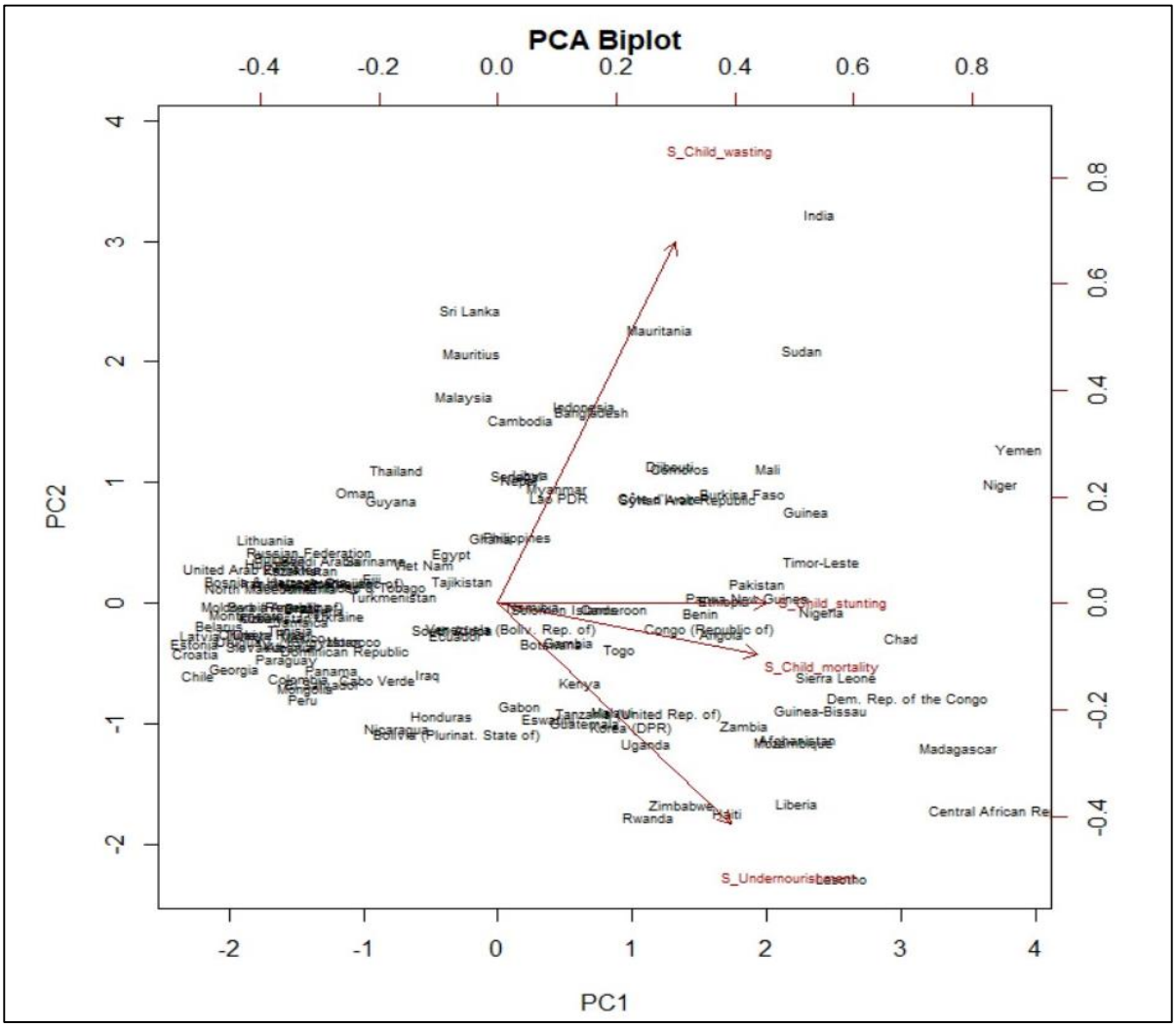


Fig.8 Biplot of first two principal component

Step 3: The four scores were summed to create one final score for each district. Thus, the final score i.e. GHI score is obtain as,

$$Final\ Score = score1 + score2 + score3 + score4$$

The four score are computed to obtain final GHI score. For example,

$$\begin{aligned} score1 = (&0.4910458 * Standarized\ Value\ of\ Undernourishment \\ &+ 0.374450 * Standarized\ Value\ of\ Child\ Wasting \\ &+ 0.5655091 * Standarized\ Value\ of\ Child\ Stunting \\ &+ 0.546678 * Standarized\ Value\ of\ Child\ Mortality) \\ &* \left(\frac{0.6412}{0.6412 + 0.2076 + 0.08517 + 0.06603}\right) \end{aligned}$$

Similarly, we can calculate score 2, score 3, score 4.

This is the final rank wise representation of 125 countries as follows:

Country	Undernourishment	Child wasting	Child stunting	Child mortality	GHI Score	Rank
Chile	4.55	1.5	3.8	4.67	4.485	1
Croatia	4.55	5	1.6	3.33	5.022	2
Estonia	4.55	6.5	2.4	1.33	5.370	3
Latvia	4.55	8	1	2.67	6.014	4
Georgia	5.27	3	11.6	6.00	8.148	5
Belarus	4.55	9.5	6.8	2.00	8.279	6
China	4.55	8.5	9.6	4.67	9.454	7
Uruguay	4.55	7	13.8	4.00	9.861	8
Turkey	4.55	8.5	12	6.00	10.576	9
Slovakia	5.09	6.5	17.2	4.00	10.826	10
Montenegro	4.55	11	14.4	1.33	11.095	11
Serbia	4.55	13	10.8	3.33	11.488	12
Kuwait	4.55	11.5	12.8	6.00	12.190	13
Costa Rica	5.45	9	18	5.33	12.702	14
United Arab Emirates	4.55	19.5	5.2	4.00	12.936	15
North Macedonia	6.55	17	8.6	3.33	13.205	16
Paraguay	7.64	6.5	15.4	12.00	13.318	17
Moldova (Republic of)	4.55	13.5	10.4	9.33	13.338	18
Uzbekistan	4.55	12	13	9.33	13.448	19
Peru	12.73	2	23	9.33	14.249	20
Albania	7.45	8	22.6	6.00	14.411	21
Colombia	12.00	5	20.4	8.67	14.424	22
Tunisia	5.45	10.5	16.8	10.67	14.570	23
Bosnia & Herzegovina	4.55	17	15	4.00	14.793	24
Mongolia	14.55	4.5	18.8	10.00	14.811	25
Hungary	4.55	20	12.8	2.67	15.102	26
Romania	4.55	16.5	17.4	4.00	15.299	27
Lithuania	4.55	24	8.2	2.00	15.326	28
Mexico	4.55	8.5	25.6	8.67	15.512	29
Bulgaria	4.55	21	13	4.00	16.007	30
Brazil	8.55	15.5	14.4	9.33	16.602	31
Argentina	5.82	13.5	24.6	4.67	16.685	32
El Salvador	14.00	5	26.6	8.00	16.691	33
Jamaica	15.09	16	9.2	8.00	16.696	34
Kazakhstan	4.55	19.5	17	6.67	17.321	35
Kyrgyzstan	8.73	10	23.6	11.33	17.538	36
Armenia	4.55	16.5	21.8	7.33	17.614	37
Panama	9.64	5.5	31.8	9.33	17.668	38
Algeria	4.55	13.5	19.6	14.67	17.702	39
Dominican Republic	11.45	11	13.4	22.00	18.742	40
Russian Federation	4.55	22	21.8	3.33	18.962	41
Iran (Islamic Republic of)	11.09	20.5	14.2	8.67	19.346	42
Saudi Arabia	6.91	22	21.6	4.67	19.954	43

Country	Undernourishment	Child wasting	Child stunting	Child mortality	GHI Score	Rank
Ukraine	8.73	13.5	32.8	5.33	20.207	44
Azerbaijan	4.55	18	24	12.67	20.521	45
Morocco	11.45	11.5	28.4	12.00	20.654	46
Cabo Verde	33.09	15	15.6	9.33	23.658	47
Fiji	12.00	23	14.4	18.67	23.711	48
Nicaragua	32.36	6	31	8.67	23.863	49
Trinidad & Tobago	22.18	25.5	11.4	10.67	24.479	50
Turkmenistan	10.36	20.5	14.4	27.33	24.627	51
Oman	5.09	33	21.6	6.67	25.044	52
Suriname	16.36	27.5	16.6	11.33	25.537	53
Guyana	4.55	32.5	19	18.67	27.354	54
Iraq	29.64	15	25.2	16.67	27.753	55
Honduras	34.00	9.5	37.4	11.33	28.655	56
Bolivia (Plurinat. State of)	35.27	7.5	36.2	16.67	29.283	57
Viet Nam	9.09	23.5	39.2	14.00	29.351	58
South Africa	14.36	16	39.8	22.00	29.921	59
Thailand	9.45	38.5	26.8	5.33	29.988	60
Ecuador	25.27	18.5	46	8.00	31.966	61
Tajikistan	16.91	25	34.2	20.67	32.646	62
Egypt	13.09	27	42.4	12.67	32.667	63
Ghana	8.91	30	35	29.33	35.437	64
Gabon	41.82	17	28.8	26.67	36.106	65
Eswatini	21.09	6	56.4	35.33	36.206	66
Venezuela (Boliv. Rep. of)	32.55	24	41.4	16.00	37.443	67
Malaysia	4.91	48.5	43.6	5.33	38.412	68
Philippines	9.45	28.5	59.2	17.33	38.823	69
Namibia	31.09	28.5	33.2	26.00	39.485	70
Senegal	10.36	40.5	36.8	26.00	40.222	71
Mauritius	12.36	60.5	20.6	11.33	40.697	72
Nepal	9.82	38.5	49.6	18.00	40.747	73
Botswana	41.64	27	33.4	23.33	41.059	74
Guatemala	24.18	4	92	15.33	41.244	75
Gambia	35.64	25.5	35	32.00	41.691	76
Sri Lanka	9.64	65.5	26.2	4.67	41.987	77
Cambodia	8.73	48	43.8	16.67	42.614	78
Libya	15.27	40.5	59.6	7.33	43.157	79
Lao PDR	8.55	36.5	52	28.67	43.309	80
Myanmar	6.91	37	53.4	28.00	43.311	81
Kenya	50.55	24.5	35.2	24.67	43.366	82
Solomon Islands	34.55	28	57.2	12.67	43.698	83
Malawi	32.36	11.5	70.4	28.00	44.046	84
Cameroon	11.64	21.5	57.8	46.67	44.338	85
Togo	31.64	23.5	44.4	42.00	45.432	86
Rwanda	57.45	5.5	66.2	26.00	46.512	87

Country	Undernourishment	Child wasting	Child stunting	Child mortality	GHI Score	Rank
Tanzania (United Rep. of)	42.73	16.5	60	31.33	47.036	88
Uganda	57.45	18	50.8	28.00	48.088	89
Indonesia	10.73	51	61.6	14.67	49.412	90
Zimbabwe	69.82	14.5	47	33.33	50.362	91
Korea (DPR)	82.73	30.5	33.6	10.00	50.424	92
Bangladesh	20.36	55	47.2	18.00	50.517	93
Côte d'Ivoire	14.00	42	46.8	50.00	51.966	94
Benin	18.00	25	64.4	56.00	52.461	95
Haiti	81.82	19.5	38.2	39.33	55.078	96
Djibouti	30.55	53	41.8	36.00	56.052	97
Angola	39.27	30	58.8	46.00	56.120	98
Comoros	24.55	49.5	57.2	33.33	56.700	99
Zambia	54.18	21	69.2	38.67	57.264	100
Congo (Republic of)	60.55	39	48	28.67	57.882	101
Ethiopia	39.82	34	73.6	31.33	58.365	102
Mauritania	15.82	68	50.2	26.67	58.606	103
Syrian Arab Republic	50.55	54	54	14.67	59.678	104
Liberia	69.82	17	59.6	50.67	60.395	105
Pakistan	33.64	35.5	75.2	42.00	60.897	106
Burkina Faso	29.45	50.5	44.2	55.33	60.956	107
Mozambique	55.45	19.5	75	46.67	61.037	108
Papua New Guinea	42.55	35.5	80.4	28.67	61.124	109
Afghanistan	54.73	18.5	89.4	37.33	62.069	110
Mali	23.27	53	43.6	64.67	62.883	111
Lesotho	83.64	10.5	69.2	48.67	63.678	112
Nigeria	28.91	32.5	63	74.00	63.762	113
Sierra Leone	50.55	31.5	52.6	70.00	65.059	114
Guinea	23.45	46	60.6	66.00	65.328	115
Guinea-Bissau	68.91	32	55.8	49.33	65.436	116
Timor-Leste	40.55	41.5	93.4	34.00	68.826	117
Sudan	21.64	68.5	77	36.67	71.579	118
Chad	57.09	41.5	56	71.33	72.896	119
Dem. Rep. of the Congo	64.18	32	83.6	52.67	73.577	120
India	30.18	93.5	71	20.67	78.914	121
Madagascar	92.73	36	79.6	44.00	79.706	122
Central African Republic	88.55	26.5	80	66.67	80.900	123
Niger	29.27	54.5	95.4	76.67	84.594	124
Yemen	62.73	72	97.4	41.33	92.355	125

CONCLUSIONS:

The conclusions of the Global Hunger Index (GHI) calculation method using the Principal Component Analysis (PCA) method are somewhat similar to the factor analysis method. In this method, a country ranked 1 is least affected by hunger, while a country ranked 125 faces the most severe hunger-related issues.

