Towards Food Security with Nutritional Health:

Multi-Scale Approaches

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A thesis submitted to the University of Oxford in partial fulfilment

of the requirements for the degree of Doctor of Philosophy

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Trinity Term 2016

Abstract

This thesis addresses multi-scale approaches for improving food security with nutritional health. It argues that four key themes: scale, nutrition, trade, and governance are not given adequate attention in food security and nutrition studies. A multi-scale framework links the overriding thematic structure, bridges gaps, and enriches analysis. It facilitates a blended approach of analysis for food security and nutrition studies, public policy, and critical geography. Nutrition is at the centre of the inquiry and addresses the triple burden of malnutrition: hunger, micronutrient malnutrition, and obesity. Nutrition is hampered by an incomplete understanding of dietary diversity. Trade and governance are complimentary and cover dynamic commodity exchanges which might develop along with improved programme delivery. At the structural core of the work are four research papers which interact with established and emergent food security indicators and data for: the international system, nations, Indian states, and districts within Karnataka.

Each paper uses specific methodological tools which are most compatible with the unique characteristics of the relevant scale. The first paper applies benchmarking and compares international FAO food security indictors with the EIU and other best practice sources to argue for improved data. In order to inform malnutrition beyond hunger, the second paper inputs FAOSTAT national food balance sheet data into a dietary food supply model of key nutritional food groups for medium activity individuals. The third paper employs Indiastat data to construct a food potential model representative of major components of the Indian food system, and compares it with production information for pulse varieties for inclusion in the NFSA. The fourth paper creates a nutritional HDI, compares it against the production of cereals and pulses, and considers weather conditions.

Results illustrate that the FAO does not give proper attention to including governance indicators or capturing dietary diversity beyond hunger. Food balance sheet

data shows that the majority of the world lacks the proper supply of key food groups to sustain a medium activity lifestyle, with fruit & vegetable deficits equally present in developed and developing nations. In India, states with the lowest food potential are located in the north and east of the country while some neighbouring states contain pulse production advantages. Further opportunities exist to use digital technologies to improve the administration of the programme. Similarly, northern districts of Karnataka require more direct NFSA intervention while the southern and coastal districts have the potential for increased production and trade of pulses.

Implications for this study are centred on the development of future food security and nutritional health studies, policy, and administration. When possible, food security and nutrition studies can broaden their conclusions by expanding their base of indicators and data to take into account multi-disciplinary information. Possibilities for richer studies are evident through the development of more robust governance and dietary diversity indicators. These could focus on measurable programme results and take into account the impact of food groups and nutritional supply on various types of malnutrition. Multi-scale analysis might inspire cross-boundary policy formulation and assist in the development and trade of food system resources. The administration of food security programmes might improve with further study and the use of technology as a tool for delivery.

This thesis clarifies how multi-scale approaches to food security and nutrition can be advanced through conceptual, methodological, and empirical work combining critical engagement, data analysis, and public policy.

Acknowledgements

I would like to thank my supervisory team, Dr. Shonil Bhagwat and Professor Sarah Whatmore, for their intellectual and personal guidance. Their encouragement to think deeply about food security and nutrition has been inspiring, their efforts and attention were most appreciated. Lunch time meetings with Shonil were a highlight.

In addition, my transfer and confirmation reviewers: Professor David Thomas, Professor Craig Jeffrey, Dr. John Ingram, and Dr. Alfred Gathorne-Hardy shared constructive and valuable feedback. I am further thankful for the support and contributions of other members of the School of Geography and the Environment who have contributed to my professional development: Dr. Joost Vervoort and Maliha Muzammil from the Environmental Change Institute; and Dr. Paul Jepson from Biodiversity, Conservation, and Management. Ruth Saxton, in the Research Degrees Office, was also very helpful.

I am grateful for the external research opportunities Oxford facilitated and the funding from Keble College, in support of my field research. Personnel at the Food and Agriculture Organization of the United Nations in Rome, Italy, were especially supportive and hospitable. In addition, Dr. Juliane Dame, from the South Asia Institute at the University of Heidelberg, shared useful research material.

My family deserves a special thank you.

Also, I have been fortunate to make many friends from around the world who were particularly supportive. I am grateful for having the privilege of studying and living in Oxford, and I look forward to furthering the work and friendships begun here.

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List of Acronyms

AAY	Household poorest of the poor (Government of India designation)
AMS	Aggregate Measurement of Support
APL	Above Poverty Line
ASEAN	Association of South East Asian Nations
BPL	Below Poverty Line
CLM	Community Land Model
CSC	Common Service Centres
DLHS	District Level Household and Facility Survey
EIU	Economist Intelligence Unit
EPI	Environment Policy Index
EPPA	Emission Prediction and Policy Analysis
EU	European Union (28 nation members. Founded 1993)
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization of the United Nations Statistics Division
FCS	Food Consumption Score
FPS	Fair Price Shops
GCAM	Global Change Assessment Model
GDP	Gross Domestic Product
HDDS	Household Dietary Diversity Score
HDI	Human Development Index
HEI	Healthy Eating Index
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IFAD	International Fund for Agriculture and Development

INFORMAS	International Network for Food and Obesity/non-communicable disease Research, Monitoring, and Action Support
IFPRI	International Food Policy Research Institute
IIPS	International Institute for Population Studies
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
ISHI	India State Hunger Index
Mbps	Megabytes per second
MDER	Minimum dietary energy requirement
MDG	Millennium Development Goals
MERCOSUR	Southern Common Market (South American States. Founded 1991)
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MHFW	Ministry of Health and Family Welfare
MPCE	Monthly per Capital Consumption Expenditure
MSP	Minimum Support Prices
NAFTA	North Atlantic Free Trade Association (USA, Canada, Mexico. Founded 1987)
NCAER	National Council of Applied Economic Research
NSEL	National Spot Exchange Limited
NFHS	National Family Health Survey
NFSA	National Food Security Act (Act of Parliament, India 2013)
NGO	Non-Governmental Organization
NNMB	National Nutrition Monitoring Bureau
NSS	National Sample Survey
OECD	Organization for Economic Cooperation and Development
PCOMRAT	Political Commitment and Opportunity Measurement Rapid Assessment Tool

PDCAAS	Protein Digestibility Corrected Amino Acid Score
PDS	Public Distribution System
PPP	Purchasing Power Parity
PTA	Preferential Trade Agreements
TPDS	Targeted Public Distribution System
UN	United Nations
UNCTAD	United Nations Committee for Trade and Agricultural Development
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Fund
UNMDG	United Nations Millennium Development Goals
UNPD	United Nations Population Division
USAID	United States Aid and International Development
WFP	World Food Programme
WHO	World Health Organization
WTO	World Trade Organization (Regulations for 160 members. India joined 1995)

Chapter 1. Introduction

The concept of food security is a work in progress. A significant debate exists between agricultural technologists (Godfray et al., 2010) and those who advocate community-based solutions (Gabriel et al., 2013). Many other researchers occupy various points along a continuum between these two poles (Coates, 2013; Paarlberg, 2010; Pinstrup-Andersen & Schioler, 2000; Watson, 2011). Corporate interests exhibit a singular thrust towards increased production and are dissonant with an activist and research community comprised of the majority of food and nutrition focused international organizations, research houses, academic departments, and development NGOs (Carolan, 2012; Coates, 2013; Godfray et al., 2010; Ingram et al., 2010). There is no clear consensus regarding how to approach the issue (Coates, 2013; FAO, 2015a; Maxwell, 1996). However, the general agreement in this environment confirms that new, multi-scale food research is required to generate effective policy, particularly in large developing nations with significant food and nutritional challenges (FAO, 1997; Maxwell et al., 2008; Sachs et al., 2010; Sanchez & Swaminathan, 2005).

India, challenged by pernicious food issues, is currently undergoing significant socio-economic changes and varied dietary transitions associated with increased urbanization, national wealth creation, and inequality (Basu, 2010; Mittal, 2007). Karnataka represents a rapidly developing state in India with stark distinctions between its urban and rural populations (NSS, 2014). A bias towards supply and grain is present in India's 2013 National Food Security Act (NFSA)/Targeted Public Distribution Scheme (TPDS) architecture (Rai et al., 2015). There is also a significant challenge in addressing food issues from a programme efficacy perspective due to pervasive corruption and leakage issues (Basu, 2010; Joshi, 2013). Potential solutions range from e-governance strategies to price interventions (Masiero, 2015; Svedberg, 2012). With the country undergoing rapid modernization and development, the pressure of the NFSA to function as the catalyst in improving dietary quality, health, and the general standard of living is immense (Kishore et al., 2014; Kumar et al., 2014). While the central government is the key driver in advancing and implementing policy, Indian state governments have an important and potentially growing role in defining and maintaining alternative food networks.

This thesis aims to improve the understanding of food security with nutritional health through multi-scale analysis of existing indicators and data. It notes that incomplete conceptualizations, methodologies, and management prevent optimal policies. In moving to remedy this situation it is evident four key analytical lenses−scale, nutrition, trade, and governance have not been given adequate attention in food security and nutrition studies. This thesis advances the literature by developing a coherent conceptual system of analysis and applying it to studies which make use of methodologies best suited to different scales (international, national, state, and district). This research opens the door for policy collaborations between actors situated in each of these contexts, and strives to influence FAO, cross-national, Indian state, and Karnataka district policies.

A multi-scale approach to food security and nutrition requires that disparate types of information be assembled into models from a variety of scale specific datasets. The benefit is the inclusion of more refined nutrition, trade, and governance conceptions in research (Directorate of Economics and Statistics, 2012; FAO, 2015a; Indiastat, 2015). Policy makers would be able to construct food security and nutrition studies which yield more accurate information regarding structural strength and weakness, and policy linkages could be developed across administrative jurisdictions (Goodman et al., 2012; Howitt, 2003; Marston, 2000; Minewald & McCann, 2014). For example, international trade policy (centred on the WTO regime) might be reimagined by nation-states to more equitably manage food item surpluses and deficits in light of global nutritional requirements (Diaz-Bonilla et al., 2003; Migotto et al., 2007). Nation-states could modify their trade policies in tandem (Nielsen, 2006) while also developing programmes to take advantage of food system strengths and target areas of nutritional weakness. States within nations such as India might work with one another to influence national and international policy, and districts within states similar to Karnataka could do this while also finding unique ways to combine national and state programmes with local solutions, such as agglomeration economies.

In the under researched area of nutrition, additional work is required to more accurately capture dietary diversity in food security and nutrition studies (Maxwell, 1996; Ruel, 2003). The core of this work accepts an understanding of food security that requires access to sufficient food for dietary requirements and adequate health for all individuals (FAO, 2008; FAO, 2012). The Food and Agriculture Organization of the United Nations (FAO), in collaboration with various partners, struggled for years to develop this concept. Initial emphasis was solely on the universal supply aspects of grains before the FAO incorporated dietary diversity in its conceptualization (FAO, 1997; Maxwell & Smith, 1992). However, the present food security discourse still underestimates the importance and potential positive impact of plants as sources of protein (FAO, 2015a). Each paper approaches dietary diversity by developing analytical frameworks, models, or indicators which support prioritizing the consumption of fruits & vegetables. The first paper makes a strong case for dietary diversity to be recorded in a manner that expands beyond animal proteins to include plant proteins. The second paper supports analysis of food supply needs through nutritional requirements rather than total calories. The third and fourth papers explore strategies for increasing pulse consumption to improve plant-based protein intake as a part of, or in tandem with, direct government intervention in Indian states and districts in Karnataka. The fourth paper also records the nutritional impact of malnutrition on a key vulnerable group (pregnant women with anaemia).

Analysis of international systems shows that the central actors of global governance, such as multi-scale government institutions, private enterprise, non-profit organizations, and academic researchers fail to collaborate (Diaz-Bonilla et al., 2006; FAO, 2015a; Friedmann, 2005; IFPRI, 2013; Lobell & Burke, 2010). Today, a plethora of crises, including unexpected price fluctuations, extreme weather shocks, and political upheavals, compound the challenge of mitigating the most significant forms of food insecurity common to low and middle income nations (IFAD, 2012; UK Office for Science, 2011). More stringent indicator formulation, data collection, and analysis will aid in meeting this challenge. Potential policy choices which include the reform of the current trade regime (McMichael, 2009; Tutwiler & Straub, 2007) and the implementation of alternative development pathways are essential (Gabriel et al., 2013; Venn et al., 2006). The first paper illustrates the priority at the international level to include measurable, performance-based governance indicators in food and nutritional studies. Building on this concept the second paper shows that it is essential for national trade and governance policies to ensure adequate supply of essential food groups required for nutrition. The third paper continues the theme by developing corruption and e-governance indicators to inform Indian state level policy. The fourth paper further develops this by considering food expenditure information unique to the district scale in Karnataka.

Food security and nutrition in India provide an important link to international food conceptualizations and processes. Researching nutrition related methodologies used in India and comparing them to international standards can improve programmes if appropriate changes are implemented (MHFW, 2013; NSS, 2014). It is also plausible that processes at finer scales of analysis in India can better inform the development of international food security indicators (FAO, 2015a). The global food system now depends on India as a food exporter with particularly large exports of horticultural products. For example, mangos represent 39% of world exports (APEDA, 2014). The stability of Indian trade, procurement, and distribution policies has significant implications beyond its borders (Hoda & Gulati, 2013). Developing proper responses to the potential supply and price fluctuations of key crops needs to be understood, particularly as the NFSA contains subsidies whose efficacy inevitably interacts directly with international food markets and has played the central role in ongoing WTO agricultural trade negotiations (Gandhi & Zhou, 2014; WTO, 2015). In Karnataka's districts, development strategies can be made based on complex webs of citizen health and nutritional requirements, food consumption and production realities, and various layers of government policy (Kadiyala et al., 2014; Rao, 2013a).

To summarize, relevant datasets are critically analysed and best available information is used. Four analytical lenses are selected to facilitate a clearer picture of food system realities and potential outcomes. A set of conceptually linked multi-scale approaches across four research papers build on one another. The implementation of scale as the overriding lens of analysis improves conceptual, methodological, and administrative realities of a food security study or policy. Nutrition provides a reference point for the perceived or actual success of food policy outcomes. Trade and governance are complimentary lenses and interact with both scale and nutrition. The results of this inquiry provide a rough blueprint for stakeholders to address challenges and interact more productively with one another across scales in today's globalized world.

1.1 Thesis Outline

The main body of this thesis is organized into four individual papers. These are linked conceptually, and progressively develop analytical approaches and empirical findings. The first two papers examine aspects of global food security while the next pair considers Indian food security. Paper one approaches current international food security and nutrition studies from a critical perspective while the second paper shifts to the inadequate treatment of nutrition and dietary diversity, specifically the supply of plant-based proteins, at national levels. The third paper considers the state level link between agriculture and nutrition (focusing on pulse production and consumption) and seeks potential pathways (such as e-governance), to reform the NFSA. Paper four explores the link between nationally administered district level studies and food and agricultural policy in Karnataka.