From the analysis, we observe that Chile, Croatia, Estonia, Latvia, and Georgia are the top 5 countries. These countries have managed to achieve low GHI scores due to effective policies in food security, healthcare, and social welfare. They have robust agricultural systems, comprehensive child nutrition programs, and high standards of healthcare, which have collectively contributed to their strong performance in the GHI. They have also maintained resilient economies and implemented widespread education and social protection programs, ensuring food security and nutritional well-being for their populations.

On the other hand, India, Madagascar, the Central African Republic, Niger, and Yemen are the bottom five countries. These countries face severe hunger-related issues due to a combination of factors such as political instability, poor agricultural practices, lack of access to healthcare, and high levels of poverty. For example, Yemen's prolonged conflict has severely disrupted its food supply chains, leading to widespread hunger and malnutrition. Madagascar suffers from food insecurity caused by poor agricultural practices and frequent natural disasters. The Central African Republic faces political instability and conflict disrupting food supply, while Niger struggles with high levels of poverty and inadequate healthcare. India's high GHI is due to undernourishment, child wasting, child stunting, and child mortality.

REMEDIES FOR BOTTOM FIVE COUNTRIES:

India: Implement targeted nutrition programs, improve healthcare access, and enhance agricultural productivity.

Madagascar: Invest in resilient agricultural techniques and disaster management strategies.

Central African Republic: Focus on peace-building initiatives and rebuilding food supply chains.

Niger: Develop comprehensive poverty alleviation programs and improve healthcare infrastructure.

Yemen: Promote peace, rebuild infrastructure, and ensure humanitarian aid reaches those in need.

From the above analysis, we observe that the GHI score for India is 121, placing it among the bottom five countries. This indicates that India needs to take effective steps to improve its current situation by significantly decreasing the four factors or variables used for GHI calculation: undernourishment, child wasting, child stunting, and child mortality. Despite India's economic growth, the high GHI score reflects persistent issues in nutritional deficiencies and child health that require urgent attention. Government initiatives focusing on improving food security, healthcare, and child nutrition are crucial to addressing these challenges and improving India's rank in the Global Hunger Index.

VALIDITY AND ROBUSTNESS:

The internal consistency of the Global Hunger Index was tested by Cronbach's alpha coefficient to judge the internal consistency of the variables.

Cronbach's Alpha - Cronbach's alpha coefficient measures the internal consistency, or reliability, of a set of survey items. Analysts frequently use Cronbach's alpha when designing and testing a new survey or assessment instrument. The Cronbach's Alpha ranges between 0 and 1. The higher value for Cronbach's Alpha (≥ 0.7)means more reliable the group of data is.

R Output of Cronbach's alpha for Principal component method is:

```
Cronbach's alpha for the 'PC' data-set

Items: 6
Sample units: 125
alpha: 0.923
```

Since, alpha is greater than 0.70 thus, we conclude that Principal component method for GHI calculation is reliable.

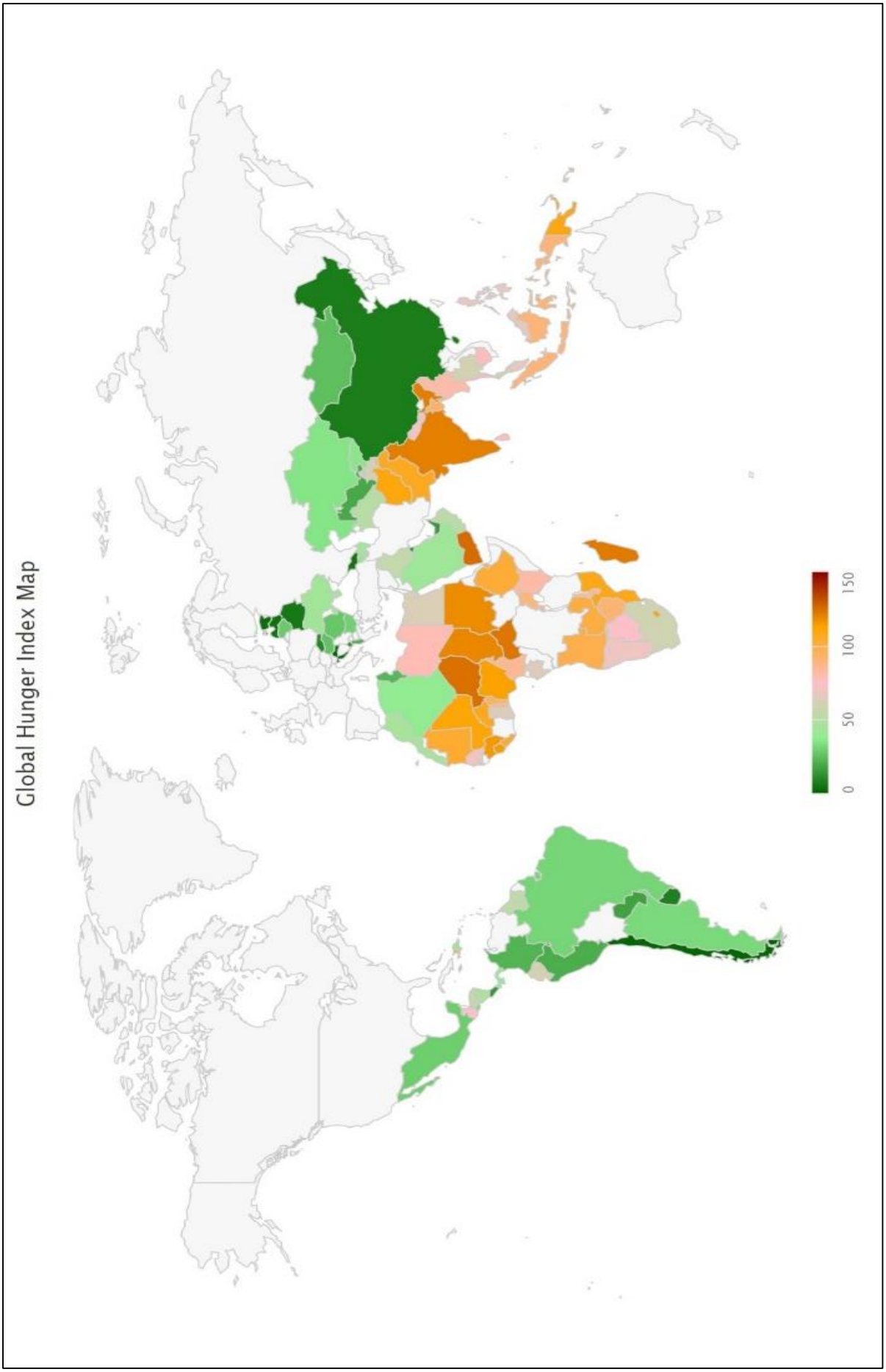


Figure 9: Global map of GHI ranking using PCA method

MULTIPLE LINEAR REGRESSION:

To derive a formula for the final score of the Global Hunger Index (GHI), we employed multiple linear regression. In this model, undernourishment, child wasting, child stunting, and child mortality are the independent variables (predictors), while the response variable is the final score of the Global Hunger Index (GHI score). For fitting the multiple linear regression model, we used the original data without standardization and the GHI score using the factor analysis method to obtain an equation for determining the GHI score.

The data used is as follows:

Country	Undernourishment	Child wasting	Child stunting	Child mortality	Score
Afghanistan	30.1	3.70	44.70	5.6	51.07
Albania	4.1	1.60	11.30	0.9	11.14
Algeria	2.5	2.70	9.80	2.2	13.12
Angola	21.6	6.00	29.40	6.9	44.25
Argentina	3.2	2.70	12.30	0.7	12.22
Armenia	2.5	3.30	10.90	1.1	12.59
Azerbaijan	2.5	3.60	12.00	1.9	14.83
Bangladesh	11.2	11.00	23.60	2.7	35.45
Belarus	2.5	1.90	3.40	0.3	5.79
Benin	9.9	5.00	32.20	8.4	41.07

Here,

- Y =GHI score
- X1 = Undernourishment
- X2 = Child wasting
- X3 = Child Stunting
- X4 = Child mortality

The mathematical equation of GHI score based on standardized vales of undernourishment, child wasting, child stunting and child mortality is given by,

$$\boldsymbol{y = 4.225e - 06 + 0.4520 * x_1 + 1.243 * x_2 + 0.4972 * x_3 + 1.657 * x_4}$$

ESTIMATION:

Using fitted multiple regression, we can estimate GHI score for any country if we have the estimates of all four variables i.e. undernourishment, child wasting, child stunting and child mortality. If we have sufficient data for time series forecasting for each variable we can forecast values for all Variables, that can be used to estimate GHI of country.

TREE METHOD:

We have already discussed earlier that some countries are excluded from the analysis due to unavailability of data. However, we can solve this problem if we have known values for some variables, even if not all. Based on these values, we can predict the mean GHI score for that country, which can be helpful in understanding the current situation of that particular country with regard to hunger-related problems.

Here, we have used the regression tree method on the original dataset of the world to predict the mean GHI score of countries. The regression tree output and tree obtained using R is as follows:

```
Regression tree:

tree(formula = Score ~ Undernourishment + Child_wasting +
       Child_stunting + Child_mortality, data = lm.data)

Variables actually used in tree construction:
[1] "Child_stunting"   "Undernourishment" "Child_mortality"

Number of terminal nodes:  7
Residual mean deviance:  23.81 = 2810 / 118
Distribution of residuals:
     Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
-11.88000  -3.35800  -0.07327   0.00000   2.68300  12.06000
```

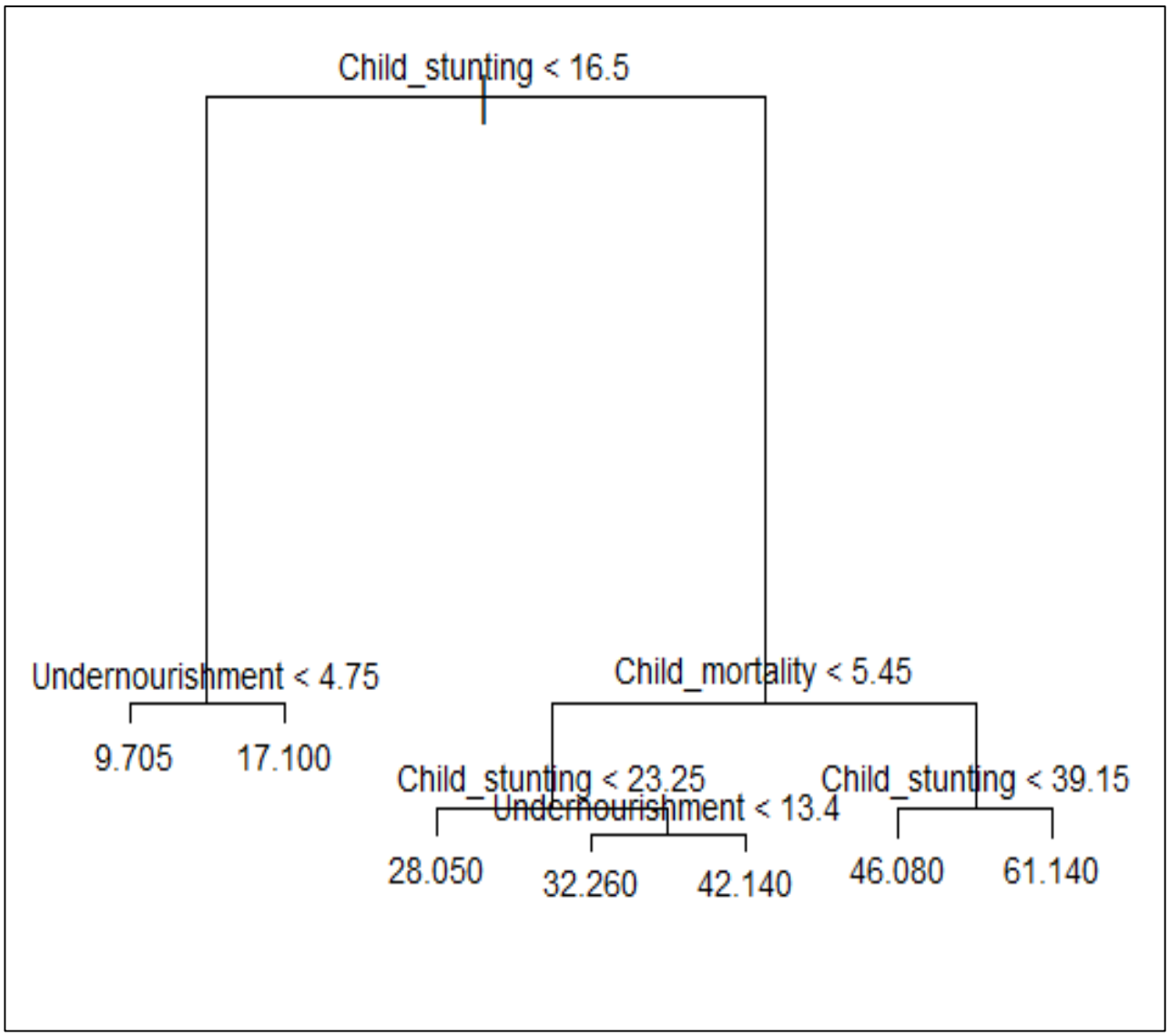


Figure 10: Tree Diagram for mean GHI score

INTERPRETATION:

1. Root Node (Top Node):
   - Decision starts at Child stunting < 16.5.
   - Tree splits based on whether Child stunting is less than 16.5 or not.
2. Left Branch (Child stunting < 16.5):
   - If Child stunting < 16.5, next decision is Undernourishment <4.75
   - If Undernourishment < 4.75, mean GHI Score = 9.705.
   - If Undernourishment >= 4.75, mean GHI Score = 17.100.
3. Right Branch (Child stunting >= 16.5):
   - If Child stunting >= 16.5, next decision is Child mortality <5.45.