This thesis employs four analytical lenses: scale, nutrition, trade, and governance. Scale and nutrition are significant across each paper. Trade has strong relevance to the second and third papers while governance is vital for the third and fourth. Due to the overlapping nature of the research, references to each are present throughout. The following tables (1.1, 1.2, and 1.3) offer a visual representation of the thesis as a whole. This includes the overall aim, specific objectives, the guiding questions, the conceptual framework (the analytical lenses), and the potential outcomes.

Table 1.1 Schematic Diagram of Thesis

Overall Aim

To improve the understanding of food security with nutritional health, through multi-scale analysis of existing food security related data and indicators

Specific Objectives

1. Address knowledge gaps between the literature on food security, nutrition indicators, and available data
2. Develop and apply quantitative models which take into account the complexity of the food system in unique spatial contexts
3. Create strategies for increased plant-based protein consumption
4. Suggest collaboration options for policy makers

Conceptual Framework

Four Analytical Lenses:
1. Scale (International, National, State, District)
2. Nutrition
3. Trade
4. Governance

Conceptual Framework

Complimentary Themes:
1. Food Security and Nutrition Indicators
2. The Link between Agriculture and Nutrition

Potential Outcome I

Re-conceptualization of food and nutritional security

All Papers

Potential Outcome II

Linking decisions about the food system to nutritional outcomes

All Papers

Potential Outcome III

Increased collaboration across scales and in non-traditional formations

All Papers

Potential Outcome IV

Improvement in the quality and collection of food system data

All Papers

Guiding Questions

Paper 1: To what extent has the FAO's conceptualization of food security helped or hindered international food security studies?

Paper 2. To what extent might more rigorous nutritional information positively impact food policy?

Paper 3. In what ways does the National Food Security Act in India need to be reformed to enhance its programme efficacy?

Paper 4. To what extent can relevant survey information be used in the reform, and subsequent implementation of district level food policy in rural Karnataka?

Table 1.2 Conceptual Framework: Analytical Lenses Informing the Thesis

I: Scale

Situates and connects food security data and models to reveal conceptual connections across contexts (Four levels: international, national, state, district)

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II: Nutrition	**III: Trade**	**IV: Governance**
Unites relevant food group data with health status, valuable for universal plant protein consumption	Illuminates universal movement of essential nutrients and the interactions between institutions and policies	Identifies weakness in food and nutrition programme delivery and supporting related development policies
Key Linkage Across Papers: *Increases in plant proteins* Consumption (district) Production (district, state) Supply (district, state, national) Conceptualization (international)	Key Linkage Across Papers: *Strategic responses to the global trade regime* Alternate development strategies (national, state, district) WTO negotiations (national)	Key Linkage Across Papers: *Improved Quality of Programmes* Corruption (state, national) Efficiency (district, state, national) Conceptualization (international)

Table 1.3 Conceptual Framework: Relationship of Analytical Lenses and Papers

Lens	Paper 1	Paper 2	Paper 3	Paper 4
I. Scale	International conceptualizations of food security made by the FAO and EIU; consensus on nutrition and governance needed	National data compiled by the FAO in food balance sheets; need for improved surveys due to data restrictions	State level data compiled by Indiastat; need for improved surveys due to data restrictions	District level data obtained from relevant NSS and DLHS surveys in Karnataka; need for improved surveys due to data restrictions
	Analysed FAO limitations using process benchmarking of the EIU and other best practices	Reorganized FAOSTAT data into WHO food groups and compared the results against cross-country nutritional requirements	Created a food potential model based on: nutritional, economic, environmental, developmental, and governance indicators	Created a nutritional HDI based on: income, education, and health
II. Nutrition	More rigorous exploration of micronutrients	Triple burden of malnutrition emphasized	Malnutrition situated at the centre of a nutrition centred model	Long and short-term nutritional impacts considered
	Suggested use of Protein Digestibility Amino Acid Score to capture dietary diversity (inclusive of plant protein sources)	Consumption of plant-based proteins used to measure dietary diversity and to shape developmental strategies	Advocated increased consumption of pulses (plant-based proteins)	Advocated increased consumption of pulses (plant-based proteins)
	Recommended linking agriculture to nutrition	Recommended linking agriculture to nutrition	Recommended linking agriculture to nutrition	Recommended linking agriculture to nutrition
III. Trade	FAO focused on infrastructural impact; EIU Indicators based on macroeconomic factors	Compared food group surpluses/deficits with imports/exports to inform development of new trade blocs; India exports vegetables & fruits despite deficits	Developed an internal system of re-distribution and potential trade of pulse resources in north and eastern Indian states; action in tandem with NFSA reform	Developed an agglomeration strategy for South Karnataka to reduce dependency on international imports
		Emphasized increased production of plant proteins for developing nations rather than the export of these assets in the WTO system	Generated results to impact WTO negotiations which influence India's public food distribution under the special safeguard mechanism	
IV. Governance	Included best-practice performance benchmarks for food and nutritional programmes which address availability, access, utilization, and corruption aspects	Favoured agricultural development strategies (multi-sectoral) that prioritize plant-based protein sources and increased fruit & vegetable production	Advocated investments in storage, production, irrigation, and technology to maximize fresh produce and plant-based protein consumption	Advocated need-based interventions in pulse and cereal distribution (within the NFSA framework) and production to reduce malnutrition
	Cross-scale collaboration (conceptualization)	Cross-scale collaboration (collect/publish data, create policy)	Cross-scale collaboration (collect/publish data, create policy)	Cross-scale collaboration (collect/publish data, create policy)

The previous tables illustrate how the four analytical lenses function across each individual paper to provide insight for more relevant food policy. They present an overview of the thesis and the central points which shape the direction of each paper. Supporting research builds a narrative of informed policy recommendations, which can be extracted for both specific paper and thesis contexts. The following sub-sections elaborate on each of the four papers, explaining the relationship between conceptual, analytical, and empirical aspects.

1.1.1 Paper 1: Towards a Holistic Approach to Food Security Data: Going Beyond FAOSTAT

To what extent has the FAO's conceptualization of food security helped or hindered international food security and nutrition studies?

The first paper examines the scale dependent policy environment of international food security and nutrition studies, situated at a super-imposed scale of *the world economy* (Taylor, 1982). While processes and information in these studies is derived from both macro and micro information, the primary site for subsequent decision making is the international arena. With this in mind, the conceptualization of food security indicators and data collection methods of large international organizations are explored (EIU, 2015; FAO, 2015a; IFPRI, 2013; WFP, 2013). The study seeks to determine the effectiveness of the FAO in creating a core set of international food security indicators. A process benchmarking method (Jack, 2009; Tuominen et al., 2012) is used to compare these with indicators from the Economist Intelligence Unit (EIU).

The paper seeks to determine the effectiveness and accuracy of established indicators and methods in describing current nutritional realities. In doing so, it emphasizes a more refined conception of proteins and micronutrients as part of a wider core set of nutritional indicators for global food security (Gomez et al., 2013; Schaafsma, 2000). Paper one also explores how governance indicators have been considered in international studies (Brinsden et al., 2013; Swinburn et al., 2013), and integrated in a large food study through the initiative of the EIU. These indicators are primarily based on qualitative observations and do not record programme performance (Carolan, 2012; IFAD, 2012). Evidence suggests that further collaboration between key actors is required to develop quantitatively verifiable information.

1.1.2 Paper 2: Many at the Table Suffer from Malnutrition – Why? Food Group Research to Improve Global Nutrition

To what extent might more rigorous nutritional information positively impact food policy?

The second paper builds on the finding from the first that the FAO has an incomplete conception of dietary diversity. As a response, it interrogates the indicator at the international level and explores how FAO food balance sheet data can be viewed through a food group perspective (WHO, 2000). Recommendations are made for expanding policy action at both the international and regional scales (Herod & Wright, 2002; Marston, 2000; Smith, 1998; Smith, 2003). Potential improvements in the use of international data (FAO, 2015a; Kearney, 2010; Popkin et al., 2012) suggest that there is an opportunity for the strategic formation of regional trade blocs (Cheriet & Rastoin, 2014; WTO, 2015). The research highlights states which have developed advanced economies and kept a flourishing and well balanced agricultural sector, thereby providing adequate supply of all essential food groups.

This paper is concerned with improving the concept of dietary diversity through a re-conceptualizing which goes beyond starch carbohydrate and animal proteins. It illustrates the potential for the provision of plant-based protein sources as an alternative, and makes reference to the strategic reform of the international trade system and alternate development trajectories (Maye et al., 2007; Tornaghi, 2014). This is an example of the application of foodscapes, as the study considers power structures (Minewald & McCann, 2014) and consumption (Mikkelsen, 2011) which are directly concerned with the provisioning of food (Goodman et al., 2012). It reviews protein supply availability, taking into account the fact that the data represents how each country has interacted with the international trade regime. Data analysis confirms mutually beneficial positions that nation blocs might employ during negotiations. Information is also used to create and maintain alternative food networks for key protein sources (Hendrickson & Heffernan, 2002; Winter, 2006).

1.1.3 Paper 3: Maximizing India's Vast Resources for Improved Nutrition: Reforming the National Food Security Act

In what ways does the National Food Security Act in India need to be reformed to enhance its programme efficacy?

The third paper builds on the second paper's development of dietary food supply beyond carbohydrates by exploring reform to include pulses in India's NFSA. While nutritional and developmental studies exist for India (MHFW, 2013; IFPRI, 2008; NSS, 2014), they are not conceived to address the entire food system nor are they designed to improve specific programmes. To close this gap, national level data from Indiastat is compiled into a state food potential model to determine the optimum means for procuring, marketing, and distributing plant-based protein sources, as recommended by researchers

(Kishore et al., 2014; Rai et al., 2015). Results will inform policy action which is designed to occur in individual states. The paper suggests the reform of the NFSA and explores potential modification of the programme. Recommendations include: a greater share of pulses in the programme; identifying appropriate plant-based and infrastructure resources in each state (Landes & Hjort, 2015; Reddy, 2004); natural environmental constraints (O'Brien et al., 2004; Sanghi & Mendlesohn, 2008); and the greater use of electronic governance in programme delivery, to reduce leakages (Masiero, 2015; Svedberg, 2012). It considers the capacity of different actors and organizations to facilitate improvements.

The paper interacts with trade through NFSA responses to international and domestic markets. This theme is present due to India's involvement in WTO negotiations and the management of subsidies which respond to commodity price fluctuations (Gill et al., 2010; Karmakar & Mukhopadhyay, 2014; WTO, 2015). The conclusion explores potential advantages for reforming the NFSA. It records the production efficiencies of pulses and suggests means for improving consumption. Findings suggests that a broader use of e-governance methods could reduce the effects of corruption (Masiero, 2015; Svedberg, 2012) and create solutions relevant to the unique needs of both urban and rural constituents.

1.1.4 Paper 4: Within Reach? Creating Multi-Scale Nutritional Policy for Rural Karnataka

To what extent can relevant survey information be used in the reform, and subsequent implementation of district level food policy in rural Karnataka?

This paper builds on the development of the state food potential model relative to the NFSA in paper three by creating a similar method of analysis for Karnataka. While some information exists at the district level in India (Directorate of Economics and Statistics, 2012; MHFW, 2013) there is no large food or nutritional study that incorporates holistic food system indicators. In order to fill this gap, the fourth paper examines the link between scale and the food and agricultural policies made in and for the state of Karnataka. The paper acknowledges the large gulf between rapidly urbanizing areas and the rural population (Ghori, 2015). Policies of decision makers at the national level are analysed, while making note of necessary processes and data which occur outside their jurisdiction at the sub-national level in the state of Karnataka and its respective districts and geographical regions. It is in this study that social processes intersect most conspicuously across numerous scales (Herod & Wright, 2002), although immediate priority is given to the understanding of local food and nutritional issues (Feagan, 2007).

Two district level studies are drawn upon. Resultant data are derived from surveys conducted by the National Sample Survey (NSS) and the District Level Household and Facility Survey (DLHS). Information is used to create a nutritional HDI model to inform district and regional food system strengths and weaknesses. Nutritional consumption expenditure (Smith & Subandoro, 2007) and health information (Hoddinott, 2001) are combined with agricultural information (Directorate of Economics and Statistics, 2012) and climate data (Government of India, 2013) to produce groups of similar districts.

Results and recommendations are used to interrogate the current NFSA and produce new strategies for districts and regions such as agglomeration (Dulsrund et al., 2015; Lall et al., 2001). They could also be used to maximize the weak but improving linkages between cross-sectoral food and agricultural policies at the national, state, and district levels (Kadiyala et al., 2014; Rao, 2014).

1.1.5 Chapter 1. Summation

The four papers collectively develop a method for unifying food security and nutrition studies across scales. Constrained by data limitations, conceptual links place nutrition at the centre while acknowledging trade and governance impacts on this part of the global food system's politics and processes. Complex relationships between the more productive use of data and relevant policy making are made lucid. A narrative is constructed which reveals a system at the international, national, state, and district levels. It fills a gap in the academic literature and has relevance for policy actors, who lack the context to record and respond to various systemic impacts at their respective scales. Further attention will be required to expand on the findings of this thesis. The following literature review elaborates on the significance of scale, nutrition, trade, and governance. Complimentary sections on indicators and the link between agriculture and nutrition focus, rounds out the review and provide context for the four lenses.

Chapter 2. Literature Review

The literature review considers ideas from food security and nutrition studies, public policy, and critical geography, located in academic journals, book chapters, government or non-profit reports, and complimentary online sources. Sections correspond to the four analytical lenses used in this thesis: scale, nutrition, trade, and governance; along with food security and nutrition indicators and agriculture to nutrition linkages. This section identifies key conceptual, methodological, and empirical developments along with the potential for further research. Published literature implicitly supports developing a set of approaches based on the analytical lenses to identify how the food system can evolve and improve nutrition. While knowledge gaps and methodological approaches differ across scales, the relevance of each analytical lens and complimentary theme to each paper in this thesis is explored.

2.1 Multi-scale Analysis

Multi-scale analysis allows for a number of interdependent food security and nutrition conceptualizations, methodologies, data, and policies to be examined more fluidly with one another. The approach facilitates an exploration of differences which exist between food security and nutrition indicators situated at different scales. It enables the construction of models which are unique to specific contexts. This allows for strategies to increase plant-based protein consumption (specifically pulses in India) to be crafted at each scale. Most importantly, multi-scale analysis allows for policy makers who are traditionally positioned in isolation to collaborate.