- If Child mortality < 5.45, next decision is Child stunting <23.25.
- If Child stunting < 23.25, mean GHI Score = 28.050.
- If Child stunting >= 23.25:
- If Undernourishment < 13.4, mean GHI Score = 32.260.
- If Undernourishment >= 13.4, mean GHI Score = 42.14.

4. If Child mortality >= 5.45, next decision is Child stunting < 39.15.
   - If Child stunting < 39.15, mean GHI Score = 46.08.
   - If Child stunting >= 39.15, mean GHI Score = 61.140

To understand the use of the tree, we can consider the case of Bhutan, which is excluded from the analysis because data on undernourishment is not available. The values for the other variables are: Child stunting = 18.3, Child wasting = 2.6, and Child mortality = 2.7. Thus, using the fitted regression tree, we conclude that the mean GHI score for Bhutan is 28.05.

RELATION BETWEEN GNI PER CAPITA AND GHI SCORE:

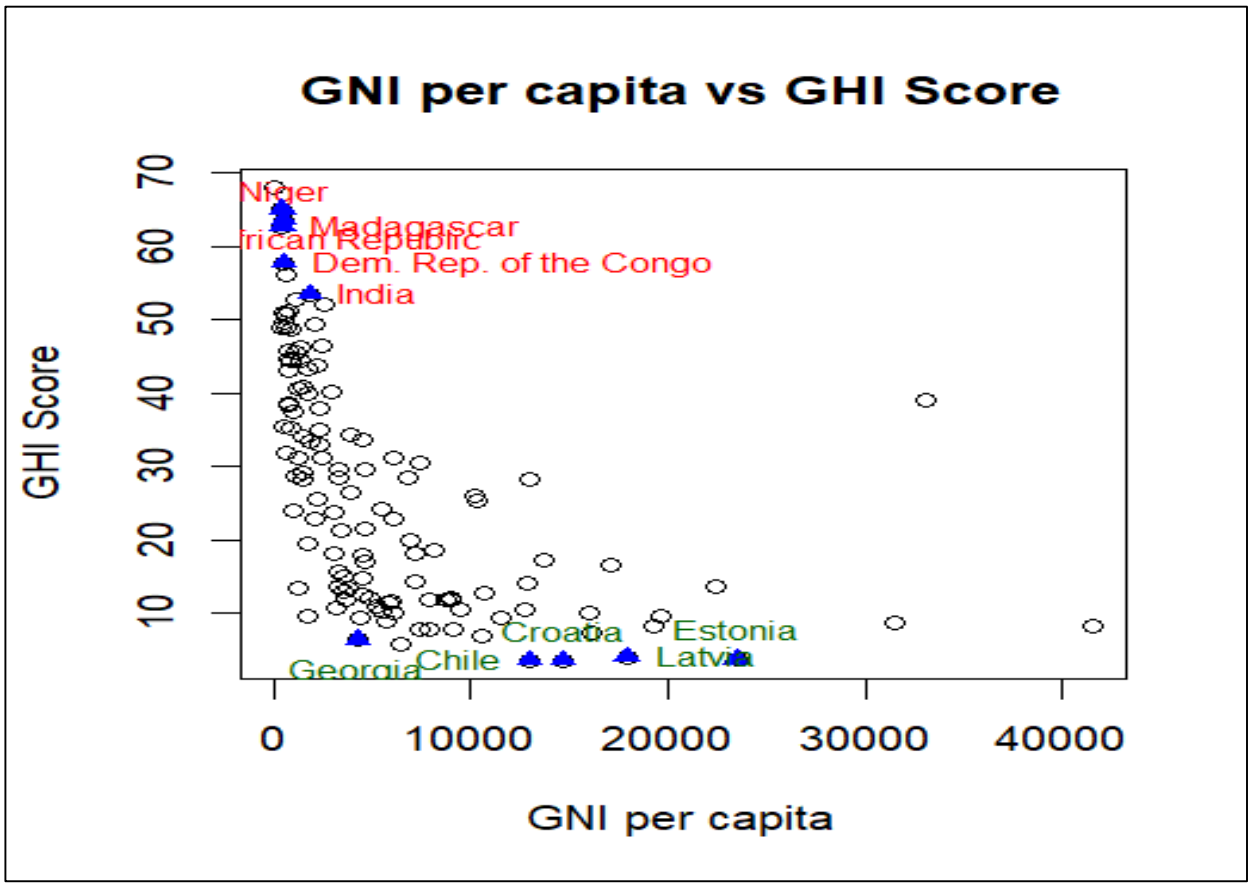


Figure 11: Scatter plot of GNI per capita vs GHI Score

The plot "GNI per capita vs GHI Score" show the relationship between Gross National Income (GNI) per capita and Global Hunger Index (GHI) scores for various countries. Generally, the plot reveals an inverse relationship, where countries with higher GNI per capita tend to have lower GHI scores, indicating fewer hunger issues. Most countries with a GNI per capita below 10,000 USD exhibit a wide range of GHI scores, often clustering at higher GHI levels. This suggests that economic wealth significantly impacts hunger levels, with poorer countries typically experiencing more severe hunger. However, some countries defy this trend by having low GHI scores despite low GNI per capita, likely due to effective social programs, agricultural productivity, and international aid. Conversely, a few countries with higher GNI per capita still face high GHI scores, potentially due to economic inequality, poor governance, and other systemic issues.

The highlighted countries illustrate these trends in more detail. For instance, countries highlighted with red: Niger, India, Madagascar, the Central African Republic, and the Democratic Republic of the Congo, despite having low GNI per capita, have very high GHI scores, indicating severe hunger issues primarily driven by chronic poverty, political instability, and frequent natural disasters. On the other hand, countries highlighted with green: Georgia, Chile, Croatia, Estonia, and Latvia, which have low GHI scores despite varying levels of GNI per capita, benefit from effective social welfare programs, stable political environments, and robust agricultural sectors, helping to mitigate hunger and food insecurity. These examples emphasize the multifaceted nature of hunger, influenced by economic, social, and political factors.

Some reasons for countries: Niger, Madagascar, India, the Central African Republic, and the Democratic Republic of the Congo to have low GHI score are as follow,

- **Niger**: Chronic poverty, frequent droughts, limited access to healthcare, and high population growth contribute to food insecurity.
- **Madagascar**: Recurrent natural disasters like cyclones and droughts, political instability, and poverty severely impact food production and security.
- **Central African Republic**: Ongoing conflict and instability have devastated the economy and agricultural sector, leading to high levels of food insecurity.

- **Democratic Republic of the Congo**: Prolonged conflict, poor governance, and lack of infrastructure severely affect food security despite the country's rich natural resources.
- **India**: Significant regional disparities in wealth and food security, rapid population growth, poverty, and issues in food distribution systems contribute to persistent hunger problems.

On the other hand, countries: Georgia, Chile, Croatia, Estonia, and Latvia had maintained their GHI score due to favourable demography, better economic conditions and good agriculture practices, etc.

CHAPTER 9: HUNGER IN INDIA

We have analysed global hunger statistics and observed that **India is ranked 121st** in the Global Hunger Index (GHI). This necessitates a thorough investigation into the factors contributing to India's high GHI ranking. To this end, we will conduct an in-depth examination of the hunger situation across various states in India. Our objective is to identify the underlying reasons for India's elevated GHI score by exploring the status of hunger within the country.

DATASET:

States/UTs	Children under 5 years who are underweight	Children under 5 years who are wasted	Children under 5 years who are stunted	Under-five mortality rate
India	32.110	19.260	35.470	41.860
Andaman & Nicobar Islands	23.650	15.990	22.470	24.540
Andhra Pradesh	29.630	16.060	31.160	35.190
Arunachal Pradesh	15.410	13.080	27.980	18.820
Assam	32.780	21.730	35.290	39.120
Bihar	41.030	22.890	42.940	56.440
Chandigarh	20.560	8.410	25.300	*
Chhattisgarh	31.330	18.880	34.600	50.400
Dadra and Nagar Haveli & Daman and Diu	38.700	21.590	39.420	36.990
Goa	24.000	19.120	25.770	10.600
Gujarat	39.680	25.100	39.020	37.640
Haryana	21.450	11.530	27.490	38.710
Himachal Pradesh	25.500	17.390	30.840	28.940
Jammu & Kashmir	20.970	18.980	26.860	18.530
Jharkhand	39.400	22.410	39.580	45.440
Karnataka	32.940	19.520	35.430	29.510
Kerala	19.670	15.750	23.410	5.190
Ladakh	20.360	17.460	30.530	29.540
Lakshadweep	25.780	17.350	32.020	0.010
Madhya Pradesh	33.000	18.950	35.670	49.200
Maharastra	36.120	25.600	35.240	28.030
Manipur	13.320	9.940	23.430	30.030
Meghalaya	26.640	12.100	46.540	39.960
Mizoram	12.660	9.780	28.860	24.040
Nagaland	26.880	19.140	32.710	33.030
NCT of Delhi	21.820	11.240	30.870	30.640
Odisha	29.690	18.060	31.010	41.080
Puducherry	15.290	12.350	19.980	3.900

Punjab	16.920	10.570	24.490	32.740
Rajasthan	27.610	16.770	31.780	37.550
Sikkim	13.130	13.650	22.330	11.180
Tamil Nadu	21.960	14.610	25.040	22.310
Telangana	31.820	21.700	33.120	29.390
Tripura	25.600	18.210	32.300	43.280
Uttar Pradesh	32.140	17.320	39.710	59.840
Uttarakhand	20.950	13.180	27.040	45.550
West Bengal	32.210	20.330	33.780	25.350

Note: In our study, we have excluded the state of Chandigarh due to the unavailability of data for one of the four key indicators of the Hunger Index, namely child mortality.

To gain a comprehensive understanding and derive meaningful insights from this data, we will conduct Exploratory Data Analysis (EDA) and obtain descriptive statistics. This approach will allow us to uncover patterns, identify anomalies, and summarize the key characteristics of the data, providing a solid foundation for further analysis.

DISCRIPTIVE STATISTICS

State	Undernourishment	Child wasting	Child stunting	Child mortality
Length:35	Min.:12.66	Min.: 9.78	Min.:19.98	Min.:0.000915
Class :character	1st Qu.:20.96	1st Qu.:13.41	1st Qu.:26.95	1st Qu.:2.222914
Mode :character	Median :25.78	Median :17.39	Median :31.1	Median:2.804038
	Mean :26.29	Mean:17.10	Mean:31.39	Mean:2.857143
	3rd Qu.:32.17	3rd Qu.:19.33	3rd Qu.:35.27	3rd Qu.:3.618526
	Max.:41.03	Max.:25.60	Max.:46.54	Max.:5.476293

Interpretation:

The descriptive statistics reveal that the average undernourishment rate across states is approximately 26.29%, indicating that around a quarter of the population is undernourished. The median value, close to the mean, suggests a fairly symmetric distribution, though the wide range indicates significant

variability. Child wasting has a mean and median of about 17.10%, reflecting a relatively normal distribution, with most states having rates between 13.41% and 19.33%, although some states have significantly higher rates. The mean and median values for child stunting are around 31%, indicating that nearly one-third of children in many states suffer from stunting. The variability is substantial, with some states experiencing extremely high rates. The average child mortality rate is approximately 2.86, with the median closely aligned, indicating a consistent distribution. However, the spread shows that while many states cluster around the mean, there are outliers with significantly higher child mortality rates. These high mean values for undernourishment, child wasting, child stunting, and child mortality reflect serious public health challenges, contributing to India's high ranking in the Global Hunger Index. Some states perform better, but others face severe issues requiring targeted interventions to improve nutrition and health outcomes.

GRAPHICAL REPRESENTATION OF DATA

- Bar plot for Undernourishment (**Highest: Bihar**)

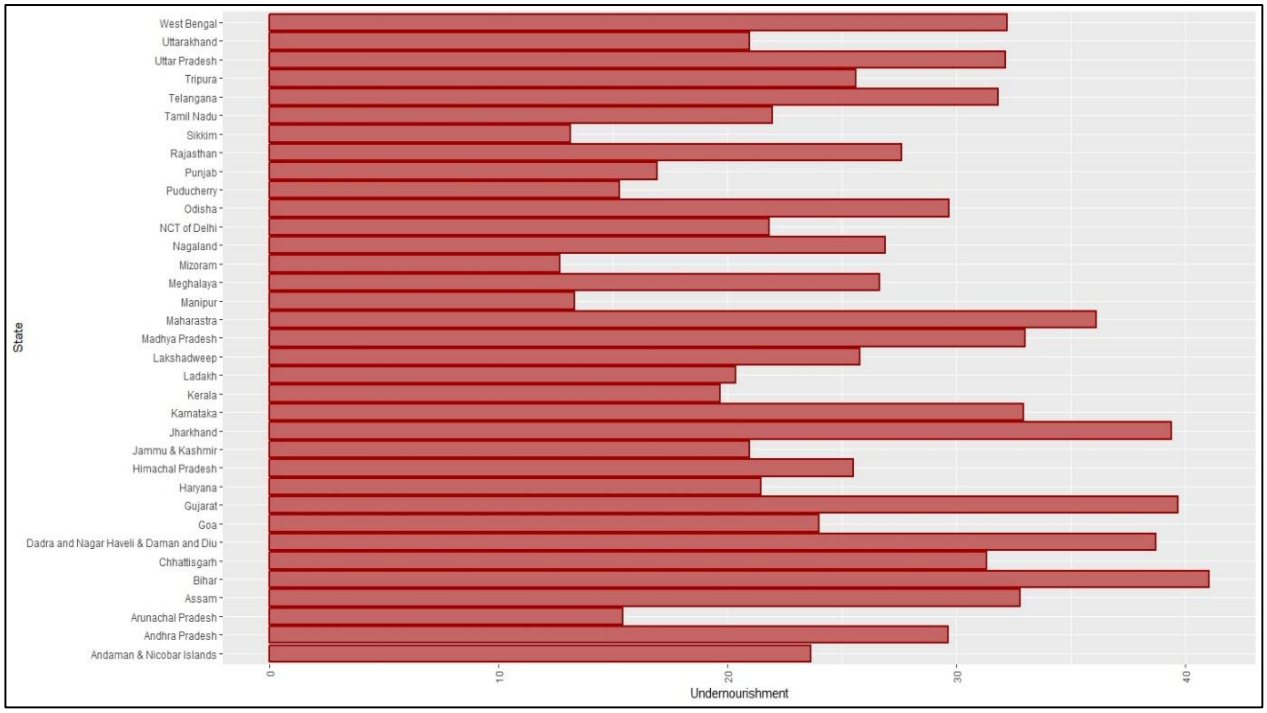


Figure 12: Undernourishment Indian States

- Bar plot for Wasting (**Highest: Maharashtra**)

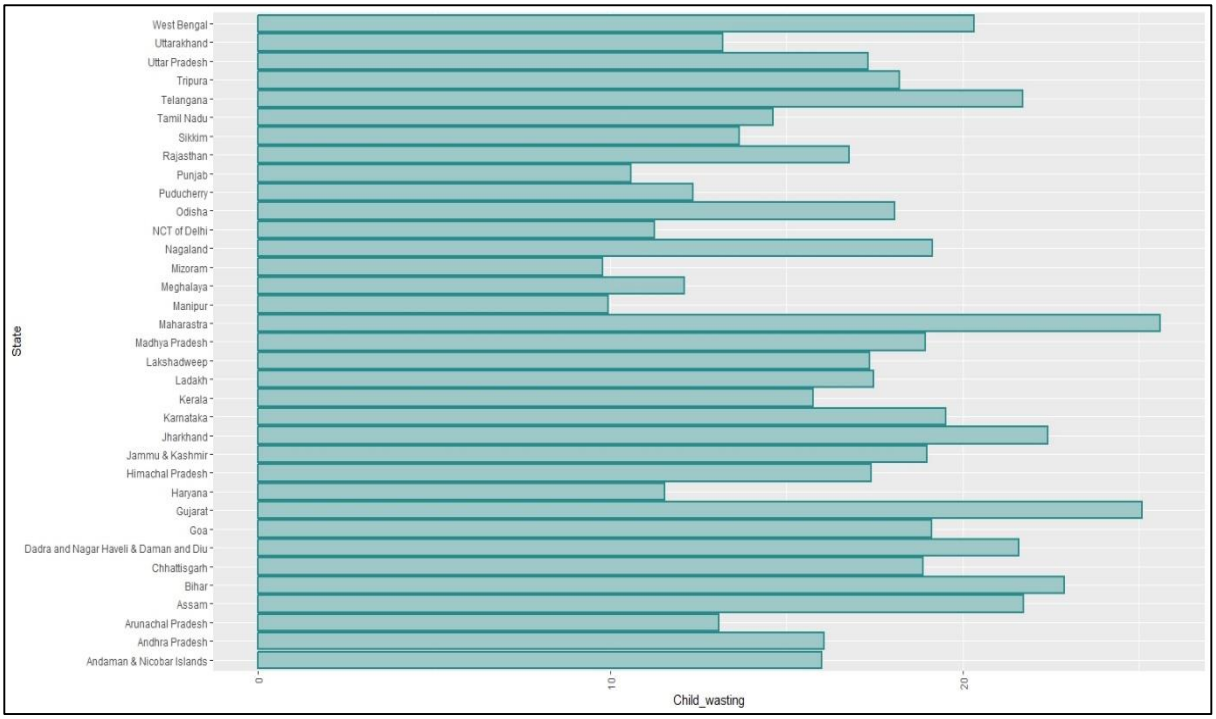


Figure 13: Wasting Indian States

- Bar plot for Stunting (**Highest: Meghalaya**)