2.1.1 Geography and Scale

Geographic scales result from economic, political and social activities, and resultant relationships. Scale can be seen as maintaining and facilitating the different processes involved in the accumulation and circulation of capital (Smith, 1995). With globalization, there has been a reconfiguration and re-territorialisation of super-imposed spatial scales (Brenner, 1999). Three main divisions are routinely discussed: the world economy, the nation state, and the urban (Taylor, 1982). Others note regional scale, in both sub-national and supra-national space, is also present (Smith, 1995). Understanding how specific scales interact with one another suggests the relationship between global, state, and urban/regional processes cannot be conceived as mutually exclusive levels for analysis (Marston, 2000).

Geographers specializing in food make significant contributions to the contemporary debate on food security, often exploring ways of understanding relationships between food and various socio-economic processes. A complex array of social and ecological problems comprise a food system (Lang & Barling, 2012), and desirable outcomes may not map neatly onto the local level (Hinrichs, 2003). For instance, the argument that the food needs of the poor are neglected brings together a number of processes at the global, national, and local levels (Smith, 1998).

This thesis acknowledges that distinct and interconnected scales are available for analysis due to institutional structures, processes, and information (data). It examines food security and nutrition conceptualizations, methodology, data, and policies both individually and collectively at four scales: international, national, state, and district levels.

2.1.2 Food Security and Scale

A series of frameworks have been created by geographers to interpret the connections and complexity in the food system. In particular, foodscapes, foodways, foodsheds, and moral economies of food have created broad conceptualizations of the food system which are inclusive of its diverse components.

The *foodscapes* framework emphasizes the social, relational and political construction of food and examines existing power structures (Minewald & McCann, 2014). It describes production, retailing, and consumption at a range of scales from global to local (Cummins & Macintyre, 2002; Mikkelsen, 2011) and discusses the possible normalizing of middle-class foodscapes for low-income areas (Shannon, 2014). Perhaps best at defining foodscape scenarios is Goodman et al. (2010), who define them as the 'processes, politics, spaces and places which are embedded and produced in and through the provisioning of food' (p.1783). The framework supports multi-scale analysis used by the trade and governance lenses in this thesis as these lenses involve institutions, actors, and processes that are far-reaching. Furthermore, these lenses, along with nutrition, are directly impacted by data and indicator availability.

Related is the *foodways* approach which explores 'the cultural and social practices that affect food consumption, including how communities eat, where and how they shop and what motivates their food preferences' (Alkon et al., 2013; Cannuscio et al., 2010). The concept is applicable to the third and fourth paper which discuss increasing pulse consumption in India as it struggles with both hunger and a nutritional transition.

Foodsheds reconstruct the geography of food by compelling social and political decisions to be oriented within specific delineated spaces (Feagan, 2007). In general, for this framework to be functional, a reconstruction of the local in response to globalization must occur. It argues in favour of situating food systems in specific places although there must be greater clarity regarding how the local is understood (Feagan, 2007). Local food systems supplement and complement those located at larger scales (Anderson & Cook, 1999) and this leads to the regionalization and rescaling of agro-food governance (Winter, 2006). For example, many food producers and consumers reconfigure their relationships (Venn et al., 2006) as space can be disconnected from place in the food system (Hendrickson & Heffernan, 2002). The influence of such literature on this thesis is significant as the four delineated spaces are international, national, state, and district. Further possibilities for regionalization are discussed—both between countries (fruit & vegetable exporting developing nations with consumption deficits) and parts within countries (pulse producing states and districts in India).

A stream of thought discusses the *moral economies of food*. Some argue for advancement through the adoption of a relational view of geographic scale and temporal connection, and that these economies are expressed through time and space in addition to visibility and invisibility (Jackson et al., 2009). This approach maintains that the food and agriculture discourse is best understood through moral economies which are primarily concerned with health, well-being, fair trade, and development (Morgan et al., 2006). It is here that researchers have experimented with how ethics shape the development of new and alternative forms of production and consumption networks (Clarke et al., 2008; Maye et al., 2007). This idea influences all four research papers. In the first paper, improvements in FAO core food security indicators are discussed. Attention is given to the development of governance measures which evaluate food and nutrition programmes and strategies. In the second paper, a more equitable global trading system is discussed in light of essential food group supply. The third and fourth papers address potential agriculture-nutrition linkages to improve food security and nutrition via increases in production and consumption of pulses.

2.2 Nutrition

2.2.1 Nutrition and Food Security

Food security has been defined by the 1996 World Food Summit definition and modified in the 2009 Declaration of the World Summit on Food Security as something that: ‘exists when people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life’ (FAO, 2008; FAO, 2012). The central significance of nutrition on food security and health has been acknowledged (McMichael, 2007; Remens et al., 2012; Watson, 2011; WHO & FAO, 2002). A major challenge is mitigating the nutritional transition from plant-based diets towards consumption of animal protein, oils and fats, sugars and carbohydrates that typically takes place with increases in affluence (WHO & FAO, 2002).

Progress has been made in the discourse towards a wider engagement with nutritional issues (Ingram et al., 2010), although currently, many studies have primarily offered analysis and solutions at very specific administrative scales (Menon, 2009). A multi-scale analysis is useful in bringing together various nutritional issues that are present in diverse, developed, or developing locations whether urban or rural.

2.2.2 Triple Burden of Malnutrition

The literature shows a triple burden of malnutrition in the world involving those who are: overweight; micronutrient deficient; or hungry (Gomez et al., 2013; Johnston et al., 2014; Leathers & Foster, 2004; Mann & Truswell, 2007). Inequality in many low and middle income nations has resulted in populations that are underweight, micronutrient deficient, or obese. This sometimes occurs simultaneously in unique socio-economic contexts (Popkin et al., 2012).

Hunger is connected to dietary quality secured through a balanced intake of nutrients across food groups. 925 million people have been categorized by the United Nations as experiencing hunger through the lack of access to sufficient major nutrients such as carbohydrates, fruits and vegetables, dairy, protein, fats, and sugars. Another one billion potentially suffer from hidden hunger in which micronutrients such as vitamins and minerals are missing from their diet. Yet a further billion people are over consuming and contracting coronary diseases and diabetes (UK Office for Science, 2011).

Over nutrition results when a person consumes too many calories. This occurs mainly in high income nations and is based on high amounts of saturated fats, salts, and sugars (Leathers & Foster, 2004). Indeed, such a phenomenon has often been described as the *nutritional transition* whereby a move from plant-based diets towards consumption of animal protein, oils and fats, processed sugars and processed carbohydrates is associated with increased affluence. Unfortunately in such circumstances healthy diets have often been available to affluent consumers while overly processed high calorie foods are more likely accessible by poorer populations (Dixon, 2009). This thesis addresses the gap in data which omits the presentation of food supply as nutritional requirements. Doing so might inform how policy makers can record and address over nutrition, as excessive carbohydrates are separated from other required food groups. Such information, found in the second paper, can better manage obesity in the developed world and nutritional transitions in the developing world. Secondary malnutrition occurs when a person has a condition or illness that prevents proper digestion or absorption of food. The causes of this include infections and parasitic agents. It is mitigated by public health measures such as providing sanitary human waste disposal and clean water (Leathers & Foster, 2004).

Micronutrient malnutrition begins when one or more essential micronutrients is lacking. The most common are vitamin A, iodine, and iron deficiencies (Leathers &

Foster, 2004). Some researchers also emphasize zinc deficiency as being a key indicator of micronutrient malnutrition (Pinstrup-Anderson & Schioler, 2000). A common indicator of micronutrient malnutrition (specifically iron deficiency) is the symptom of anaemia which occurs when a person has a lower than normal amount of red blood cells (Leathers & Foster, 2004). Protein-calorie malnutrition is the under consumption of calories or protein which can only be solved by increasing the amount of food a person eats. A person would not have enough protein or calories necessary for normal growth, health, and activity if they had this condition (Leathers & Foster, 2004). Those impacted commonly experience wasting (Mann & Truswell, 2007). Micronutrient malnutrition is caused by food access challenges, extreme poverty, and the green revolution which has impacted dietary diversity. This occurs when genetically engineered foods, which are designed for traits associated with higher yields, displace traditional crops that are higher in micronutrients (Carolan, 2012). The four individual research papers of this thesis give considerable attention to addressing the knowledge gap between the accepted importance of dietary diversity and protein consumption and functional data. The first paper uses process benchmarking to confirm that the present indicators used by the FAO do not fully capture dietary diversity and protein consumption beyond animal sources. The second paper creates a food group dietary supply model to determine food supply based on nutritional requirements. The third and fourth papers explore increased pulse consumption relative to deficit states and districts. The fourth paper records pregnant women with anaemia (as a vulnerable group with potential protein consumption deficits) as part of the health aspect of a nutritional HDI.

India is salient as it contains over 20% of the global hungry (and the largest absolute total) and experiences hunger issues in every state (Menon et al., 2009). According to the 2013 Global Hunger Index over 17% of India's population is undernourished (Basu, 2010). Endemic pockets of hunger are present, seasonal shortfalls of foodstuffs are common and malnutrition is widespread, especially for women and children (Ramachandran, 2007). It is striking that carbohydrate and protein consumption has declined in both urban and rural areas. Both of these food groups, along with fat consumption, have remained lower on a per capita basis than the Recommended Dietary Allowance (RDA) guidelines for Indians (Kumar et al., 2014). The third and fourth papers use state food potential and nutritional HDI models to address hunger and dietary diversity issues by including pulses in the NFSA.

2.2.3 Urbanization

The global dietary shift is associated with increased affluence in which diets based on plants are cast aside in favour of animal proteins, fats, and processed foods (Dixon, 2009; WHO, 2002). This trend has close connections to urbanization and the growth of the global middle class (Shetty, 2002) which often select animal-source foods and shun traditional and local foods of higher nutritional value as inferior (Seale et al., 2003). There is currently a debate between those who support the idea of animal proteins (Smil, 2008) and those who emphasize post-obesity diets with less red meat (Eschel & Martin, 2006) as key to dietary richness. Unfortunately, processed foods are more likely to be consumed by poorer populations (Dixon, 2009). While urbanization and rising wealth has improved food security around the world, it has not delivered on improved nutrition for everyone (Chicago Council on Global Affairs, 2011). The second paper uses results to suggest a potential alternative development pathway for developing, rapidly urbanizing nations to maintain larger shares of plant proteins relative to overall protein consumption.

The reality is that food needs are not homogenous and the relationship between intake and nutrition vary greatly based on socio-economic factors (Nabhan, 2004). To illustrate, India has considerable food consumption deficits for fruits & vegetables (Deaton & Dreze, 2009). Driven by a growing middle class supported by increasing economic development, India is experiencing a dietary shift from a traditional population of mostly vegetarians to one where the majority consume meat, albeit primarily poultry (MacDonald & Iyer, 2012). This has paired with urban lifestyles to create an obesity epidemic (Yadav & Kishnan, 2008). Recent data from the National Sample Survey (NSS) of India indicates that, although cereal consumption continues to dominate in rural areas, in recent years there has been a sharp increase in the demand for livestock products in addition to fruits and vegetables (Gandhi & Zhou, 2014). In urban areas consumption of cereals is no longer the dominant pattern and both livestock products and fruit & vegetable products are in higher demand (Gandhi & Zhou, 2014). In the Indian states discussed in paper three this fact is linked to increased pulse consumption in urban and rural contexts.

2.2.4 Rural Populations

In India the quantities of pulses consumed are not consistent with standards prescribed by the Indian Council of Medical Research (Reddy, 2004). Pulses are a major source of protein among poorer segments of the population but consumption is very low. Rural populations consume more cereals, fewer pulses, and less oil and fat compared to urban populations (FAO, 2006). The current structure of the TPDS programme is based on rice and wheat which alone cannot make up for critical vitamins, minerals and other nutritional inputs necessary for the healthy development and functioning of individuals (Rai et al., 2015). The fourth paper makes the most significant contribution of the thesis to the study of rural consumption. Focusing on Karnataka, nutritional strategies are linked to the governance of the NFSA through collaboration by district, state, and national actors. In particular, agricultural production and trade strategies for key crops required for nutrition in certain regions of the state, are also present. These strategies are linked to the nutritional HDI’s identification of strengths and weaknesses in the food system, and socio-economic structure of Karnataka.

2.2.5 Regions

A long-term challenge is to understand whether national food systems provide the correct balance of nutritious foods and if populations consume recommended dietary requirements (Dangour et al., 2012). Increasingly, regional strategies to address the triple burden have been discussed (Gomez et al., 2013), and rapidly urbanizing countries exhibiting deficits in fruits & vegetables are exploring peri-urban agricultural solutions which incorporate a mosaic of urban and rural worlds inspired by home gardens (Lerner & Eakin, 2011; Tornaghi, 2014).

A thorough understanding of the nutritional challenges faced by the global community is essential for solving food system shortcomings. Placing dietary quality at the centre of the discussion enables a more responsible use of resources. It leads to the linking of health and nutritional goals with agriculture, which assists in the creation of more effective food security and nutrition studies and successful development strategies.

2.3 Trade

2.3.1 Trade and Food Security

Trade is considered to be essential for ensuring consistent availability and access to healthy, nutritious food (FAO, 2008). Opening national agricultural markets to trade and international competition can offer economic benefits and developing countries would benefit from the removal of barriers for products in which they have a competitive advantage (Watson, 2011). In addition, the reduction of escalating tariffs for processed commodities in both developed and developing countries would prove advantageous (Watson, 2011). The possibility of earning incomes from activities other than food production, and the complex relationship between production and distribution, suggests that giving priority to food production should be avoided in nations that have competitive advantage in exportable goods which can be traded for food (Dreze & Sen, 1989). The positive effect of trade liberalization assumes the traditional argument which focuses on two linkages: the fact that a large number of poor people work in the agricultural sector where trade distortions are particularly high; and, that liberalization could lead to higher world agricultural prices and raise activity and remuneration in the agricultural sector in developing countries (Shaw, 2007).

In contrast, openness in agricultural trade has been argued to have negative effects (IAASTD, 2009). In numerous cases, a focus on export leaves many small-scale producers, who form the majority of the rural poor population, vulnerable to volatile international market conditions. The concentration of agricultural market power, away from producers towards a limited number of large trade and retail agribusiness corporations, also provides a challenge for the food insecure (IAASTD, 2009). Key linkages occur between corporate interests connected to an agro-industrial complex and associated trading system. These *linked entities* set prices for nutritious food more suited to the affluent, located primarily, but not exclusively, in developed nations (Bhegin et al., 2003; Campbell, 2009; Friedmann, 2005; Hester & Harrison, 2005; McMichael, 2009). World Trade Organization (WTO) subsidies have preserved farm subsidies for the global north while the south is forced to reduce protections, import staples, and export high-value foods (Friedland, 1994; McMichael, 2009). To illustrate, trade in fruits & vegetables has expanded at a higher rate than other commodities (Huang et al., 2004) and doubled from 2000 to 2008 with developing countries exporting due to global demand (Fernandez-Stark et al., 2011). This thesis is primarily and generally concerned with improving food security and nutritional health at the global scale and more specifically in India. As such, it adopts a sceptical position towards current international trade architecture and works towards developing and applying models and independent policies to increase plant-protein consumption to mitigate malnutrition and manage dietary transitions.

Global realities are present in India. There has been a dramatic increase in India's agricultural trade, which has risen between the years of 1990-1991 and 2011-2012 both as a percentage of its total GDP (from 5% to 18%) and as its total share in global exports (from 0% to 2.1%) (Hoda & Gulati, 2013). Although India ranks first and second in the global production of fruits and vegetables respectively, adequate intake of these foods is recorded at less than 1/3 of the national population (Swaminathan, n.d.). Most food, if not wasted, is exported to developed nations (Gill et al., 2010) and organic farming has emerged for export markets. This sector exists under contract farming arrangements which export fruits and vegetables to developed nations (Gill et al., 2010).

These realities are made lucid by multi-scale analysis which strives to understand nutritional flows between nations and the global food system. The second paper creates a model which explains the movement of essential food groups and opens the door for partial mitigation through reductions in fruit & vegetable exports from developing nations.

The third and fourth papers select indicators, develop models, and suggest policy collaborations which assume a renewed commitment by the Indian agricultural sector to increase domestic pulse consumption.

2.3.2 Trade Reform

In response to this environment, outright trade reform is proposed. The advantages common to developed countries would be minimized by eliminating tariffs and reducing surplus dumping into developing nations (Brooks et al., 2008; Diaz-Bonilla et al., 2003). The *Right to Food* movement plays a strong role in supporting this position (De Schutter, 2011; Hawkes & Plahe, 2013). Critics have noted the presence of a significant disconnect between intent and implementation of the concept due to varying national interests (Hawkes & Plahe, 2013; Toledo & Manzella, 2012; Vidar, 2011) and also due to its incompatibility with other international trade agreements (Andersen, 2006; Cohen & Ramanna, 2008; Coleman & Reed, 2009; Santilli, 2012). Still, the movement argues in favour of more effective or mandatory food aid (Barrett, 2011; Shaw, 2011; Singer, 2011) and for trade reform of agricultural products between developing and developed nations (De Schutter, 2011; Diaz-Bonilla et al., 2003; Hawkes & Plah, 2013).

The road to trade reform is complex. Agriculture is the major hurdle in the completion of the current Doha (Qatar) round of World Trade Organization negotiations, despite the fact that low-income individuals in developing countries would be the most likely to benefit from a successful conclusion (Anderson & Martin, 2005). At present, the talks are suspended (the result of a 2008 impasse) due to the conflict between developed nations and a group of developing nations proposing a Special Safeguard Mechanism (SSM) which would allow them to raise applied tariffs on specified farm products when import prices fall or import volumes increase beyond threshold levels (WTO, 2008).

India's central role in WTO agricultural trade negotiations aims to protect its developing *Right to Food* policy architecture (WTO, 2015). A recent agreement was made between India and the USA on moving forward with trade reform with the condition of protecting the right to public stockholding programmes for food security. However, this agreement is interim and the final outcome is to be determined (WTO, 2015). The outcome is important within the context of this thesis since the NFSA programme is impacted by negotiations and policy would need to reverse the trend of those farmers switching to rice and wheat production (instead of more nutritious crops) for better prices (Rai et al., 2015). It should be noted that the models and collaborations suggested in the third and fourth papers assume the NFSA will not be impacted by negotiations going forward.

2.3.3 Trade Blocs

Trade and investment is increasing between developing countries (UNCTAD, 2009) and there has been a significant rise in the proliferation of regional blocs which interact with the global system through common policies concerning the exchange of agricultural commodities (Nielsen, 2006). These blocs are seen by many as possessing greater bargaining power in WTO negotiations (Beddington et al., 2012; FAO, 1997; Nielsen, 2006; Shaw, 2007). The second paper suggests that potential exists for a number of fruit & vegetable exporting developing nations to form a bloc to better advocate for the nutritional needs of their citizens.

The FAO has noted a general weakening of the multilateral trade system (FAO, 1999). The emergence of a small number of powerful regional trade blocs such as the European Union (EU), the North Atlantic Free Trade Association (NAFTA), the Southern Common Market (MERCOSUR) and the Association of South East Asian Nations (ASEAN) worldwide is a reality (FAO, 1999). The prevalence of free trade agreements often suits countries that are balancing an open economic policy with apprehension regarding open competition from other countries (FAO, 1999). Most countries are members of one or more trade groups. Liberalization at the regional or multilateral levels are based on preferential trade agreements (PTAs) which exclude or limit trade liberalization of sensitive agricultural products (Nielsen, 2006).

2.3.4 Microeconomic Concerns

The sustainability of the NFSA is questioned in light of changing food baskets (Joshi, 2013). While a slow but steady diversification of diets has taken place, inflation might reverse a nutritional transition recently noted by the government in consumer surveys (Basole & Basu, 2015a; Gandhi & Zhou, 2014). India is the largest producer, consumer, and importer of pulses in the world, accounting for 33% of the global area under cultivation and 20% of total production with an imbalanced import (Canada and Australia) to production percentage of 17.8 (NCAER, 2014).With this in mind, there is a movement to experiment with providing pulses instead of cereals in the NFSA. A trial investigation to discover whether this strategy would lead to better nutrition outcomes is suggested as the general protein consumption by poorer consumers is declining. (Kishore et al., 2014). Some have argued that encouraging localized supply allows regions to export their particular strengths and unlock productive efficiencies (Desrochers & Shimizu, 2012). The third and fourth papers employ a mixture of quantitative models, weather data, and crop production and consumption information to determine which areas have the strongest potential to increase pulse contributions.

Pulse demand is significantly more responsive to changes in income than food grains, but is less responsive than wheat and rice (Price et al., 2003). Substitution for middle and lower income consumers does not typically occur between pulses and other protein-rich foods such as meat, milk, or fish; but rather most commonly with cereals, vegetables, and fruits (Price et al., 2013). Decreases in production and increases in prices, have taken pulse consumption out of the reach of many of the poor for some time (Gopalan, 1995). The nature of a household's exposure to food prices often reflects the fact that rural households are both producers and consumers of food. It is important to note how much of household income depends on selling food and what produce is purchased (Lobell & Burke, 2010). The fourth paper addresses this by recording the consumption expenditure of households on food as the income component of the nutritional HDI. In any given area there can be a relationship between local food prices and availability which is driven primarily by local shifts in production. Alternatively, integration with regional or global food markets might be present (Lobell & Burke, 2010). Here, multi-scale analysis allows for a closer look at a series of policies which could impact nutritional consumption as found in papers two, three, and four such as: national trade and exports of pulses or horticulture, state minimum agricultural wages, and district consumption expenditure.

The Government of India’s Minimum Support Prices (MSP) are the amount of rupees (Rs) at which major food crops are acquired for eventual release into the nationwide PDS. In practice the extent to which the MSPs are binding vary greatly by crop and state and even within states. For example, the procurement of pulses and oilseeds has been minimal as market prices exceed MSPs (Jacoby, 2013). While India’s per capita protein consumption is not significantly below recommended nutritional requirements, widespread disparities in income are present that impact vulnerable groups, particularly women and children in rural areas (Pavaskar, 2014). This makes the inclusion of vulnerable groups (pregnant women with anaemia) in the nutritional HDI at the rural district level in Karnataka, particularly valuable for targeted policy making.

2.4 Governance

2.4.1 Situating Governance with Food Security and Nutrition

Consensus is lacking among scholars and policy makers concerning a single definition of governance (Kaufmann et al., 2011). Recently INFORMAS created a healthy food environment policy index which emphasises food consumption to maximize fruits & vegetables, food prices for trade, governance for transparency and accountability, and platform of interaction (Swinburn et al., 2013; Brinsden et al., 2013). This thesis takes inspiration from this initiative and adopts a broad conceptualization of governance that includes programmes, investments, and collaboration within and between different levels of government which directly and indirectly impact food and nutritional security; and the general quality of service delivery, including corruption. A multi-scale approach enables a cross examination of these aspects. While economic issues are discussed in the context of governance and visa-versa, trade is used as a separate lens as it primarily concerns systems that in a free market are minimally influenced by governments.

Studies have shown the link between governance and economic indicators is present (Apaza, 2009) and it has been argued that the broader issues of governance and affordability need to be addressed as they limit what personal responsibility can achieve (Donald, 2013). The role of effective governance in reducing inequality is extremely important in mitigating poverty and food insecurity (McKeon, 2011). Good governance has been connected to higher degrees of prosperity, better education, gainful employment, and freedom from hunger on a sustained basis (IFRI, 2001). Hunger has been significantly reduced in instances where national governments in the developing world have performed well (Paarlberg, 2002).

The stability of household incomes and food prices is of particular importance in improving food security and nutrition. With respect to nutritional issues, the literature has emphasized the importance of access and affordability to staple crops as the foundation for healthy, nutritional diets (IFAD, 2012; Lobell & Burke, 2010; Lotze-Campen et al., 2006; Von Braun et al., 2012). However, less attention has been paid to the cost of complimentary food items which are necessary for optimum health. The research in this thesis strives to address this knowledge gap by focusing on fruits & vegetables (mostly pulses) and their access and affordability.

Policy responses to improve food and nutritional security through fruits & vegetables are plentiful. They range from addressing wages and income through adjustments to subsidies and taxes (Brooks et al., 2008); to suggesting improved property and ownership rights (Agarwal, 1998; De Soto, 2000); to supporting women in delivering household nutrition (Cotula, 2006; Momsen, 2010; UNSCN, 2010; World Bank, 2010; Young, 2012); and to investments in the community and home production (Schanbacher, 2010; World Bank, 2010).

In more extreme cases, where there is increased variability in purchasing power, the government can implement targeted programmes in vulnerable households. These can include employment generation schemes (Sahn & Von Braun, 1989) or domestic food assistance programmes to either increase access to food or improve food choices and nutritional impact (Barrett, 2002). The third paper of this thesis makes use of a rural employment generation scheme while the fourth paper makes use of income expenditure on food as part of its model.

2.4.2 National Food Security Act

The 2013 NFSA expands upon the TPDS programme and seeks to ‘provide food and nutritional security by ensuring access to adequate quantity of quality food at affordable prices’ (Kishore et al., 2014, p.29). This ambitious flagship programme aims to provide subsidized food and improved access to nutrition for the poor by granting food subsidies to 75% of rural and 50% of urban households (Kishore et al., 2014; Kumar et al., 2014; Joshi, 2013; Rai et al., 2015). The three key challenges for implementation of the programme are: the identification of the poor and ensuring that subsidized food reaches those in need; a large subsidy burden which is used to generate employment through infrastructure and development programmes; and the sustainability of the scheme with the impacts of changing food baskets and climate change. Due to these constraints, and from the beginning of its conception, the idea of piloting the programmes in several locations and making swift policy changes has been emphasized (Joshi, 2013). In order to address the first challenge the third paper is informed by state level information using a corruption indicator and suggests mobile phones be integrated into programmes. The second challenge is addressed in the fourth paper through the suggestion of multi-district regional agricultural development strategies. The final challenge is confronted in the third and fourth papers with the inclusion of pulses in scale specific policy strategy, and through the consideration of extreme weather information (paper three) and rainfall (paper four).

The implementation of the act intersects with two key lenses of the thesis: scale and governance. A key challenge in implementing the bill is the identification of the poor and ensuring that subsidized food reaches the undernourished targets. In various incarnations, India’s TPDS has stood for decades as the chief policy instrument used by the government to address the food needs of its citizens (Rai et al., 2015). The Food Corporation of India buys food grains from farmers at an administered price (Minimum

Support Price or MSP) and arranges to sell these to consumers at subsidized prices by allocating the food grains to different states which in turn manage their TPDS. A state distributes to consumers through a network of more than 460,000 Fair Price Shops (FPS) in urban and rural areas throughout the country. Each shop covers a population of circa 2,000 people. The keystone of the TPDS is the placement of the Fair Price Shop Dealer and its relationship to both central and state level government. The central government is responsible for ensuring availability, acceptability, and affordability of food while the state is responsible for ensuring accessibility (Karmakar & Mukhopadhyay, 2014).

2.4.3 Corruption

It has been argued that India's food-based programmes undermine the ability to improve food security and nutrition (Karmakar & Mukhopadhyay, 2014). The government introduced the Targeted Public Distribution System (TPDS) in 1997 which created classifications of food grain beneficiaries and their entitlements based on monthly household income (Rai et al., 2015). The problem with this rationing system is that it has not given adequate attention to the delivery mechanism and corruption is present at Fair Price Shops (FPS) which are mandated to transfer food to the poor (Basu, 2010). There are leakages from the procurement process to the point of delivery at the Fair Price Shops (FPS) in addition to poor infrastructure for the storage of procured food grains (Rai et al., 2015). As a result, it is estimated roughly 45-55% of all food is lost. Unfortunately, there are few rigorous studies on the TPDS and its impact on calorie intake, food security, nutrition, or household welfare (Kishore et al., 2014).

Some advocate the development of new arrangements to overcome these issues. Speculation concerning the most effective form of intervention include: a variant of the targeted public distribution system; issue of food stamps to targeted groups; open market sale of food grains by the Food Corporation of India; or a combination of all these measures (Karmakar & Mukhopadhyay, 2014).

An e-governance adaptation could be one solution to limit leakages (Masiero, 2015) with the possible implementation of a cash transfer system based on biometric identity and multi-purpose smart cards (Svedberg, 2012). Some argue that due to unavoidable market corruption, the best solution involves selling food to traders who ultimately deal directly with the consumer. This system requires a voucher realized through a smartcard or direct banking connected to a phone (Basu, 2010). The idea of a switch to smartcards or food coupons will make the current distribution system irrelevant as there is no need for the food grain trade to be channelled through the government. (Basu, 2010). There have been examples of some women, often the prime distributors of household food, preferring to obtain rations from Fair Price Shops rather than cash deposits to their banks (Kishore et al., 2014). In addition, mobile phones have been championed in rural areas (Lumpkin, 2013). This is noteworthy as India has 600 million unique cell phone users, of which 370 are in rural areas (Landes & Hjort, 2015). Corruption is addressed in the third paper through a TPDS programme indicator. Data availability is scale dependant and is only possible at the state level in India. Furthermore, the paper illustrates state-wide mobile phone potential for programmes.

2.4.4 Urbanization

The link between food security and inequality is more apparent with global urbanization trends, particularly in developing countries with large populations such as India (Dreze & Sen, 1989; Harris-White, 1999). Food researchers note the trend of urbanization across much of the developing world and the movement of many agricultural labourers to rapidly expanding centres (FAO/Transparency International, 2011).