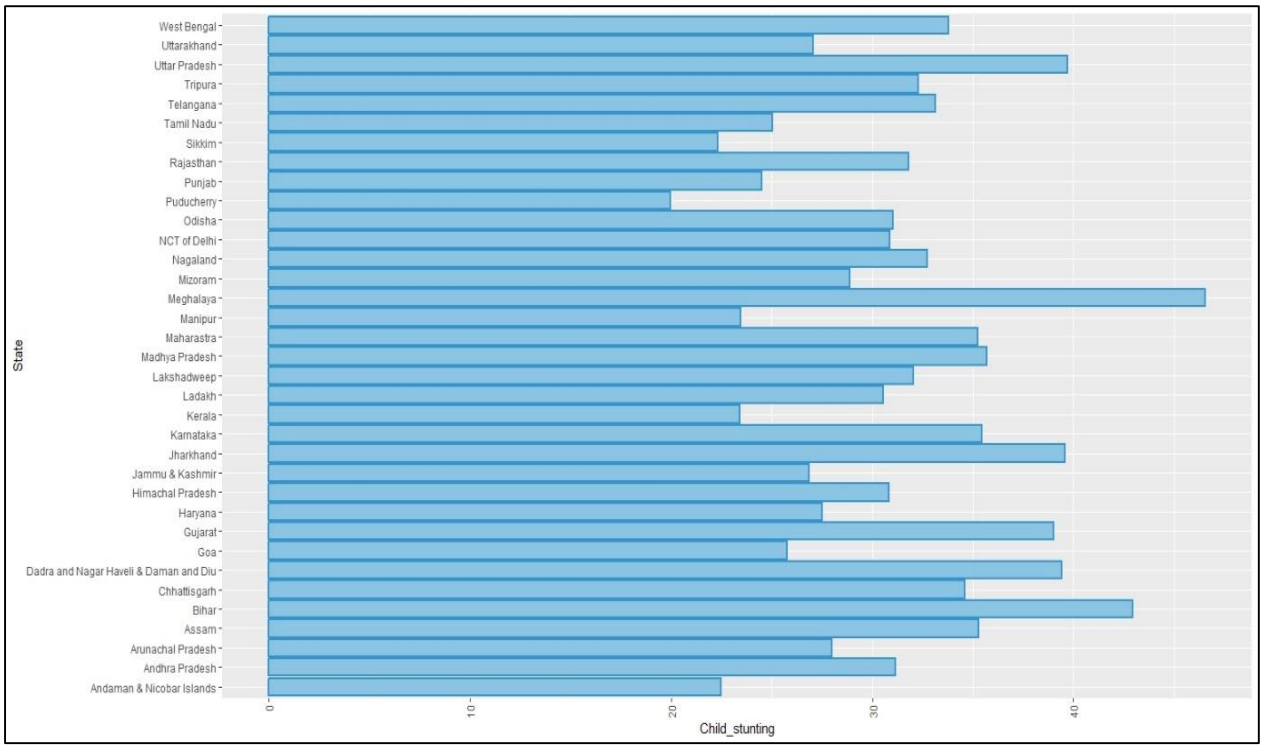


Figure14: Stunting Indian States

- Bar plot for Mortality **(Highest: Uttar Pradesh)**

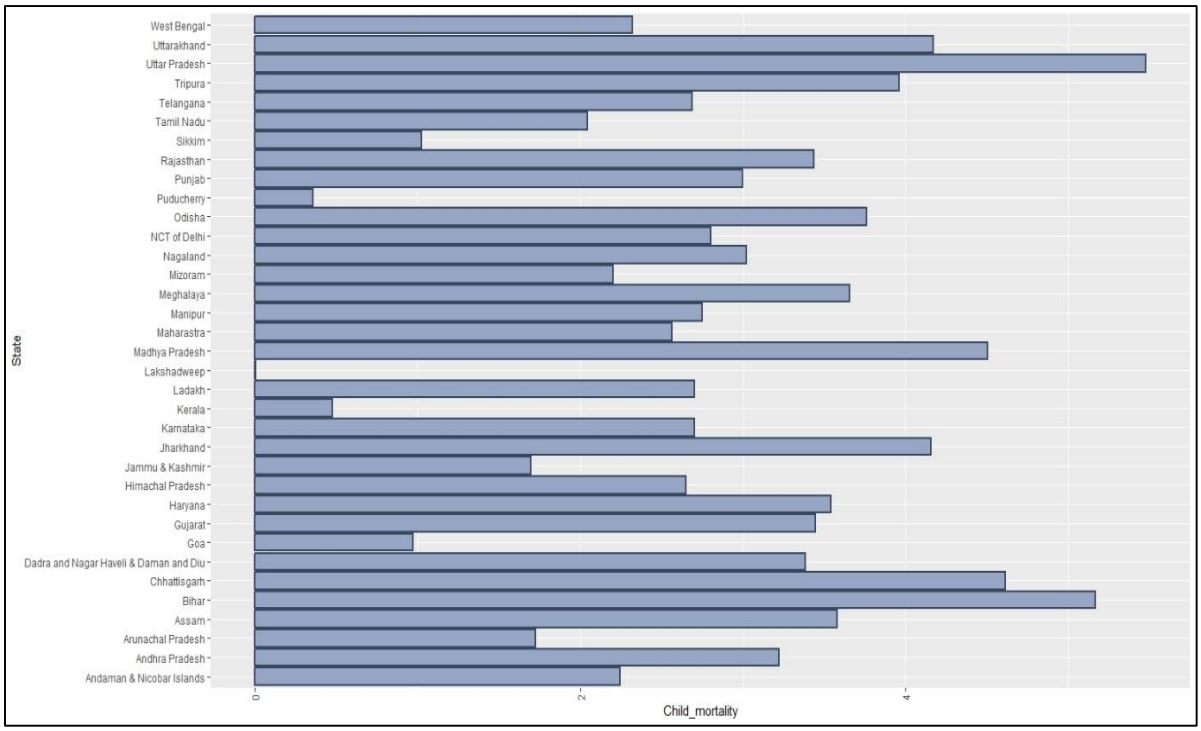


Figure15: Mortality Indian States

- **<u>Boxplot:</u>**

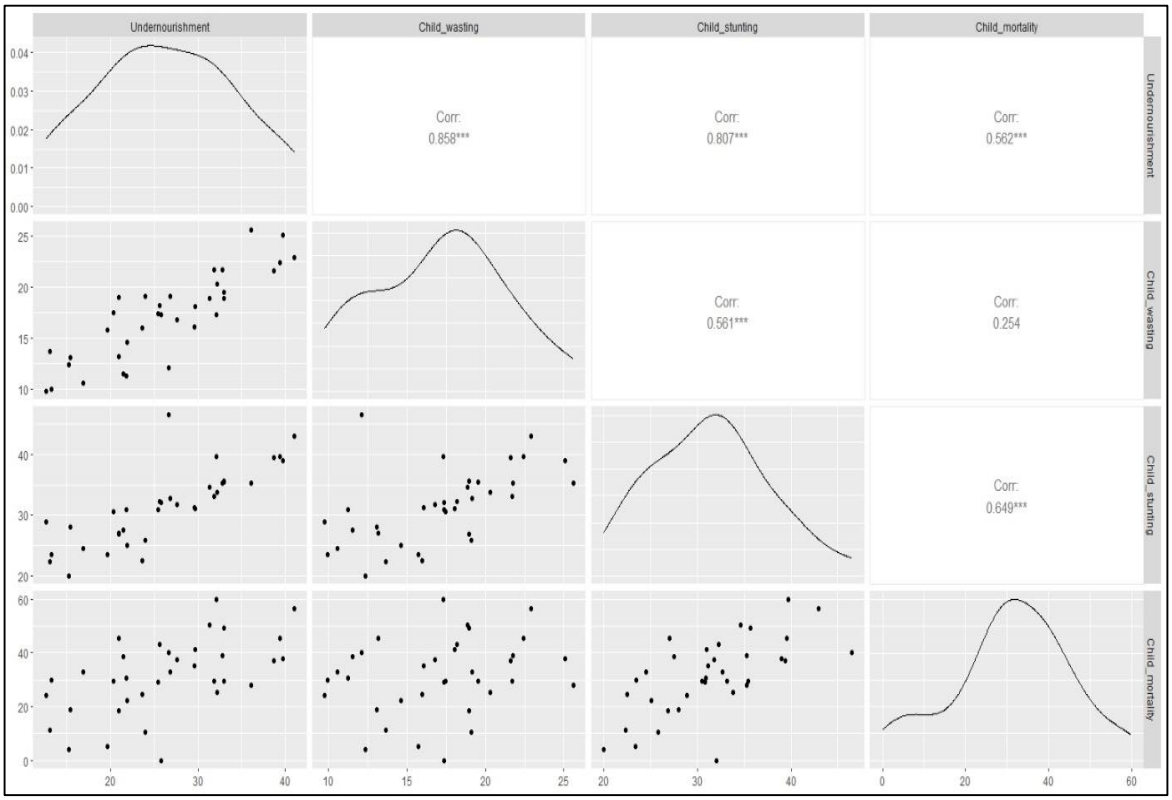


Figure 16: Boxplot

Interpretation:

The Pair plot for the indicators of the hunger index of Indian states reveals that most states have moderate levels of undernourishment, child wasting, child stunting, and child mortality, with fewer states showing extreme values. Undernourishment is strongly correlated with child wasting (0.850) and moderately with child stunting (0.691) and child mortality (0.524). Child stunting, which is more prevalent, has significant correlations with undernourishment (0.691) and child mortality (0.649). Child wasting, while related to undernourishment (0.850), has a weaker correlation with child mortality (0.254). These findings indicate that states with higher undernourishment and stunting rates are likely to experience higher child mortality, highlighting the importance of comprehensive interventions addressing multiple aspects of hunger and malnutrition.

- **Boxplot:**

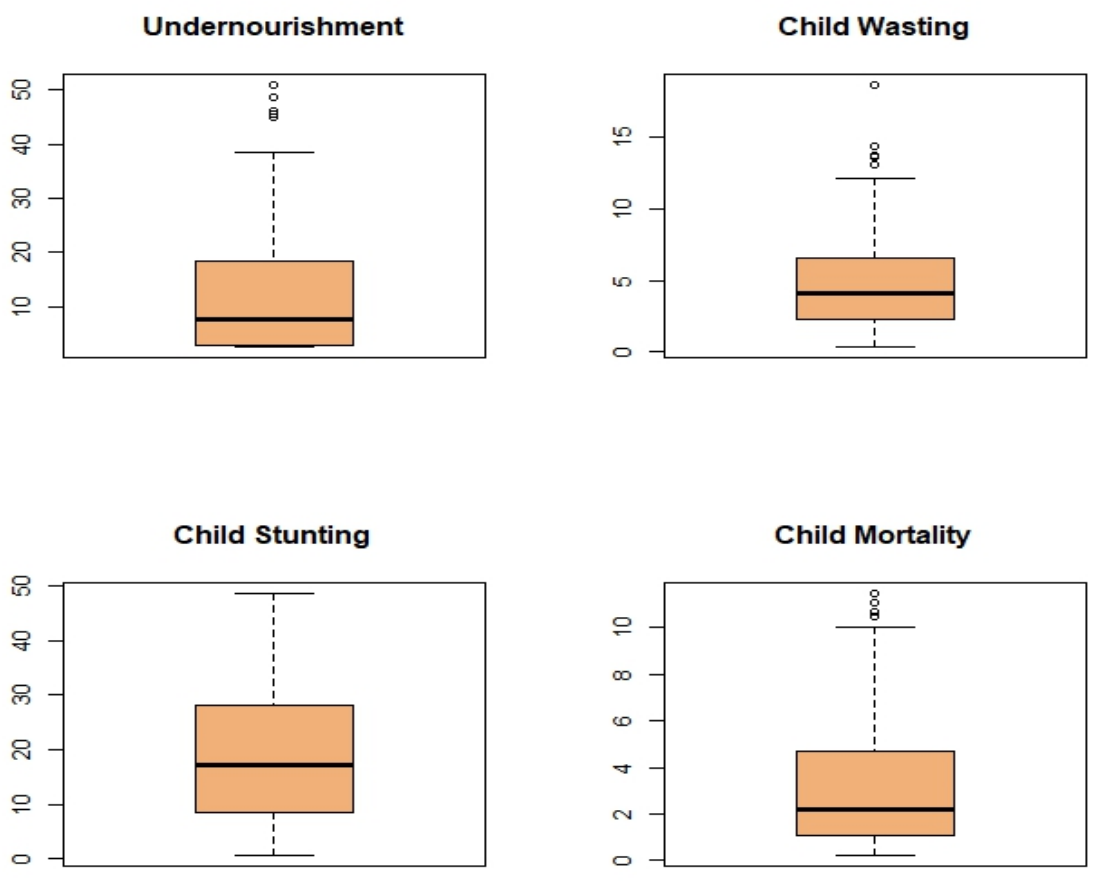


Figure17: Boxplot of

Interpretation:

The boxplots illustrate significant variability in hunger and nutrition indicators across Indian states. The median levels for undernourishment, child wasting, child stunting, and child mortality are around 20%, 7%, 30%, and 3%, respectively. Undernourishment and child stunting show a wider interquartile range and more substantial disparities, with several states exhibiting much higher values, especially above 40% and 50%, respectively. Child wasting and child mortality have lower medians and narrower ranges but still show notable outliers, indicating worse conditions in certain states. These disparities underscore the need for targeted interventions to address the uneven distribution of hunger and nutritional deficiencies among Indian states.

PRINCIPAL COMPONENT ANALYSIS METHOD:

As we have used the Principal Component analysis method to compute the GHI score, we will now apply the same method to calculate the Hunger Index for the states of India. This will provide more detailed insights into India's current situation regarding hunger levels. By following similar steps, we will determine the hunger index for each Indian state, which will help us understand regional disparities and identify areas with low hunger indices. This detailed analysis will be crucial for developing targeted interventions and policies to address hunger more effectively across different states.

Steps to develop Hunger index for Indian states using principal component method are as follows:

Step 1: Before calculating hunger, index data should be standardized. We use similar method for data standardization by using threshold frequency i.e. the integer value slightly greater than the highest value of respective parameters.

- Undernourishment has a threshold frequency 45 because its highest value is 41.03.
- Child Wasting has a threshold frequency 30 because its highest value is 25.60.
- Child Stunting has a threshold frequency 50 because its highest value is 46.54.
- Child Mortality has a threshold frequency 10 because its highest value is 5.47.

Thus, standardization is done as,

$$\frac{\text{Prevalence of undernourishment}}{45}\times 100 = \text{standardized undernourishment value}$$

$$\frac{\text{Child Wasting rate}}{30}\times 100 = \text{standardized child wasting value}$$

$$\frac{\text{Child Stunting rate}}{50}\times 100 = \text{standardized child Stunting value}$$

$$\frac{\text{Child mortality rate}}{10}\times 100 = \text{standardized child mortality value}$$

Step 2: We have already discussed the method of Principal Component Analysis (PCA) for computing the Global Hunger Index (GHI) score for countries. We will use the same method to compute the hunger index score for Indian states. We calculate four scores for each state using eigenvalues and sum these four scores to get the final hunger score for the Indian states. To compute the scores, we use R software and obtain the output as follows:

```
Rotation Matrix:
                           PC1        PC2          PC3        PC4
Std_Undernourishment 0.5678357 -0.2051808  0.06375884 -0.7946057
Std_Child_wasting    0.4734583 -0.6196862  0.33991432  0.5256277
Std_Child_stunting   0.5290332  0.1993391 -0.78151050  0.2638733
Std_Child_mortality  0.4165617  0.7308583  0.51926333  0.1506259

Importance of components:
                          PC1    PC2     PC3     PC4
Standard deviation     1.6968 0.8964 0.50891 0.24119
Proportion of Variance 0.7198 0.2009 0.06475 0.01454
Cumulative Proportion  0.7198 0.9207 0.98546 1.00000
```

Interpretations:

1. **Proportion of Variance:** This indicates the proportion of the total variance explained by each principal component. PC1 explains 71.98% of the variance, PC2 explains 20.09%, PC3 explains 6.47%, and PC4 explains 1.454%.

2. **The rotation matrix** indicates how much each original variable contributes to each principal component. Each value represents the correlation between the variable and the principal component.
   - PC1 has high positive loadings for all four variables, indicating that it is a combination of high undernourishment, child wasting, child stunting, and child mortality. It can be interpreted as a general measure of hunger severity.
   - PC2 contrasts child mortality and stunting against child wasting. High values of PC2 might indicate states with high child mortality and low child wasting rates, or vice versa.
   - PC3 primarily contrasts child stunting against child wasting and mortality, indicating that high values might represent states with high child stunting and lower values of wasting and mortality.
   - PC4 contrasts undernourishment against child wasting and mortality, suggesting that high values might represent states with high undernourishment and lower values of wasting and mortality.

3. **Biplot**: The first two principal components for the standardized data. The blue state names represent the scores for the first two principal components. The red arrows indicate the first two principal component loading vectors (with axes on the top and right).

Step 3: The four scores were summed to create one final score for each state. Thus, the final score i.e. GHI score is obtain as,

$$Final\ score = score1 + score2 + score3 + score4$$

The four score are computed to obtain final GHI score. For example,

$$score1 = (0.5678357 * Standardized\ Value\ of\ Undernourishment + 0.4734583 * Standardized\ Value\ of\ Child\ Wasting + 0.5290332 * Standardized\ Value\ of\ Child\ Stunting + 0.4165617 * Standardized\ Value\ of\ Child\ Mortality) * \left(\frac{0.7198}{0.7198 + 0.2009 + 0.06475 + 0.01454}\right)$$

Similarly, we can calculate score 2, score 3, score 4.