Urbanization is strongly linked to food availability through the challenge of enhancing food supply for the most vulnerable while increasing incomes and ensuring other entitlements for food in new settings (FAO, 2006). It is encouraging that urban agriculture initiatives are gradually expanding into the developing world, particularly across Asia, to partially mitigate these stresses while fostering nutritional access and quality, community development, and economic independence (Gottlieb & Fisher, 1996; Guitart et al., 2012; Hardman & Larkham, 2014; Zezza & Tasciotti, 2010). The second paper touches on these as being particularly salient for nations which are undergoing a nutritional transition due to mass urbanization and facing issues of calorie and micronutrient malnutrition (such as India), and more developed countries (such as the UK) which are dealing with obesity.

2.4.5 Rural Development and Climate Change

The challenges of urbanization are compounded by a series of rural investment, production, market, and distribution issues (FAO, 2006). Many of the poorest live in remote areas disconnected from the world food markets. Rural farmers, who often live close to the line of being both net food consumers and producers, are affected in complex ways by a price increase (Godfray et al., 2010). In rural areas national government action is important in achieving, at minimum, basic *Green Box* measures. These measures range from those directed at the agricultural sector such as investments in research and development and market inspection, to indirect measures such as rural roads, telecommunications, education, and healthcare (Tutwiler & Straub, 2007). Understanding the closely related factors of effective governance in creating and maintaining rural development, and the presence and nature of corruption and social discrimination, is important in capturing poverty and food insecurity (IFPRI, 2001; McKeon, 2011; Tutwiler & Straub, 2007).

There is a direct correlation between improvements in governance and agricultural investment (FAO, 2012). Internationally, the improvement in storage facilities is essential as it is estimated that 30-40% of food is lost to waste due to poor infrastructure and/or lack of cold storage (Godfray et al., 2010). Furthermore, research shows that supermarkets and retail chain infrastructure do not necessarily guarantee food due to impact on smallholder chains (Humphrey, 2007), food deserts (Donald, 2013), and poor evidence that people will actually purchase healthy food if retail outlets are built (Wrigley et al., 2003). In India these challenges are palpable. Food supply chains need to be improved for better linkages between small farmers and consumers, prompting suggestions for experimenting with different supply chain and institutional models. The national government might play a decisive role in implementing models which are efficient and contribute to small farmer productivity and income (Gandhi & Jain, 2011).

Infrastructural challenges and food waste contribute to the problem and those states with the best cold storage facilities for fresh produce are not immune (Barne & Ramachandran, 2002). It is estimated that 35-40% of fresh produce in India is lost because neither wholesale nor retail outlets have cold storage. This is despite the fact the Food Corporation of India maintains a buffer stock. (Rai et al., 2015). In response, a panel appointed by Narendra Modi recommend the NFSA increase cold storages (Gupta & Dash, 2015). Infrastructure addressed at the state level in the third paper provides insights into which states might be able to store large amounts of pulses for distribution.

Climate change can affect each aspect of food and nutrition security because of the dependence of food systems on the mean and variability of the weather (Lobell et al., 2011). Agricultural productivity has been negatively impacted in light of temperature and precipitation increases due to climate change (UK Office for Science, 2011). This often results in extreme weather scenarios such as erratic changes in temperature, seasonal timing shifts, inconsistent rainfall totals and patterns, and reduced crop and livestock performance yields (Birdlife, 2009; Easterling et al., 2007; UK Office for Science, 2011).

Studies show that improving irrigation is the most important factor in increasing pulse yields in India (NCAER, 2014). Water resources are expected to be threatened by scarcity caused by climate related alterations in rainfall, surface water availability, and water quality (UNSCN, 2010). It is crucial to note that areas currently suffering from food insecurity are expected to experience the most negative impacts from a variety of situations including: climate change on agricultural production (Beddington et al., 2011; Segre & Gaiani, 2012) and social disturbances in rural areas (UNSCN, 2010).

Food systems are entangled with many dimensions of human and natural systems at multiple levels and time frames. Ultimately, governance challenges are generated by many factors, including climate change (Ericksen, 2008). The development of the agricultural sector (McKeon, 2011), wider rural infrastructure, and research and development are important (Tutwiler & Straub, 2007). As a result, extreme weather events are included in the state food potential model and irrigation investment strategies have been included as recommendations in the third paper. Rainfall concerns are taken into consideration in the fourth paper.

2.4.6 Collaboration

The vacuum caused by urbanization and poor governance in developing countries enabled a series of dynamic organizations to act in a series of diverse policy environments. A significant trend in contemporary food systems is the increasing importance of hybrid forms of governance (Paarlberg, 2010; Schilpzand et al., 2010). A multi-scale approach enables broad research to uncover possible productive collaborations for food and nutrition programmes.

Indian states and districts face unique food and nutritional challenges which are linked to the central government. Critics note the absence of information and awareness due to the lack of a national nutritional programme (Rao, 2015). The argument suggests that without a national programme of inter-sector monitoring, interventions on the ground become difficult in the absence of a guiding design or principle (Rao, 2015). Compounding this is a general lack of think tanks, research, and capacity building organizations at state and district levels (Rao, 2015). The development of more targeted regional strategies has been discussed for quite some time (Gaiha, 1999). The third and fourth papers each suggest the development of regional food security and nutrition strategies in tandem with the NFSA. These would require groups of states and districts to work together based on their resources and geographic position.

A common approach internationally when addressing nutritional issues across disparate sectors is to create national multi-sectoral nutrition planning agencies. Often without real authority over the range of sectors involved, they prove ineffective in coordinating efforts across these sectors (The World Bank, 2010). A remedy, albeit only if granted sufficient authority and resources, is the creation of cross-sectorial coordination bodies. Such institutions ensure that incentives are introduced to motivate sector institutions to prioritize activities and allocate resources targeting improved nutrition (World Bank, 2010).

Unfortunately, in India district and state linkages to a wider national effort are unclear (Rao, 2014). However, Karnataka is the first Indian state with a nutrition mission (Paarlberg, 2012) along with initiatives to combat malnutrition and monitor multi-sectoral programmes such as anaemia control. It intervenes in target groups such as children under the age of three, pregnant and nursing mothers, and adolescent girls (Rao, 2013a) and collaborates with state government organizations (Kadiyala et al., 2014). The fourth paper builds on this policy environment by including information on target groups (pregnant women) in the health indicator of the nutritional HDI. It also links potential district and state policies in Karnataka to the national effort.

2.5 Food Security and Nutrition Indicators

Food and nutrition security has been defined as a condition under which adequate food (quantity, quality, safety, socio-cultural acceptability) is available and accessible and satisfactorily utilized by all individuals at all times to live a healthy and happy life (Weingartner, 2010). Food system and nutritional health indicators have been used by a variety of international organizations, academics, and governments. Some commentators have noted that historically the search for viable indicators is driven by the lack of a ‘gold standard’ measure for food security. As a result, consumption, malnutrition, and assets/ income have all been extensively used (Maxwell et al., 1999). There has been a continuing debate about indicators, their measurement, and limits to their reliability (Wiesmann et al., 2002). While food availability was emphasized historically, measures which only focus on it neglect unequal distribution and uses of food within populations (Barrett, 2010). As such, multiple measures are required to effectively capture the complex dimensions of food security (Hendriks, 2005). In response to these challenges, research is including more survey-based anthropometric and perceptions information (Barrett, 2010). The FAO Committee on World Food Security maintains that despite extremely daunting logistical hurdles, it is essential to have information from large countries such as India at sub-national or regional levels (FAO, 1997). Indicators are useful to those who wish to create a study which can lead to an improved understanding of the problem such as governments, international organizations, and academics. It is an important step before appropriate policy can be created, tested, and implemented. This section is concerned with the conceptual foundation for the indicators employed in latter chapters of the thesis.

2.5.1 Nutritional Indicators

The most common indicators have traditionally explored food security from a consumption perspective (Bouis, 1993) and form the main food security benchmark (Chung et al., 1997), with two branches of study being caloric intake and dietary diversity (FAO, 2015a). Beyond consumption, further indicators consider the anthropometric status of individuals to determine food system impacts on health outcomes.

The most common calorie or energy-based indicator is the FAO's *average dietary energy supply adequacy* (FAO, 2015a). It gives an estimate of adequacy of food supply for calories (FAO, 2015a). Most countries frequently generate and update the data required for this indicator as it is inexpensive (Perez-Excamilla & Segall-Correa, 2008). While it gives insight into overall consumption potential it does not capture nutritional needs or distribution. Specifically, dietary quality is not taken into account, distribution at the household level cannot be ascertained, it assumes caloric consumption above minimum thresholds indicate food security, and it establishes an average per capita caloric requirement cut-off without considering physical activity levels, gender, and age (Perez-Escamilla & Segall-Correa, 2008). Furthermore, there is a high degree of measurement error and data is often of questionable validity (Perez-Escamilla & Segall-Correa, 2008). It had been commonly paired with the *prevalence of undernourishment* (POU) indicator which attempts to cover these gaps (FAO, 2015a).

The *prevalence of undernourishment* indicator was first introduced in 1961 and is the official indicator to evaluate the goals of target 1C of the first Millennium Development Goal to eradicate extreme poverty and hunger (Cafiero et al., 2014). POU is used by the FAO as its classic food security indicator and is present in annual hunger maps published by the organization (FAO, 2014). It captures three parameters: the mean quantity of calories available for human consumption, the inequality of access to those calories among the population, and the mean minimum amount of calories required by the population (Haen et al., 2011). The indicator has been criticized as not capturing dietary diversity (Babatunde & Qaim, 2010), due to cut-offs which underestimate malnutrition (Svedberg, 2002), and the use of data which is not necessarily robust (Svedberg, 2000). The indicator seems to have a central position as it confirms the FAO's idea of calories being the starting point and most important aspect of food security as implied through the plurality of its indicators (FAO, 2015a). This is further confirmed through its long history and extensive use by multiple UN agencies.

Recently, a *prevalence of food inadequacy* indicator has been added that is conceptually analogous to the *prevalence of undernourishment*. It increases physical activity caloric requirements to the medium level to include those who are likely to be conditioned in their economic activity by insufficient food (FAO, 2015a). Complimentary indicators selected by the FAO in their core group include: *depth of food deficit* and *percentage of the population under the daily minimum energy supply* (FAO, 2015a). Developed by the organization, these indicators often suffer from data gaps due to the challenges of global data collection.

Dietary diversity indicators have also been explored. The FAO has drawn upon the *share of dietary energy supply derived from cereals, roots and tubers, average protein supply*, and *average protein supply of animal origin* (FAO, 2015a). The concept is rooted in capturing the number of unique foods consumed over a given period of time (Hoddinott & Yohannes, 2002). It correlates with measures of food consumption and is a good measure of food access and caloric availability (Hoddinott & Yohannes, 2002). A more varied diet increases acquisition of micronutrients and is associated with improvements in standard nutrition indicators such as: *birthweight* (Rao et al., 2001), *child anthropometric* *status* (Hatloy et al., 2000), *improved haemoglobin concentration* (Bhargava et al., 2001), and *reduced risk of mortality from cardiovascular disease* (Kant et al., 1995).

Despite agreement regarding the importance of dietary diversity, there are a variety of constructions of this measure. Counting the number of food groups consumed, whether in groups of eight in the food consumption score or ‘FCS’ (Hatloy et al., 1998; WFP, 2008) or the 12 used to construct FAO food balance sheets known as the household dietary diversity score or ‘HDDS’ (Kennedy et al., 2011; Swindale & Ohri-Vachaspati, 1999), occurs over 24 hour recalls and other reference time periods using food records and composition tables (Perez-Escamilla & Segall-Correa, 2008). Dietary intake studies measure actual food consumption and cover both dietary quality and quantity. Unfortunately, they are high cost, there is a high variability in food and nutrient intakes and memory recall biases are often present (Perez-Escamilla & Segall-Correa, 2008). The FCS produces a richer consumption profile over a longer reference period but takes longer to assemble (WFP, 2008). In contrast, the HDDS provides a clear picture at the population level and is useful when time and resources are limited (Kennedy et al., 2011). However, both measures assign weights to all food groups which leaves open the possibility of awarding a high score to an unbalanced diet lacking in essential nutrients.

In areas with fewer resources, information of food item purchases obtained through household expenditure surveys can be interpreted to ascertain nutritional consumption. While this method identifies vulnerable households and takes into account dietary quality there are some drawbacks. Unfortunately, the method measures food availability but not necessarily consumption and cannot measure foods consumed outside the household. Furthermore, it is difficult to standardize methodology across countries and surveys are expensive and logistically difficult to undertake (Perez-Escamilla & Segall-Correa, 2008).

Anthropometric indicators have been used by a number of studies to capture the direct impact of food insecurity on the health of vulnerable groups. The global hunger index used by IFPRI, Concern Worldwide, and Welthungerhilfe use these at the core of their study (IFPRI, 2013; Von Grebner et al., 2010). The approach is consistent with the positioning of non-profit and advocacy organizations which are concerned with direct interventions to improve the health of individuals. Presently, the global hunger index is used solely to rank developing countries based on arbitrary cut-off points (Masset, 2011). Two anthropometric indicators: *percentage of the population that is malnourished*, and the *percentage of malnourished children under five*, are combined with the *percentage of children who die before the age of five* (Von Grebner et al., 2010).

The *percentage of malnourished children under five years of age* is often considered the most objective indicator, with well documented and standardized methodology for age, height, and weight of children (Bodnar, 2011). It is generated by UNICEF and has been adopted along with the *prevalence and number of undernourished individuals* as core indicators of the United Nations MDGs (Cafiero et al., 2014). Amongst nutritional deficiencies that result in anaemia, iron deficiency is frequently a contributing factor (Moron & Viteri, 2009), and is included as a component of many indicators. Anthropometric indicators have some positive attributes such as being highly standardized, inexpensive, and frequently applied in national surveys. Unfortunately, some have noted that due to similarities between the indicators double counting is possible (Masset, 2011). It is difficult to use them to draw conclusions regarding the obesity component of malnutrition (Perez-Escamilla & Segall-Correa, 2008) and they do not cover specific nutrients that might be deficient (Svedberg, 2011).

The fourth chapter of this thesis builds on these issues. In the first instance, the caloric minimums which are emphasized in major food system and nutritional studies are expanded. Congruent with the recent FAO initiative, this chapter examines nutritional requirements for medium rather than low activity individuals. In addition, dietary diversity is expanded beyond the indicators: *energy supply from cereals, roots and tubers* and *average supply of protein of animal origin*. Making use of the FAO's food balance sheets (Swindale & Ohri-Vachaspati, 1999), the chapter computes food item information into four main food groups required for nutritional health (WHO, 2000).

2.5.2 Additional Food System Indicators

Economic indicators are used by studies to predict the potential for adequate food to be secured, both by governments and citizens. A number of economic indicators are relevant to food access. These indicators capture the purchasing power of families and determine if they can acquire food via production, income generation, or transference (Moron & Viteri, 2009).