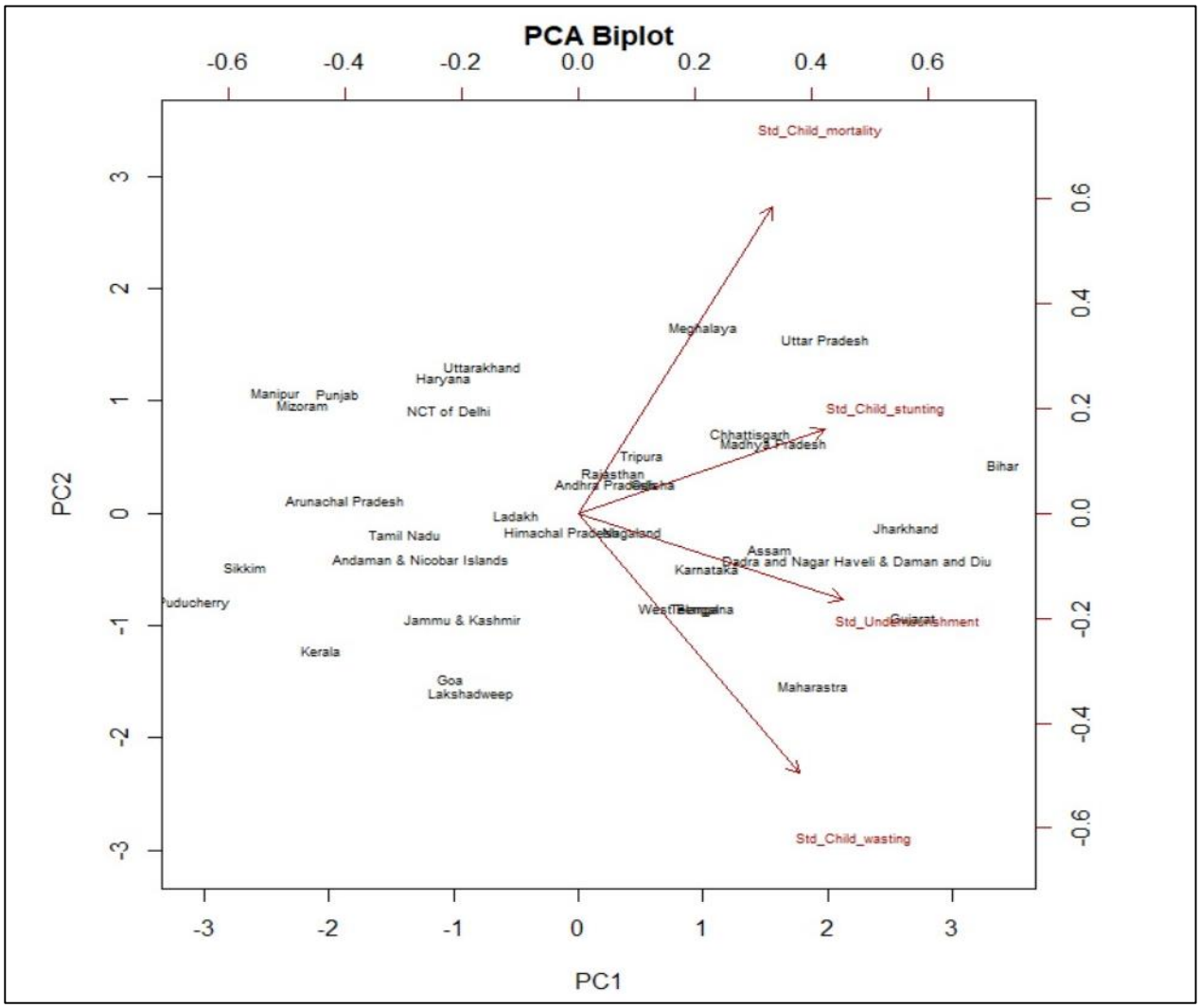


Figure 18 Biplot of first two principal component 1: Indian States

This is the final rank wise representation of 35 states as follows:

State	Undernourishment	Child wasting	Child stunting	Child mortality	Score	Rank
Puducherry	33.98	41.17	39.96	3.57	39.03	1
Sikkim	29.18	45.50	44.66	10.23	43.34	2
Kerala	43.71	52.50	46.82	4.75	48.46	3
Manipur	29.60	33.13	46.86	27.48	49.60	4
Mizoram	28.13	32.60	57.72	22.00	50.36	5
Arunachal Pradesh	34.24	43.60	55.96	17.22	52.30	6
Punjab	37.60	35.23	48.98	29.96	54.98	7
Tamil Nadu	48.80	48.70	50.08	20.42	58.14	8
Lakshadweep	57.29	57.83	64.04	0.01	58.81	9
Goa	53.33	63.73	51.54	9.70	58.84	10
Andaman & Nicobar Islands	52.56	53.30	44.94	22.46	59.68	11
Jammu & Kashmir	46.60	63.27	53.72	16.96	60.62	12
NCT of Delhi	48.49	37.47	61.74	28.04	63.30	13
Haryana	47.67	38.43	54.98	35.43	64.28	14
Ladakh	45.24	58.20	61.06	27.03	66.49	15
Uttarakhand	46.56	43.93	54.08	41.69	67.91	16
Himachal Pradesh	56.67	57.97	61.68	26.48	70.51	17
Andhra Pradesh	65.84	53.53	62.32	32.20	75.73	18
Rajasthan	61.36	55.90	63.56	34.36	76.20	19
Nagaland	59.73	63.80	65.42	30.23	76.26	20
Tripura	56.89	60.70	64.60	39.61	78.69	21
West Bengal	71.58	67.77	67.56	23.20	78.91	22
Odisha	65.98	60.20	62.02	37.59	79.90	23
Telangana	70.71	72.33	66.24	26.90	81.01	24
Karnataka	73.20	65.07	70.86	27.01	81.90	25
Meghalaya	59.20	40.33	93.08	36.57	83.70	26
Assam	72.84	72.43	70.58	35.80	87.72	27
Maharashtra	80.27	85.33	70.48	25.65	88.63	28
Chhattisgarh	69.62	62.93	69.20	46.12	88.69	29
Madhya Pradesh	73.33	63.17	71.34	45.03	90.35	30
Dadra and Nagar Haveli & Daman and Diu	86.00	71.97	78.84	33.85	94.49	31
Uttar Pradesh	71.42	57.73	79.42	54.76	96.05	32
Gujarat	88.18	83.67	78.04	34.45	98.14	33
Jharkhand	87.56	74.70	79.16	41.58	99.58	34
Bihar	91.18	76.30	85.88	51.65	108.65	35

CONCLUSIONS:

From the Global Hunger Index (GHI) using the factor analysis method, we obtain a GHI rank of 119 for India, indicating a severe condition. This can also be observed through the values of the variables: undernourishment, child wasting, child stunting, and child mortality across various states of India, which have significantly high values. This data shows that India is suffering from serious hunger-related issues.

The Hunger Index for Indian states, calculated using the factor analysis method, ranks 35 states from 1 to 35. A state ranked 1 is least affected by hunger, while a state ranked 35 faces the most severe hunger-related issues.

From the analysis, we observe that Puducherry, Sikkim, Kerala, Manipur and Mizoram are the top 5 states, we can also observe that these five states have less value for each variable as compare to other states that are more affected due to hunger, indicating that they have successfully addressed hunger-related issues by controlling the four factors considered in the study. The reasons behind these states having a low hunger index include:

- **Puducherry**: With its effective public distribution system and healthcare services, Puducherry has managed to maintain lower levels of undernourishment and child mortality.
- **Sikkim**: It is one of the most developed North-Eastern states of India, known for its organic farming and robust health and nutrition programs.
- **Manipur**: Despite its geographical challenges, Manipur has made significant strides in food security and child nutrition through various state-led initiatives.
- **Mizoram**: It has witnessed significant development and has a relatively effective healthcare system that ensures better child health outcomes.
- **Kerala**: It has consistently high levels of development, particularly in health, education, and social services, which contribute to low hunger levels.

These factors contribute to these states having low values for the variables considered in the Hunger Index calculation.

On the other hand, Dadra and Nagar Haveli and Daman and Diu, Uttar Pradesh, Gujarat, Jharkhand, and Bihar are the bottom five states, reflecting the most severe hunger situations compared to other states in India. These states have higher values for all the variables considered, highlighting the need for

significant efforts to improve their situations. The reasons behind these states having a high hunger index are:

- **Uttar Pradesh**: Despite being a developing state, it struggles with high levels of poverty and inadequate healthcare and nutrition services, leading to high rates of child malnutrition.
- **Dadar Nagar Haveli and Daman Diu**: These union territories face developmental challenges, with limited access to quality healthcare and nutrition, resulting in poor child health indicators.
- **Jharkhand**: This state is still underdeveloped, with significant issues related to poverty, tribal population marginalization, and lack of access to basic services.
- **Gujarat**: Although it is economically developed, there are disparities in wealth distribution, and the state faces challenges in addressing malnutrition and child health effectively.
- **Bihar**: Bihar remains one of the poorest states in India, with low levels of development and high levels of child undernutrition and mortality.

India needs to work extensively to improve the situation in each state by implementing various schemes to tackle hunger-related issues. These schemes should focus on improving healthcare infrastructure, ensuring food security, enhancing nutritional education, and addressing socio-economic disparities to achieve better outcomes.

To improve its Hunger Index, India should focus on states moderately or seriously affected by hunger-related issues by implementing targeted nutritional and healthcare programs. Strengthening the public distribution system to ensure food reaches the most vulnerable populations can help alleviate undernourishment. Additionally, enhancing maternal and child health services and investing in rural development initiatives can address the root causes of malnutrition. Collaborating with local governments to create state-specific strategies will ensure that interventions are tailored to the unique challenges of each region.

India's Hunger Index Using PCA Method

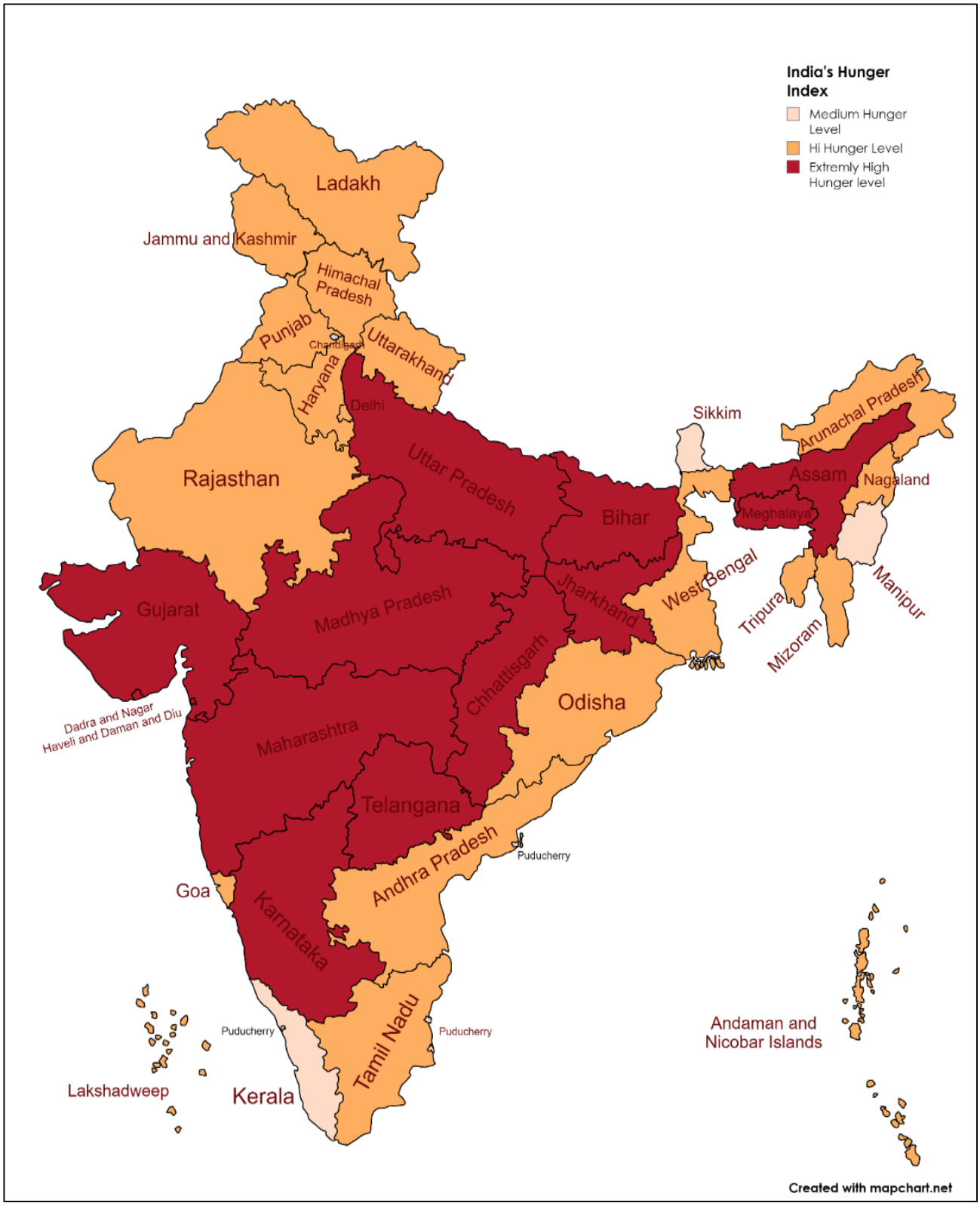


Figure 19: Hunger Index Ranking Indian States Using PCA Method

VALIDITY AND ROBUSTNESS:

The internal consistency of the Hunger Index of Indian states can also be tested by Cronbach's alpha coefficient to judge the internal consistency of the variables.

R Output of Cronbach's alpha for Principal component method is:

```
Cronbach's alpha for the 'PC' data-set

Items: 7
Sample units: 35
alpha: 0.888
```

Since, alpha is greater than 0.70 thus, we conclude that Principal component method for hunger index calculation for states is reliable.

MULTIPLE LINEAR REGRESSION FOR STATES

To derive a formula for the Hunger Index for Indian states, we employed multiple linear regression in the same way as we did for the Global Hunger Index. For fitting the multiple linear regression model, we used the original data without standardization and the hunger index score using the principal component analysis method to obtain an equation for determining the GHI score.