Income and price indicators have been used to give a general picture. *Gross domestic product* (GDP) is typically listed by food systems and nutritional studies (FAO 2015a; EIU 2015). A collection of related indicators which explore food prices are important: *food price index for consumers*, *price of the basic food basket*, and *percentage of income allocated for purchasing food* (Moron & Viteri, 2009). In defining food security indicators the FAO has built on this foundation to emphasize *domestic food price index*, *domestic food price variability*, and *share of food expenditure of the poor* to explain microeconomic dynamics impacting food access (FAO, 2015a). It is essential to note that the majority of small farmers are situated between net production and net consumption and often do not benefit from high food prices (Naylor & Falcon, 2010). There has been a movement at the vanguard of food security indicator development which emphasizes *presence and accessibility of local markets for marginalised groups*, along with *access to microfinance and credit* (Oxfam Australia, 2014). Although these have yet to be adopted into active indexes, Oxfam has been a leader in this respect, as the consideration of broad structural factors to poverty are inclusive of microeconomic indicators in its model (Oxfam Australia, 2014).

The third paper of this thesis captures food access issues. Given that higher food prices are not linked to improved conditions for vulnerable smallholders a different approach is taken. The indicator of minimum agricultural wage covers this issue and expands on *gross domestic product* to identify economic constraints on those made vulnerable by an economic reality of subsistence agriculture. The fourth paper takes food consumption expenditure information and links it to the income aspect of the Human Development Index (HDI).

Food supply is linked to trade in indicators. Macroeconomic stability of external and internal trade balance are important factors for food availability (Ecker & Breisinger, 2012). The FAO analyses the dynamic using *per capita food production variability, per capita food supply variability*, *cereal import dependency ratio*, and *value of food imports over total merchandise exports* (FAO, 2015a). Markets would be more readily accessible for consumers through adjustments in domestic trade regulations combined with modifications to import and export barriers (Bodnar, 2011). The second paper of this thesis notes the importance key indicators have given to trade relationships and food supply. It interacts with the international system using FAO food balance sheets to determine the trade and supply characteristics of key food groups required for nutrition (WHO, 2000).

Infrastructure and logistical indicators have also been included with food system and nutrition concerns in mind. This aspect has been regularly tied to increases in production volume through developments in irrigation and roads (Bodnar, 2011). The *percentage of paved roads, road and rail line density* are used by the FAO and other large studies (FAO 2015a; EIU, 2015). A gap is present in that further food system information regarding food production, distribution, and health are not yet explained. *Access to improved water sources* and *sanitation facilities* are often included in research (FAO 2015a; EIU 2015; Oxfam 2014). Despite advances, data on cold storage facilities, which are essential for the effective transport of many crops, is not present in studies.

Agro-ecological indicators have been shown to be important as they interact with various aspects of the food system such as natural resource management and poverty (Pangaribouwo, 2013). Oxfam's Monitoring for Better Impact (MoBI) food security indicators include: *percent of arable land equipped for irrigation relative to water resources*, along with a growing movement to consider *general ecosystem health* (Oxfam Australia, 2014). The inclusion of these indicators is consistent with Oxfam's commitment to examine and mitigate structural obstacles to poverty (Oxfam, 2016). The Famine Early Warning Systems Network (FEWS NET) makes use of information from real-time satellite rainfall records, the normalized difference vegetation index, and temperature records (Jones et al., 2013). Unfortunately, the purpose of the organization is to report for 25 countries and mostly (but not exclusively) works to avert emergency famines (Jones et al., 2013). Similarly, academics have also explored the link between the environment, infrastructure, and development. In particular, changes in temperature and precipitation due to climate change have been explored (Lobell et al., 2011).

Governance indicators for food security and nutrition have not been extensively developed. Despite this, the discussion increasingly supports the importance of this aspect to the food system and nutritional outcomes. A series of government interventions are possible which can directly and indirectly improve food security. Strategies are suggested which aim to increase production through research and extension, inputs, irrigation, or reorganization of producers and markets (Bodnar, 2011).

Observers have noted that governance is only available at the national level (Cicone et al., 2002). This emerging section of studies typically focuses on qualitative measurements of governance culture and the perception of policies. Many studies have borrowed directly using general non-food and nutrition-specific governance indicators. Here, the World Bank's set of Aggregate Government Indicators for nations based on: *vice and accountability*; *political instability and violence*; *government effectiveness*; *regulatory burden*; *rule of law*; and *graft* (Kaufmann, 1999) are referenced to provide a metric of governance (Cicone et al., 2002). The FAO records *political stability* and *absence of violence/ terrorism* in its core group (FAO, 2015).

The Economist Intelligence Unit (EIU) has made an extensive list of governance indicators drawing mostly from its own non-survey based estimates and spread throughout the three categories of affordability, availability, and quality and safety (EIU, 2015). These include: *presence of food safety net programmes*, *access to financing for farmers*, *political stability risk*, *national dietary guidelines*, *national nutrition plan or strategy*, and *nutrition monitoring and surveillance* (EIU, 2015). However, critics have noted that it is not clear that these indicators are more effective than others in explaining food security and that these aspects can become obfuscated by the overall scores produced by the index (Pangaribowo et al., 2013). As the magazine's readership is largely interested in the intersection between economic and political affairs (including governance), the use of a significant number of governance indicators in the EIU's model is consistent with the overall mission and target audience.

The most extensive food security governance work has come from the International Network for Food and Obesity/ non-communicable disease Research, Monitoring and

Action Support (INFORMAS), which functions as a global network of organizations and researchers (Brinsden et al., 2013; Swinburn et al., 2013). The organization created a public sector module that determines how much progress different levels of government have made (Brinsden et al., 2013; Swinburn et al., 2013). It created a series of domains based on good practice and benchmark statements for food consumption, food prices, governance, along with a platform of interaction between the previous three (Brinsden et al., 2013; Swinburn et al., 2013). The drawback of this framework is that it is geared solely towards obesity, and hence its applicability is slanted towards more developed nations.

2.6 Agriculture to Nutrition

2.6.1 Strength of the Link

The Scaling up Nutrition Movement was launched in 2010 and calls for two kinds of actions to improve nutrition. The first is direct or nutrition-specific interventions that affect the immediate determinants of nutrition (food/nutrient intake and disease) and the second is nutrition-sensitive developmental interventions that affect the underlying determinants of adequate nutrition, of which a major contributor is agriculture (Herforth & Dufour, 2013). Recently, expansion of the concept included a third component of cultivating, strengthening, and sustaining enabling environments to support all nutrition relevant actions (Gillespie & Mergetts, 2013; Thompson & Amoroso, 2011).

The agricultural sector offers the greatest potential for achieving sustained improvements in the nutritional status of the rural poor and benefits include general economic growth, increased farm productivity, and greater market access (Thompson & Amoroso, 2011). The nutrition-sensitive approach expands the scope of the agro-food system to encompass all elements from input delivery and production of food, to distribution networks, storage, processing, retail, and utilization including consumption

(Jaenicke & Virchow, 2013). The third paper considers input delivery inclusive of e-governance. It identifies high yielding areas of production, illustrates cold storage infrastructure potential, and explores possible distribution relationships for Indian states. The fourth paper addresses high yielding areas of production and explores possible regional distribution strategies (e.g. agglomerations) in Karnataka.

A number of recent literature reviews, which collectively evaluate thousands of studies, suggest that agricultural interventions aimed at improving nutritional status have mixed results (Arimond et al., 2011; Webb & Kennedy, 2012; Masset et al., 2011). Empirical evidence confirming positive net impacts on nutrition outcomes is scarce. Where positive impacts have been documented, mechanisms are poorly articulated. This reflects partial, imperfect knowledge of the links along the chain from agriculture to nutrition (Webb, 2013). It is not always clear if a change in production will improve or worsen nutrition and health (Hoddinott, 2012). Despite the drawbacks, agricultural interventions have been successful in promoting consumption of specific foods (Masset et al., 2011). In particular, interventions that have deflated fruits & vegetable prices and emphasize education generally increase the consumption of these foods (Waterlander et al., 2013). In India, the link between agriculture and nutrition has mostly focused on the connection between policy and food prices (Gillespire et al., 2012). However, it has not been determined if lower prices for cereals help or hinder diet diversification, or if the TPDS has any impact on nutrition (Kadiyala et al., 2014). The third and fourth papers begin the process of studying the Indian food system with nutritional goals. The methodologies and models are constrained by data availability but serve as blueprints and proxies for use in future studies.

Improved evaluations are necessary and the absence of evidence is not the same as the absence of impact (Ruel & Alderman, 2013). There is a need for additional and better designed research (Arimond et al., 2011) and it is advisable for nutritional indicators to be included in evaluations of agricultural programmes (IFPRI, 2011). It has been acknowledged that casual chains are long and complex. Sets of regressions outlining how agricultural actions and contexts are related to income, food consumption, and nutrition have been proposed (Meeker & Haddad, 2013).

In India, there is a dearth of unit-level data that contains information on both agriculture and nutritional outcomes which limit the rigour of research (Kadiyala et al., 2014). This is manifest in a data disconnect where nutrition surveys typically omit agricultural, and often food consumption information, while agricultural and economic surveys function in similar fashion for anthropometric outcomes (Gillespie et al., 2012). It is important for research to expand beyond ways of maximizing household calorie consumption to also include dietary diversity (Kadiyala et al., 2014). The third and fourth papers approach this gap by merging agricultural and food system indicators and information with nutritional and dietary data. The models reveal areas where nutritional data can be improved upon relative to production and commodity trade information. The third paper could benefit from information on the intra-state trade in pulses. More detailed yield and weather information would also be useful at finer scales beyond state and district levels. In the fourth paper, pulse and cereal consumption in Karnataka, which is inferred from consumption expenditure information, could also benefit from surveys which also record production volume, price, and quality. Presently much relevant data is not available.

2.6.2 Agriculture and Nutrition Collaborations

Integration of agriculture and the food system with nutrition and health outcomes is often difficult due to the lack of capacity for cross disciplinary integration between government specialists (Gillespie & Margetts, 2013). A number of pathways forward have been identified for governments. These include: incorporating nutrition objectives into their design; targeting the vulnerable and improving equity; maintaining and improving the natural resource base; and improving processing/storage/preservation (Herforth & Dufour, 2013). Paper one addresses the need for the first path by building on an EIU indicator for the presence of health and nutritional strategies. The second paper also encourages governments to improve their trade and development strategies based on nutritional surpluses and deficits revealed by the food group dietary supply model.

In India, increases in the production of pulses and infrastructure development to ensure proper food storage, is encouraged to improve the food security of the country (Basu, 2010). The third and fourth papers address the maintenance of the resource base by recording agricultural land impacted by extreme weather events and irrigation issues. Improvements in preservation are touched upon by examining cold storage potential in the third paper. In the fourth paper vulnerable groups, specifically pregnant women with anaemia, are directly incorporated into the nutritional HDI.

Governments might pursue two kinds of policy action. They could change the behaviour of farmers, consumers, food processors, and other economic agents in the system through incentives, regulations, and knowledge. Governing bodies could also accept present behaviours and introduce health-specific and nutrition-specific interventions to compensate for any nutritional damage incurred or lack of improvements (Pinstrup-Andersen, 2013). For countries where diets are low in both calories and micronutrients, the most common government action is to provide missing public goods (IFPRI, 2011). At the next stage of the dietary transition, when most people in a country consume basic adequate calories, the main task is to deliver services such as income and nutrition safety nets for the urban poor (IFPRI, 2011). The final issue concerns the problem of obesity (IFPRI, 2011).

The most apparent agricultural intervention in nutrition comes through social safety nets. This can take the form of programmes that distribute transfers to households or specific vulnerable members in need through cash or food (Ruel & Alderman, 2013). The majority of civil society, industry, and government officials in India recognize that the contribution of agriculture and the food system to nutrition is limited. This is due to an emphasis on wheat and rice rather than pulses and other foods (Gillespie et al., 2015).

2.6.3 Value Chains

The agriculture and nutrition sectors have tended to operate in separate spheres. A nutrition-sensitive growth strategy could increase demand for, and access to, nutritious foods along the value chain through investments in safety nets and education, nutrition, and health programmes (IFPRI, 2011). This value chain offers opportunities for improving nutrition by determining food availability, food prices (affordability), and food (nutrient) quality (IFPRI, 2011). It is important to identify and narrow the nutrition gaps by first assessing their locations (Thompson & Amoroso, 2011).

Based on current food availability it is only theoretically possible for people to consume enough calories but not maintain nutritious diets (Herforth & Ahmed, 2015). To illustrate, fruit & vegetable availability cannot meet population dietary recommendation in most countries (Siegel et al., 2014) and pulse availability (one of the most significant plant protein sources) has declined globally as a proportion of calories consumed (Khoury et al., 2014). Expensive healthy diets are best mitigated through the lowering of prices of micronutrient rich foods rather than of staples. Results suggest that own-price elasticities rather than cross-price elasticities have a much larger impact on consumption of specific food groups (Herforth & Ahmed, 2015). Furthermore and significantly, it is generally perceived that greater access to fruits & vegetables is associated with increases in consumption (Caldwell et al., 2009). These results support research into strategies that focus on including pulses in the NFSA framework at the state and districts levels.

One idea takes advantage of untapped potential to leverage value chains to improve nutrition. It builds on food supply chains by adding value for chain actors involved with production, processing, distribution, retailing, promotion, labelling, and consumption (Ruel & Alderman, 2013). This strategy is ideal for inclusion at finer scales as discussed in this thesis. As value chains focus on one food at a time, this approach is relevant for the third and fourth papers which address pulses specifically. Efforts to integrate nutrition into value chains should therefore focus on measures which address the specific dietary and nutrition gaps identified in target populations (Ruel & Alderman, 2013). The second paper identifies food group surpluses and deficits (including fruits & vegetables) for 145 nations. The third and fourth papers provide suggestions to increase overall Indian pulse consumption through the strategic management of resources in states and districts. This supports the position of some critics who advocate for a more decentralized system where states would be given more influence (Karmakar & Mukhopadhyay, 2014). Again, the idea of testing and assessments within a time frame of roughly the next decade has been suggested (Ruel & Alderman, 2013). The NFSA stands as an opportunistic case study for the wider development of the discourse as it is in a nascent stage of development.

2.6.4 Sustainable Intensification

Sustainable intensification is a strategy whereby agricultural holders aim to produce more food from the same area of land while reducing environmental impacts (Watson, 2011). Researchers who support increased production of food have specifically targeted improving the productivity of crop yields. This evolves from the realization that the competition for land makes an increase in cultivation unlikely and costly (FAO, 2011; Godfray et al., 2010). Significant debate exists between technologists and environmentalists regarding this method of agricultural development (Paarlberg, 2010). A moderate position argues that a combination of community based innovation derived from local agricultural knowledge and increased production from technologies developed by agricultural science, is the most favourable path to address the needs of the rural poor (IAASTD, 2009).The third and fourth papers of this thesis argue that current production efficiencies in Indian states and the districts of Karnataka could be harnessed to improve pulse production. While not emphasized, this thesis advocates possibilities to achieve a balance between biodiversity conservation and food production, where food is produced in a sustainable manner and conservation does not greatly limit crop yields (Gabriel et al., 2013).