The data used is as follows:

State	Undernourishment	Child wasting	Child stunting	Child mortality	Score
Andaman & Nicobar Islands	23.65	15.99	22.47	2.25	59.68
Andhra Pradesh	29.63	16.06	31.16	3.22	75.73
Arunachal Pradesh	15.41	13.08	27.98	1.72	52.30
Assam	32.78	21.73	35.29	3.58	87.72
Bihar	41.03	22.89	42.94	5.17	108.65
Chhattisgarh	31.33	18.88	34.6	4.61	88.69
Dadra and Nagar Haveli & Daman and Diu	38.7	21.59	39.42	3.39	94.49
Goa	24	19.12	25.77	0.97	58.84
Gujarat	39.68	25.1	39.02	3.44	98.14
Haryana	21.45	11.53	27.49	3.54	64.28

Here,

- Y =GHI score
- X1 = Undernourishment
- X2 = Child wasting
- X3 = Child Stunting
- X4 = Child mortality

The mathematical equation of Hunger Index score of states based on standardized vales of undernourishment, child wasting, child stunting and child mortality is given by,

$$\boldsymbol{y = 2.691e - 05 + 0.8002 * x1 + 0.8198 * x2 + 0.7482 * x3 + 4.825 * x4}$$

TIME SERIES ANALYSIS OF UNDER-FIVE CHILD MORTALITY OF INDIA

Time series analysis can be used to forecast future values using past data, here we have obtained sufficient past data only for under five child mortality rate. We cannot perform time series analysis for rest of variables due to insufficient data.

Data of for under five child mortality rate is yearly from 1969 to 2020. So, forecasting time Series is the best option for the given data. Time series analysis of for under five child mortality rate is performed and forecasting is based on this is done using the ARIMA model.

This is the year wise data of under-five child mortality rate for year 1990 to 2021:

Year	Under-five Mortality rate	Year	Under-five Mortality rate
1969	201.9	1997	106
1970	191.6	1998	99.4
1971	215.4	1999	97
1972	225.1	2000	89.1
1973	178.8	2001	88.1
1976	211	2002	84.4
1977	209.7	2003	84.7
1978	197.5	2004	83.9
1980	179.4	2005	79.5
1982	164.1	2008	69
1983	161.7	2009	64
1986	168.3	2010	59

1987	154.9	2011	55
1988	147.5	2012	52
1989	133.7	2013	49
1990	119.2	2014	45
1991	120.1	2015	43
1992	120	2016	39
1993	108.4	2017	37
1994	109.1	2018	36
1995	110.5	2019	35
1996	109.1	2020	32

To study this data using time series analysis, first plot the time series to check for the presence of a trend. To check the stationarity of the time series, use the Dickey-Fuller test. The results are as follows:

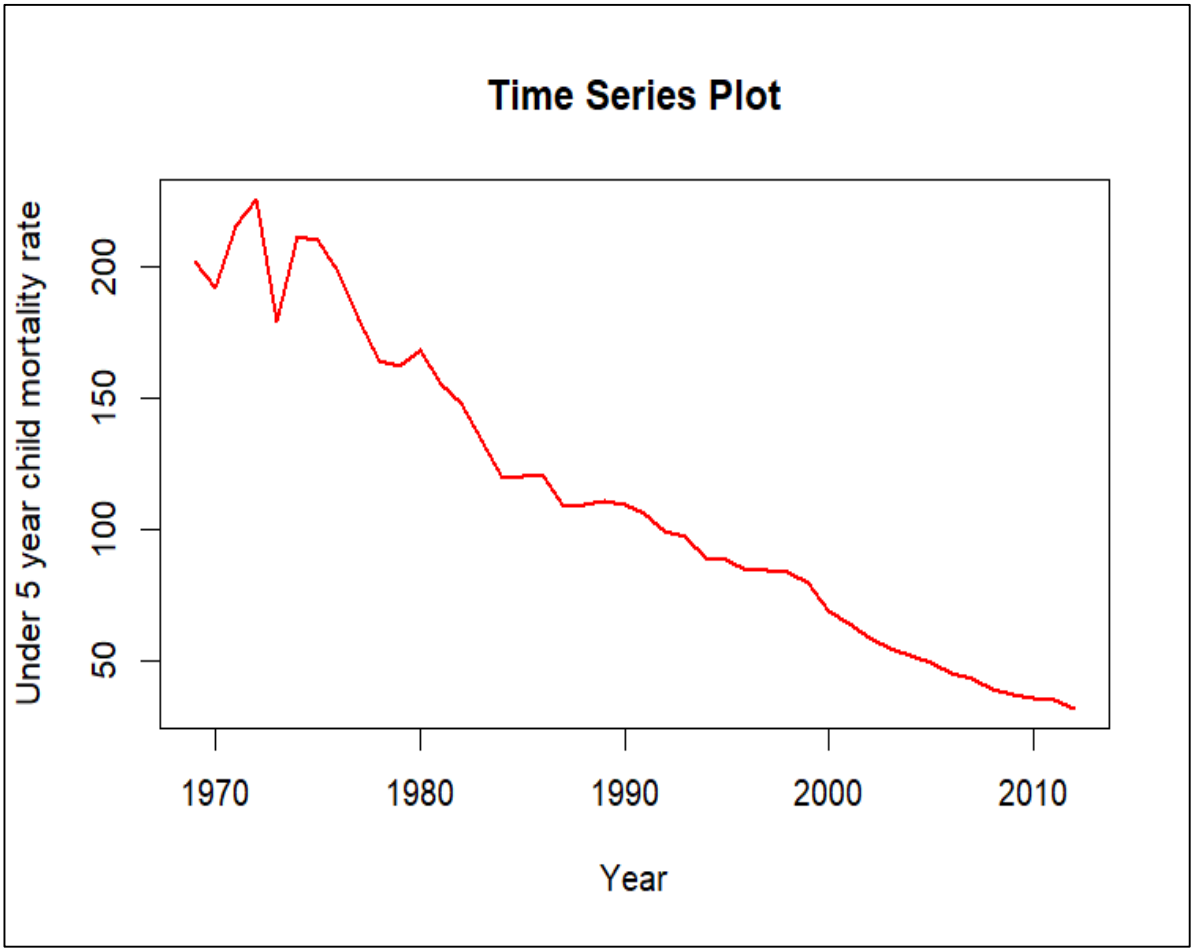


Figure 20: Time Series Plot for Under 5 child mortality

The time series plot shows the under-five child mortality rate over time, from the early 1970s to around 2010. Here is an interpretation of the plot. There is a clear downward trend in the under-five child mortality rate over the period shown. This indicates a significant decrease in child mortality rates over the years. Despite some fluctuations, the consistent downward trend is a positive indication of progress in reducing under-five child mortality rates.

Test of stationarity Dickey-Fuller test output:

```
Augmented Dickey-Fuller Test

data:  time_series
Dickey-Fuller = -1.3465, Lag order = 3, p-value = 0.8325
alternative hypothesis: stationary
```

The output of Dickey-Fuller test, gives the p-value is 0.8325, we fail to reject the null hypothesis that the time series has a unit root, which means it is non-stationary. There is insufficient evidence to suggest that the time series is stationary.

To obtain the forecasted values for under-five child mortality rate, fit ARIMA mode, fitted model series is obtaining as follows:

```
Series: time_series
ARIMA(0,1,1) with drift

Coefficients:
          ma1    drift
      -0.4863  -4.0782
s.e.   0.1445   0.8133

sigma^2 = 106.5:  log likelihood = -160.49
AIC=326.98   AICc=327.6   BIC=332.27
```

Interpretations:

The output presents the results of fitting an ARIMA(0,1,1) model with drift (i.e. MA (1) with drift) to a time series. This model specifies, one differencing step to make the series stationary, and one moving average term. The drift term is -4.0782 with a standard error of 0.8133, suggesting a consistent downward trend in the data by approximately 4.0782 units per time period. The model's residual

variance is 106.5, reflecting the dispersion of the residuals around zero. The log likelihood of the model is -160.49, which, along with the information criteria (AIC = 326.98, AICC = 327.6, BIC = 332.27), helps in comparing the goodness of fit with other models. Overall, the ARIMA (0,1,1) with drift model indicates a downward trend in the time series and fits the data well, as evidenced by the relatively low information criteria values.

This indicates that a substantial improvement in child health outcomes over the years, likely due to various factors such as improved healthcare, nutrition, sanitation, and overall socio-economic development.

Forecasted values of under-five year mortality rate for five years are as follows:

Year	Under-five year mortality
2021	26.16506
2022	22.0869
2023	18.00875
2024	13.93059
2025	9.852438

Forecast value plot is as follows:

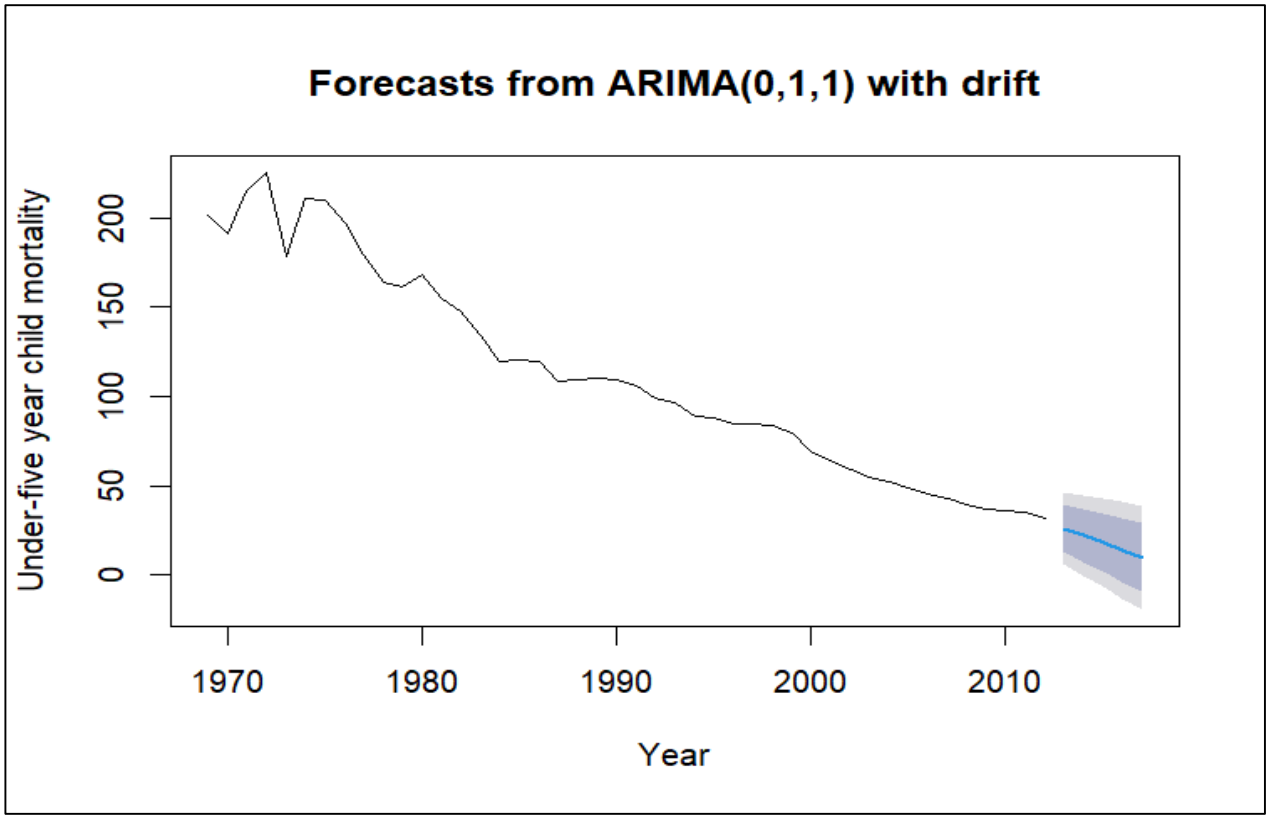


Figure 21: Forecasts value plot ARIMA (0,1,1)

CHAPTER 10: STEP TAKEN TO REDUCE HUNGER

STATUS OF HUNGER IN INDIA:

1. **THE NATIONAL FAMILY HEALTH SURVEY (NFHS-5):** ` The National Family Health Survey (NFHS-5) has shown improvement in stunting and waste and a significant reduction in Under-five Mortality Rate. As per the recent report of NFHS-5 (2019-21), the nutrition indicators for children under 5 years have improved as compared with NFHS-4 (2015-16). Stunting has reduced from 38.4% to 35.5%, Wasting has reduced from 21.0% to 19.3% and Underweight prevalence has reduced from 35.8% to 32.1%.