Although investments to enhance agriculture production and boost global food supply are crucial for long-term reductions in hunger, they might not solve scarcity of access to nutritious and diverse diets (as opposed to scarcity of calories) that many people face (Ruel & Alderman, 2013). To illustrate, evidence shows that agricultural growth is associated with increases in calorie consumption but does not necessarily result in more diverse diets (IFPRI, 2011). In addition, agricultural growth is often associated with reductions in malnutrition with the notable exception of India (IFPRI, 2011). A popular explanation, argued by over 20 Indian authors, suggests that corruption has caused a failure in governance (Haddad & Zeitlyn, 2009). The third paper considers this issue by including corruption as an indicator in the state food potential model. It also proposes the use of technology to reduce leakages. Addressing this concern is potentially game changing as it has the potential to re-orientate the discussion on agricultural development for nutrition in India.

2.6.5 Literature Review Summation

The literature review provides an overview of the current discourse on scale, nutrition, trade, and governance, and their interaction with the four papers as analytical lenses. The complimentary themes of food security and nutrition indicators and the link between agriculture and nutrition are also discussed.

Multi-scale analysis encourages strategies to increase plant-based protein consumption across scales and is designed to enable new collaborations between policy makers. Geographers have conceptualized scale to interact with food-specific frameworks such as foodscapes, foodways, foodsheds, and moral economies of food. The importance of nutrition to food security requires new approaches to address the triple burden of malnutrition and the urban and rural challenges that accompany nutrition transitions. The development of trade strategies which move beyond the export of essential fruits & vegetables from developing countries is essential. In addition to reform of WTO architecture, the emergence of dynamic trade blocs and attention to the relationship between trade, price, and income are desirable. Governance interventions (for programmes such as the NFSA) might develop cross-scale collaboration to reduce corruption, target vulnerable groups, and respond to food system challenges posed by infrastructure limitations and climate change.

Food security and nutrition indicators are used by a variety of actors despite the lack of a gold standard measure. A move towards more balanced nutritional information which incorporates robust dietary diversity and anthropometric survey data is desirable. Complimentary food system indicators should strive to capture macro and micro economic factors in addition to infrastructure, agro-ecology, and governance. The possibilities for applying these indicators are encouraging, as agriculture to nutrition interventions have shown promise but are in need of more vigorous development. The NFSA is a relevant case study to explore how indicators can be developed to influence value chain, nutrition-sensitive, and sustainable intensification strategies to improve nutritional outcomes.

The analytical lenses and complimentary themes discussed in the literature review represent an integrated set for improving the understanding of food security and nutritional health beyond existing research. The following methodology chapter outlines the methods and datasets used in addressing the research questions posed in each of the papers.

Chapter 3. Methodology

3.1 Description of the Research

This thesis is based on a series of investigations into how multi-scale approaches to food security and nutrition studies can be used to illuminate and clarify concepts, data, and policy to advance nutrition, trade, and governance as analytical lenses for improved food security. It interrogates food security and nutrition studies and policies in order to generate more robust analysis. The dissertation is a combination of qualitative analysis and quantitative datasets employing food, nutritional, and related information.

A multitude of food and nutritional studies exist which have been produced by international and Indian researchers. This chapter systematically reviews the construction of the four papers included in this dissertation. It references how each dataset has been used by food researchers, includes particular strengths and weaknesses of the content, and the similar methodological approaches used by researchers. It describes the methodological process employed by each paper in the thesis.

This thesis explores a number of datasets addressing food security and nutrition situated at the international, national, state, and district levels of analysis. The first group is concerned with international or universal conceptions of food security. A multi-scale approach allows for a Food and Agriculture Organization of the United Nations (FAO) conceptualization of food security to be interrogated at the international, supra-national level (EIU, 2015). Similarly, Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT) data are used to enable cross-national food comparisons using food balance sheets and complimentary information gathered by international partners (e.g. World Bank) (FAO, 2015a). Information is also collected from Indiastat webpages and Indian government survey reports (Directorate of Economics and Statistics, 2012). These results are used to compare states across their food system. District level nutritional data are restricted to consumption expenditure information from those districts included in the latest National Sample Survey (NSS) (NSS, 2014). District Level Household and Facility Survey (DLHS) information includes data on nutritional impacts (MHFW, 2013).

3.2 International Food Security and Nutrition Studies

3.2.1 Paper 1: Towards a Holistic Approach to Food Security Data: Going Beyond FAOSTAT

3.2.1.1 Methods

In order to answer the first question, ‘To what extent has the FAO’s conceptualization of food security helped or hindered international food security studies?’ a process benchmarking methodology was used. This method directly compares the activities of one organization with another recognized industry leader (Tuominen, 2012). It is well established when studying public service performance but has been only recently integrated into food and agricultural studies (Brinsden et al., 2013; Swinburn et al., 2013). In implementing the method, the first resource accessed was FAOSTAT- the database of the statistics division of the FAO situated at the international level. Its core group of food security indicators were drawn upon to generate a comparative benchmark. These were critically approached and compared with the Economist Intelligence Unit’s (EIU) group of indicators. The study, category, indicator used, data collection method, and timescale were recorded in tables for direct comparison with EIU stand-alone indicators. A total of nineteen indicators were analysed. A discussion section finalized any conceptual or methodological disconnects which might be present and also referenced best practice benchmarks from partners (e.g., WHO). The paper effectively uncovered the process by which food security indicators are consistently developing, both conceptually and methodologically.

This paper closes the research gap by introducing a more robust process benchmarking approach, analysing the FAO’s core set of food security indicators, against a governance centred international food study (the Economist Intelligence Unit’s *Global Food Security Index*, 2015). The fundamental goal of the paper is to broaden the base of international food security conceptualization, as there is no uniformity of indicators in publications. The study is limited in the sense that benchmarking is an ongoing process and, it is inevitable that any findings regarding best practice will be eclipsed in the near future. Furthermore, the rapid development and likely integration of governance indicators into food and nutritional studies is certain to continue irrespective of findings.

3.2.1.2 Background

This paper begins with food and nutritional indicators at the international level of analysis representing the conceptualizations of the global research community. It notes that benchmarking in food security and nutrition studies has recently been pioneered with a strong connection to governance. The initiative has yet to be implemented in large cross-country holistic food and nutrition studies. Two large food and nutrition benchmarking initiatives have been developed recently. The first is an approach used by the World Health Organization (WHO) called International Network for Food and Obesity/non-communicable disease Research, Monitoring, and Action Support (INFORMAS). The second was created by the United Nations Millennium Development Goals (UNMDG, 2012a, b, c). Each is explored in greater detail in the following sections.

The WHO identifies the reduction of obesity and diet-related non-communicable diseases as a key programme goal. A number of researchers explore and subsequently develop new benchmarking methodologies which centre on *healthy food environments* (Swinburn et al., 2013). INFORMAS develops a healthy food environment policy index to assess the extent of government policy implementation on food environments in comparison with international best practice (Brinsden et al., 2013). This produces a framework for approaching transparency and synergies between different levels of government (Swinburn et al., 2013).

The INFORMAS index is constructed from consultations which include a wide group of national public health experts, comprehensive evidence on the extent of implementation of food policies, and the use of international benchmarks for the ratings. The assessing and benchmarking of government policies is seen as a means for increasing the accountability of governments for their actions on food environments (Vandevijvere et al., 2015). INFORMAS has specific objectives in support of this. It strives to: develop a global network for monitoring, benchmarking, and supporting policy; collect and analyse data on food policies and actions; compare food environments against good practice benchmarks between countries over time; and employ results to strengthen public health efforts (Swinburn et al., 2013).

Critically, this framework only concentrates on some aspects of food and nutritional security, and focuses on obesity and non-communicable diseases. However, INFORMAS is sometimes seen as a compliment to existing monitoring efforts by the WHO, which includes other frameworks inclusive of food environments, such as the Global NDC monitoring framework (Vandevijvere et al., 2015). It is expected that the framework will support governments, international agencies, WHO, FAO, and other relevant organizations in their goal to achieve healthy food environments (Swinburn et al., 2013). Initial research categorizes the level of implementation against international standards while acknowledging there is little evidence regarding best practice. The framework strives to change this over time through the increased participation of countries (Vandevijvere et al., 2015).

Surveys and questionnaires are also being explored by the United Nations Millennium Development Goals. The Political Commitment and Opportunity Measurement Rapid Assessment Tool (PCOMRAT), is designed as a tool to measure a country’s political commitment to food security and nutrition. While the study is innovative in its use of benchmarking and the placement of food security and nutrition at the centre of governance surveys, it only covers ten countries (Fox et al., 2013).

PCOMRAT searches for the means to access information through three components. Component 1 addresses the political commitment and prioritization of food and nutrition policy and has three sub-divisions. The first evaluates the verbal declaration of support for an issue by high level political leaders; the second the institutional infrastructure created to support an issue, and the third budgetary commitments made in support of it. Component 2 features the policy window of opportunity and is different in that it consists of three streams. The problem stream is comprised of issues in food and nutrition that capture the attention of policy makers. It contains credible indicators which are neutral, objective, and based on scientific evidence. The policy stream consists of solutions which may be facilitated by cohesive communities of experts. The political stream reflects events which can change the political process. Component 3 takes note of stakeholders and institutional settings. Overall, the tool is designed to help Millennium Development Goals (MDGs) build a supportive enabling environment to improve nutrition (Fox et al., 2013).

3.2.2 Paper 2: Many at the Table Suffer from Malnutrition – Why? Food Group Research to Improve Global Nutrition

3.2.2.1 Methods

The second question, 'To what extent might more rigorous nutritional information positively impact food policy?' creates an opportunity for new metrics to reclassify food. The paper answers the question by accessing 2010 FAOSTAT data situated at the international scale. FAOSTAT food balance sheet supply information was computed into WHO required food groups for nutrition: starch carbohydrates, proteins, fruits & vegetables, and dairy. The data were processed for 145 nations into one of five author designated hunger groups. The hunger groups were created by modifying an International Food Policy Research Institute (IFPRI) study (IFPRI, 2013). The hunger groups are: industrialized, upper middle, lower middle, upper developing, and lower developing and results are presented in a map.

For each hunger group, average supply surpluses/deficits were recorded for each food group by comparing FAOSTAT data with WHO recommended dietary consumption totals. Results are presented in a table which includes the urban population percentage for each hunger group. Fruit & vegetable exporters were noted as were the corresponding percentages of exports per hunger group. Food balance sheets were further used to calculate protein sources from plant-based sources for each hunger group. Urbanization levels based on World Bank figures were inserted for comparison and results calculated and displayed in a map. Food balance sheets enable the calculation of export surpluses of fruits & vegetables for nations in designated hunger groups. A discussion section applies the results to suggest how the consumption of plant-based protein sources might be increased by developing nations, taking into account nutritional and supply/trade realities.

While the study is limited by relying on food supply data, findings are valuable for policy analysis and future research.

3.2.2.2 Background

FAO food balance sheets outline a country's food supply during a specific reference period, and measure the food consumption from a supply perspective. Food balance sheets are unable to give any indication of the differences that might exist in the diets of different population groups nor do they explain seasonal variations in the food supply. The FAO proposes that food consumption surveys should occur at various times of the year. Implementing this would be a considerable challenge as there is no standard 12 month reference period that is internationally suitable for recording supply, and utilization of all products. While a January-December schedule is not ideal, it does capture the bulk of the harvest. In certain contexts some commodities are better understood through production, trade, and utilization statistics, while others require food consumption surveys for clarity (FAO, 2001).

Food balance sheets are assembled from a variety of sources although quality and coverage vary considerably among countries and commodities. They comprise transformations of data from sample surveys, censuses, and administrative records of best estimates. Three core conditions should usually be met for their construction: the country should have a comprehensive statistical system which records all components of food balance sheets from producers to consumers; concepts of the information adopted should be those related to the food balance sheets; and the information should be consistent with respect to measurement unit and time reference period. The FAO notes that this ideal does not exist, and that there are only a few instances in developed countries where the second and third conditions are met (FAO, 2001). Furthermore, in many cases basic data are obtained from different sources and are subject to inconsistencies. National data are not always constructed in the same manner as food balance sheets since they are not necessarily generated by their governments to be used as such. Data are often incomplete and unreliable and time reference periods may not be consistent throughout. Also, time lags exist between publication dates (FAO, 2001).

Additional coverage problems exist for the basic data in the food balance sheets. Production statistics generally reflect commercialized food crops, while subsistence production, such as home produce or hunting for household consumption, are not typically included. Information on waste might also be incomplete, and often does not include waste due to storage, transportation, and other factors. Furthermore, there are significant gaps in the utilization of supply for non-food purposes such as feed, seed, and manufacturing; along with data for farm, commercial, and government stocks (FAO, 2001).

The World Bank supplies the other data source referenced in this paper. The amount of urbanization was recorded with contributions from two sources. Calculations were made using World Bank population estimates and urban ratios from the United Nations World Urbanizations Prospects (World Bank, 2015). There is some room for error, as the primary sources relied upon are national censuses. Some censuses are more recent than others, and the resources available to conduct them vary from country to country. Furthermore, population estimates are made by the UN in the absence of a recently conducted census (UN Department of Economic and Social Affairs, 2015).

This paper makes use of FAOSTAT as the best available data source. It acknowledges the limitations discussed by the FAO. Despite this, the data is employed with confidence, making note of numerous internationally respected studies which use the resource. Large holistic food security and nutrition studies employ a considerable number of FAO calculations in their models (EIU, 2015). The breadth of FAOSTAT data enables studies with different themes to extract relevant content. Examples include: the relationship between food and trade (Diaz-Bonilla et al., 2006), poverty (Alkire & Foster, 2011), hunger (IFPRI, 2013), and agricultural systems (Leimbach et al., 2011).

3.3 Indian Food Security and Nutrition Studies

There are a number of food security and nutrition studies concerning India which use different indicators and methodologies. Large international organizations, along with international and domestic academics, import or develop models to explore food and nutritional issues.

The India State Hunger Index (ISHI) developed by the International Food Policy Research Institute, University of California Riverside, and Welthungerhilfe, uses data from the National Family Health Survey (NFHS) and National Sample Survey (NSS). The following three indicators are consistent with the IFPR's global framework: *the proportion of population that did not consume an adequate level of calories*; *the proportion of underweight children under five years of age*; and *the mortality rate among children under five years of age*, expressed as the percentage.

The indicators are relevant for this thesis. First, *the proportion of the population that did not consume enough calories* is estimated using the NSS. This survey is based on household consumption data. Second, *the proportion of children under five who are underweight* is estimated using unit-level data from the NFHS data set, and the result then combined with WHO thresholds (Menon, 2009).