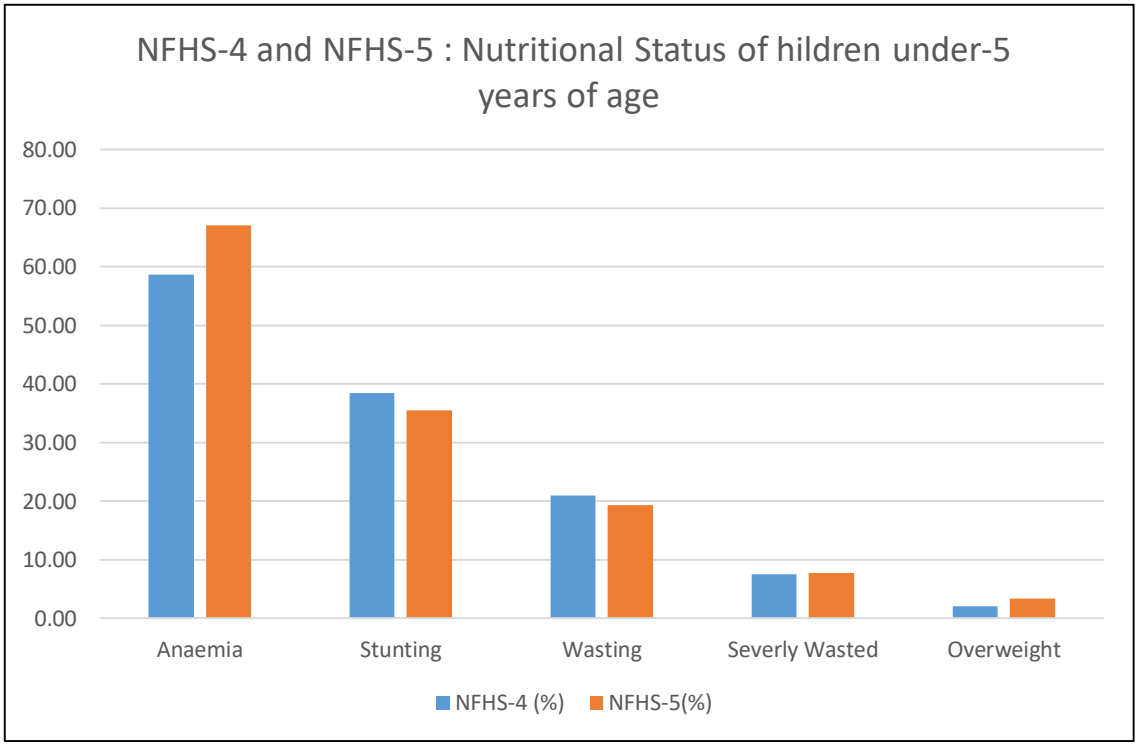


Figure 22

2. **THE STATE OF FOOD SECURITY AND NUTRITION IN THE WORLD (SOFI) REPORT 2023:** It is published jointly by five UN organisations i.e. the Food and Agriculture Organization of the United Nations, the International Fund for Agricultural Development, the United Nations Children's Fund, the World Food Programme and the World Health Organization. It also presents

worrisome estimates of widespread and worsening food insecurity in India. According to the SOFI report, India has the lowest cost of a healthy diet among BRICS nations and its neighbours. For instance, in India, a healthy diet costs 3.066 PPP dollars per person per day, the lowest among the countries considered. While food prices remain relatively low in India, a healthy diet is unaffordable to nearly three-fourth of the people given their low incomes. For instance, in India, 74% were not able to afford a healthy diet, the fourth highest share among the nations considered. Only countries like Nepal, Pakistan, Sierra Leone, Nigeria, Niger Burkina-Faso, Ghana, Liberia, Guinea and Guinea Bissau had a higher share of their respective populations than India which were not able to afford a healthy diet. The SOFI-2023 report also said 233.9 million (24 crore) people in India are 'undernourished'. (GNR 2021)

REASONS BEHIND INDIA'S PERSISTENT PROBLEM OF HUNGER:

1. **RISING POPULATION:** Despite, a major part of the Indian population is engaged in agricultural activities, the availability of food remains a challenge due to this increasing population of the country.

2. **CLIMATE CHANGE:** There is a persistent issue of climate change with erratic rainfall and increasing frequency of extreme events that have impacted agricultural activities everywhere, creating unfavourable conditions for food production. Climate variability affecting rainfall patterns and agricultural seasons, and climate extremes such as droughts and floods, are among the key drivers behind the rise in hunger, together with conflict and economic slowdowns.

3. **INEFFECTIVE IMPLEMENTATION POLICIES:** There is a poor implementation of the existing schemes and policies in India. For example, the Integrated Child Development Services (ICDS) and the National Health Mission (NHM) have not achieved adequate coverage. Apart from that, food wastage is also an emerging challenge that undermines the efforts to end hunger and malnutrition. According to the FAO, the global volume of food wastage is estimated at 1.6 billion tonnes of primary product equivalents.

4. **LACK OF AWARENESS:** There is a lack of awareness among the population of India about the existing programmes of the government. There is also issue of lack of education and training on new techniques, technologies and agricultural products which has led to less agriculture production. Traditional farming methods are slightly more time-consuming and delay the production of food grains, etc. The change from multi to mono cropping systems limits the diversity of agricultural products. Inclination towards cash crops and changing food habits result in malnutrition, undernutrition and even micro-nutrient deficiencies.

5. **MULTIDIMENSIONAL NATURE:** Hunger and the related undernutrition is the result of various associated factors ranging from water, sanitation, access to food items. A person's 'nutritional quotient' is also dependent on demographic factors like gender, caste, age, etc.

STEPS TAKEN BY INDIAN GOVERNMENT TO FIGHT HUNGER:

1. **NATIONAL FOOD SECURITY ACT 2013:** The National Food Security Act of 2013 aims to provide for food and nutritional security in the human life cycle approach by ensuring access to adequate quantities of quality food at affordable prices for people to live a life with dignity. The Act provides for coverage of up to 75% of the rural population and up to 50% of the urban population for receiving subsidized food grains under. Targeted Public Distribution System (TPDS), thus covering about two-thirds of the population. The eligible persons will be entitled to receive 5 Kgs of food grains per person per month at subsidised prices of Rs. 3/2/1 per Kg for rice/wheat/coarse grains.

2. **INTEGRATED CHILD DEVELOPMENT SERVICES (ICDS) SCHEME:** It provides for supplementary nutrition, immunization and pre-school education to the children is a popular flagship programme of the government. It was launched in 1975, it is one of the world's largest programmes providing for an integrated package of services for the holistic development of the child. ICDS is a centrally sponsored scheme implemented by state governments and union territories. The scheme is universal, covering all the districts of the country. The Scheme has been renamed as Anganwadi Services. The

services are now offered as part of the Saksham Anganwadi and Poshan 2.0 (Poshan 2.0)

3. **PRADHAN MANTRI MATRU VANDANA YOJANA:** Under-nutrition continues to adversely affect the majority of women in India. In India, every third woman is undernourished, and every second woman is anaemic. Pradhan Mantri Matru Vandana Yojana (PMMVY) is a Maternity Benefit Programme that is implemented in all the districts of the country. It is a Centrally Sponsored DBT scheme that provides a cash incentive of 5000/- to Pregnant Women and Lactating Mothers of 19 years of age or above for the first live birth. The incentive is paid in three instalments upon fulfilling certain health and nutrition conditions.

4. **INTEGRATED NUTRITIONAL SUPPORT PROGRAMME SAKSHAM ANGANWADI AND POSHAN 2.0:** It aims to address the problems of malnutrition in children, adolescent girls, pregnant women, and lactating mothers. It also seeks to develop and promote practises that foster health, wellness, and immunity through a strategic shift in nutrition content and delivery and the development of a converging eco-system. Poshan Tracker: The 'Poshan Tracker' ICT application was created and implemented by the Ministry of Women and Child Development as a crucial governance tool. The Poshan Tracker has included WHO's expanded tables to dynamically determine stunting, wasting, underweight, and obesity status based on a child's height, weight, gender, and age.

5. **EAT RIGHT INDIA MOVEMENT:** It is an outreach activity organized by the Food Safety and Standards Authority of India (FSSAI) for citizens to nudge them towards eating right. Eat Right India adopts an integrative or 'whole of the government' approach since the movement brings together food-related mandates of the agriculture, health, environment and other ministries. It also adopts a 'whole of society' approach, bringing all stakeholders together on a common platform. Eat Right India is aligned to the National Health Policy 2017 with its focus on preventive and primitive healthcare and flagship programmes like Ayushman Bharat, POSHAN Abhiyaan, Anemia Mukt Bharat and Swacch Bharat Mission.

LESSON FROM INTERNATIONAL EXPERIENCE:

FOME ZERO: HOW BRAZIL IS TACKLING HUNGER AND FOOD INSECURITY

ABOUT FOME ZERO:

Hunger is a multi-sectoral problem requiring an integrates, cross-government response. The Fome Zero programme recognises that poverty reduction, food security, and support for small-scale agriculture are intimately connected. Its interlinked initiatives are intended both to increase access to food for the poorest people and to support food production from small-scale and family farmers.

FOME ZERO HAS THREE MAIN POLICY PILLARS:

- The Bosla Familia is the world's largest conditional cash programme. It provides direct income, under certain conditions to 12.7million access to financial benefits is based on access to basic rights such as health, education, and food in order to support poverty reduction more effectively.
- The school meal programme provides 47 million free meals every day.
- The strengthening of family agriculture pillar. It is intended to strengthen and stimulate small-scale and family-based agriculture in order to increase the quality of the food supply and support increased incomes for rural households. This programme included subsidized credit, training and technical assistance and insurance for small-scale and family framers. The Family Agriculture Food Procurement Programme aims to ensure a stable market price for product from small-scale farmers, for example by buying local food product for government feeding programmes or for local food banks.

THE WAY FORWARD:

- **Holistic Approach**: There is a need of adoption of holistic approach to address the challenge of food security. It can be done by looking at diverse issues from a common lens such as inequality, food diversity, indigenous rights and environment justice and sustainable green economy.

- **Addressing loopholes in food security management**: Food management in India is one of the main reasons for food insecurity. It can be done by ensuring transparency in food stock holdings by using technological advancements as using IT to improve communication channels with farmers. It can help them to get a better deal for their produce while improving storage houses with the latest technology is equally important to deal with natural disasters.
- **Improvement in data collection**: There is an urgent need to critically re-evaluate the methods and data sources of food security assessment. It can be done with improved and real-time data from the Indian Government, coupled with closer coordination with international organizations, particularly the FAO and the WHO. This collaborative effort is essential to ensure a more accurate representation of India's food security situation and to effectively combat hunger and malnutrition.
- **Political will and government initiatives**: There is a need of significant political will and government action to transform its food and nutrition landscape. The existing government initiatives and schemes should be implemented carefully and adequately so that no one is left behind.
- **Agricultural investment**: For managing food security, there is a need to invest in agricultural research and development to develop high-yield and climate-resilient crop varieties. It can be done by promoting sustainable farming practices, including organic farming and precision agriculture and improved access to modern farming technologies, such as improved seeds, fertilizers, and irrigation systems.

CONCLUSION: It may be true that there are issues in methodology of Global Hunger Index, showing such poor state of hunger in India. However, it is crucial to acknowledge that while significant progress has been made, there are still issues that persist in ensuring food security in India. The challenge lies in identifying these specific areas and taking immediate steps to combat hunger and malnutrition in all its forms.

CHAPTER 11: OVERALL CONCLUSION

- Analysis of all 125 countries we conclude that countries India, Madagascar, the Central African Republic, Niger, and Yemen have severed hunger related issues whereas countries like Chile, Croatia, Estonia, Latvia, and Georgia as has successfully tackled hunger related issues.
- Thus, organizations such as Food and Agricultural Organization (FAO), World Food Programme (WFP), United Nations Children's Fund (UNICEF), International Fund for Agricultural Development (IFAD) has to focus more on moderate or severely affected countries.
- We can also conclude that GNI per capita has inverse relation with GHI score i.e. countries with low GNI per capita has sever hunger related issues. Hence countries can reduce there GHI score by significantly improving GNI per capita.
- Along with GNI the demographic conditions of the countries also affect the GHI score. Mostly countries with harsh demographic conditions have GHI score.
- India rank 121st in all of the 125 countries which mean that India is severely affected country, despite India is improving its economy in past few years but it has to work more to improve its medical facilities, food distribution scheme etc.
- Among the all states of India Bihar, Jharkhand, Gujrat, Uttar Pradesh, Dadar Nagar Hawali & Diu Daman are some of the severely affected states and in comparison, Puducherry, Sikkim, Kerala, Manipur and Mizoram are less affected states.
- Akshaya Patra Foundation, Rise Against Hunger, Feeding India, No Hungry Child are some of the organizations working in India to reduce Hunger issues.
- The time series analysis for under five-year child mortality rate of India has downward trend which indicates that India has successfully achieved medical facilities for child care but India has to work a lot in all of the states to reduce Undernourishment, Child wasting, Child Stunting and Child Mortality to improve bad hunger situation.

CHAPTER 12: REFERENCE

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