Further, the National Nutrition Monitoring Bureau (NNMB) provides data on dietary intake by 24 hour dietary recall, along with nutritional status by anthropometry and nutritional deficiencies. This data reports on ten states in India: Kerala, Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra, Orissa, Gujarat, Madhya Pradesh, West Bengal, and Uttar Pradesh. The India Nutrition Profile is conducted across all states, however the last one was completed in 1994 (FAO, 2006).

Researchers also experiment with the construction of studies centred on food groups at the household level. The approach breaks down consumption into: maize, other cereals, roots/tubers, meat/fish, eggs, milk, vegetables and pulses (Babu & Sanyal, 2009). Food consumption certainly plays a role in larger food security models. Swaminathan (1990) develops a conception by tracking changes per person in staple food production, imports, and consumption as a core indicator in measuring holistic food systems.

3.3.1 Paper 3: Maximizing India's Vast Resources for Improved Nutrition: Reforming the National Food Security Act

3.3.1.1 Methods

In order to answer the third question, 'In what ways does the National Food Security Act in India need to be reformed to enhance its programme efficacy?' the thesis drew upon a large dataset (Indiastat.com) to create a state food potential model. The model used five key drivers: economic, nature, nutrition, development, and governance to determine which states were in the greatest need of government assistance. Each driver in the model was represented by proxy indicators which were weighed equally to produce five food potential groups: high, good, moderate, low, and severely low. Indian state results are presented in a map. The paper seeks to discover actions India can undertake to improve food security and nutritional health by comparing the consumption ratio between pulses and cereals and recording it in a chart. Absolute and relative production advantages were recorded in 14 pulse producing states for five pulse varieties: *Cicer,* (massor, red lentil); *Cicer arientinum,* (gram, brown/white chickpea); *Vigna radiata,* (moong, green chickpea); and *Vigna mungo,* (urad, black chickpea). Cold storage capacity for each state was recorded as a percentage and presented with productivity information in a chart. The technological connectivity of Indian states and regions was then recorded, comprising information on internet and cellular phones and presented in a bar chart capturing the number of connections per capita. The discussion suggested policy recommendations across nutrition/utilization, development/availability, and governance/access categories. Conclusions enabled the placement of state level nutritional supply, and wider organizational recommendations, to actively suggest a public food policy which aggressively aims to increase nutritional quality and programme reach.

This paper fills a conceptual gap found in Indian food security and nutrition studies. It used disparate data collected by Indiastat from a variety of sources to create a holistic food potential index. The index went beyond nutritional, poverty, anthropometric, and food item studies previously created by researchers. The results act as a valuable means for informing state and national food policy in light of ongoing NFSA and WTO reform.

3.3.1.2 Background

Various sources collected by Indiastat.com:

Technology: (Lok Sabha Unstarred Question No. 4636, dated 11.08.2014). Selected State-wide Number of Internet (Narrowband + Broadband) and Broadband Subscribers in India (As on March, 2014) '*Total Number of Internet Broadband Subscribers*.' The data is the result of a question posed to the Minister of Communications and Information Technology asking for information to be stated regarding the status of Internet and broadband connectivity in the country, including north-eastern region, state-wide.

Cellular Operators Association of India. Metro City/ Circle-wide Number of Cellular Phone Subscribers in India (January and February, 2015). The figures are compiled from the reports of the following mobile phone companies: Bharti Airtel, Vodaphone, IDEA, Aircel, Telewings, Videocon and MTNL (COAI, 2015).

Cold Storages: (Rajya Sabha Unstarred Question No. 3172 dated 04.05.2012. '*Selected State-wide Status of Cold Storage Capacity in India* (As on 04.05.2012).' Data comes from the following question to the Ministry of Food Processing Industries: a) whether there is a shortage of cold storage facilities in the country; and b) if so, the details thereof; State-wide. The question is answered and data are provided referencing a study conducted by the National Spot Exchange Ltd. (NESL) in December, 2010 which analyses the production, consumption and shelf life pattern of major fruits and vegetables.

Economic: Ministry of Agriculture, Gov't of India. (13153). State-wide Daily Rates of Minimum Wages for Agricultural Workers under Minimum Wages Act, 1948 in India (As on 31.03.2011) '*Minimum Wages for Unskilled Agricultural Workers (Rs. Per Day).*' The data are derived from the 'Report on the Working of The Minimum Wages Act, 1948 For The Year 2011.' Information is based on the annual reports/returns from the Chief Labour Commissioner and the State Governments. A weakness in the collection exists in that there is no uniformity in the wage structure across various states. Some states pay consolidated wages made up of basic and dearness allowance, while others report dearness allowance separately. Additional shortcomings include variance in response rates between states and state-wide irregularities in implementation of the Act (Government of India, 2011).

Nature: (Lok Sabha Starred Question No. 270 dated on 15.03.2011). State-wide Area of Arable Land/Degraded Land and Land Affected by Natural Calamities (2010-2011). '*Percentage of arable land affected by Natural Calamities*.' The data are the result of a question posed to the Minister of Agriculture who was asked to state: a) whether large tracts of arable land in the country including Odisha are affected by degradation and natural disasters leading to fall in agricultural production and productivity; and b) if so, the details thereof along with the details of arable land available in the country and the percentage of such land susceptible to natural disasters. This indicator is not typically present in food security and nutrition studies as the most precise measurements are to be obtained at finer scales of data collection. Some exceptions do exist. Action Aid produced a study at the global level which includes 28 countries and explores climate variability alongside other vulnerability and capacity indicators (Action Aid, 2011). Otherwise, this indicator is often explored using temperature and/or precipitation indices and crop yields (Hansen & Jones, 2000; Tebaldi & Lobell, 2008).

Nutrition: National Family Health Survey (NFHS). State-wide Present Rate of Malnutrition in India (2005-2006 and 2007-2012). '*Underweight Children under 3 Years*.' The data comes from the NFHS-3 which collects information across the 29 states to generate a nationally representative sample of 124,385 women age 15-49 and 74,369 men age 15-54 in 109,041 households (Arnold et al., 2009). Anthropometric measurements are conducted by an interviewing team which uses a scale designed and manufactured under the guidance of UNICEF. The study employs the international reference population indicator released by WHO in April 2006 (WHO Multicenter Growth Reference Study Group, 2006) and is accepted by the Government of India (IIPS & Macro International, 2007). Training workshops are to train representatives of the 18 field organizations, including health coordinators who receive a two week training session at the International Institute for Population Studies (IIPS), Mumbai. Furthermore, eight health coordinators with medical training are employed for the supervision of data collection. All children are weighed and measured by the interviewing team which consists of health investigators (IIPS & Macro International, 2007).

Development: Ministry of Road Transport and Highways, Government of India. (ON291). State-wide Road Length in Relation to Area and Population in India (as on 31st March, 2011) '*Road length (in Kilometres) per 100 square kilometres of Area*.' The information is found in ‘Basic Road Statistics of India’, a publication which acknowledges that information for the publication (for which this indicator is a small part), involves 280 source agencies spread across the country (Government of India, 2012). It is unclear which sources are used to compile the results for this indicator. However, throughout the document State Public Works Departments, Local Self-Government Departments/State Panchayati Raj Departments, State Departments of Municipal Administration/Urban Affairs, State Rural Departments, etc., are cited (Government of India, 2012).

Governance: Comprised of two components described in a) and b) below. Both are used to calculate the proportional number of convictions in the public distribution system.

a) (Lok Sabha Starred Question No. 64, dated on 14.08.2012 & Lok Sabha Starred Question No. 569 dated on 7.05.2013). State-wide Action Taken against Irregularities in Supply of Ration under PDS (Control) Order, 2001 in India (2006 to 2013). ‘*Number of Persons Arrested/Prosecuted/Convicted*.’ The data comes from the response to a question posed to the Minister of Consumer Affairs, Food and Public Distribution asking: c) the details of the raids carried out and the number of cases registered across the country including Rajasthan and Andhra Pradesh under the Essential Commodities Act, 1955 and other legislations in order to check hoarding during each of the last three years and the current year, State/ UT-wise; and d) the number of persons actually convicted under the said legislations during the above period.

b) Ministry of Consumer Affairs, Food and Public Distribution, Govt. of India. (13357). *State-wide number of Households, below Poverty Line* (BPL) *Households, Fair Price Shops and Ration Cards in India* (As on 31.03.2012) ‘*No. of Fair Price Shops*.’ These state-wide figures are made available by the ministry.

3.3.2 Paper 4: Within Reach? Creating Multi-Scale Nutritional Policy for Rural Karnataka

3.3.2.1 Methods

'To what extent can relevant survey information be used in the reform, and subsequent implementation of district level food policy in rural Karnataka?' This paper constructed a nutritional HDI model using proxy indicators for income, health, and education for 27 of 30 districts in Karnataka. It used the HDI index method (UNDP India, 2011) to link information on income (yearly expenditure on food), health (number of non-anaemic pregnant women), and education (literacy of those over seven years of age) into six categories of nutritional HDI: adequate, slightly inadequate, moderately inadequate, significantly inadequate, severely inadequate, and alarmingly inadequate. Results are presented in a table.

State level consumption expenditure information for Karnataka was computed using NSS data. Consumption of pulses and cereals were calculated for each district using the monetary value method by which expenditure was used to estimate quantity consumed. Six categories of estimated consumption were presented in a table: surplus, slight deficit, moderate deficit, significant deficit, severe deficit, and alarming deficit. Production yield figures were taken for pulses and cereals in each district (Directorate of Economics and Statistics, 2012) and recorded in six categories in a table: highest, high, moderate, low, very low, and lowest.

The discussion section suggests linkages between nutritional goals and public policy, and makes recommendations for district strategies presented in a map: NFSA, pulse or cereal production, cross-district collaboration, horticulture production, and none. This paper is located at the national level in its critical position vis-à-vis the programmes, and draws on sub-national state and district level information to inform the nutritional breadth of programme coverage and its linkages to the agricultural system.

3.3.2.2 Background

The United Nations Development Programme (UNDP) creates a HDI Index for India based on income, education, and health indicators. The model employs NSS survey findings for income and educational status and training. Consumer expenditure information is used for the income indicator. Similarly, a question regarding the status of education and vocational training generates educational results. The UNDP also uses the SRS Based Abridged Life Table for the life expectancy figures to capture their health indicator (UNDP, 2011). This makes the NSS a prime source for state and district level data in future studies.

This paper builds a modified index based on a reimagined nutritional HDI. It contributes to the field by building on the strengths of the UNDP HDI methodology. Similar to the third paper, best available data was used from disparate sources to directly address nutritional strengths and weaknesses. The results are useful in the planning of more nuanced food policy in the state of Karnataka, giving due consideration to the complexity of its districts and regions.

The NSS functions as a part of the Ministry of Statistics and Programme Implementation of the Government of India. Nutritional intake information is based on data gathered from state and district level household food expenditure. The government obtains its information in Karnataka through surveys. A total of 256 rural villages were involved with 2048 rural households sampled for data (NSS, 2014).

An NSS survey records percentage expenditure on foodstuffs by income group for: cereals, pulses, milk, oils, eggs/fish/meat, vegetables, fruits, beverages and intoxicants (FAO, 2006). The study is useful in that it records total dietary intake of foodstuffs and respective percentages of fat, protein, and carbohydrates. A weakness of the methodology is that it does not consider inter-family distribution as part of its results (FAO, 2006).

However, surveys are taken across a fairly broad spectrum of the population in each state. Food items are calculated by quantity and value over the past 30 days. Findings for each item are based on consumption of home produce and total consumption. A further weakness is that a significant number of studies indicate that government surveys do not fully incorporate food expenditures that occur outside the home in their consumption expenditure calculations (Smith & Subandoro, 2007). Rural households are surveyed across three broad categories: relatively affluent households, remaining households having principal earning from non-agricultural activity, and other households.

The District Level Household and Facility Survey (DLHS), similar to the UNDP, and the National Family Health Survey (NFHS) collects information on amount of time in school and literacy rates. National and state level information on school enrolment and literacy rates are available with 2005-06 as the most recent reference year (IIPS & Macro International, 2007). At the district level, the DLHS only has information pertaining to literacy percentages.

The Ministry of Agriculture of the State of Karnataka Directorate of Economics and Statistics, presents information on the 'Area, Production and Productivity During 2009-10.' Annexure-8 details cereals and minor millets along with pulses for 29 districts. A source is not given for the data so it is assumed that the information was a product of the organization's calculations (Directorate of Economics and Statistics, 2012).

3.4 Study and Data Limitations

Data on nutritional outcomes, the food security of nations, and sub-national units are limited. Calculations were made using the most recent data and it is plausible that various statistical trends have changed between any specific reference year and writing. It is also possible that short-term events associated with political, economic, and environmental stresses could have directly impacted data. In addition, challenges exist which have been moulded by scale specific realities. The greatest similarities exist between FAOSTAT food balance sheet data, based on national information, which are more or less thematically harmonized. These datasets are best suited for explaining the relationship between the international trade regime and regional and national food policy. In contrast, the drivers used in this study to compare Indian states are: Economic, Nature, Nutrition, Development, and Governance. Data at the state level in India might not be available in other nations so comparative analysis is uncertain. District level information is the sparsest of all scales approached in this thesis; however, this constraint is overcome by implementing a more modest nutritional HDI model which incorporated available proxy indicators for income, health, and education.

Indicators which capture environmental and governance aspects have not been accepted into global conventions. The impact of climate change on the agricultural system and the level of corruption within the TPDS in India serve well as proxies, and encourage the tabulation of similar information in other developing countries. However, limitations may be present. Peer nations may lack a significant public food distribution system with which to monitor the impact of corruption. In the absence of a monitoring system, a proxy indicator needs to be constructed to capture effective governance, particularly as it relates to the food and nutritional needs of vulnerable groups. Similarly, the impact of climate change on the agricultural systems of developing nations requires a collaborative effort between government, researchers, and farmers. In both instances a larger international effort, leading to conceptual consensus, monitoring systems, and data is advisable.

Chapter 4. Paper 1: Towards a Holistic Approach to Food Security Data: Going Beyond FAOSTAT

(Submitted to *The Geographical Journal*)

This paper supports the central aim of the thesis by expanding on FAO conceptualizations to facilitate and advance connections between the food system and nutrition. It reveals potential areas of conceptual refinement that could result in improvements in the breadth and accuracy of data. This research engages with the lenses of nutrition and governance, focusing primarily on dietary diversity as a measure of nutrition and qualitative representations of programme performance and administrative environments for governance. Trade is also considered, albeit in a more limited sense.

4.1 Abstract

There are significant conceptual disconnects among food security and nutrition studies. International organizations, academics, research houses, and NGOs employ different methodological techniques and data sources. This often leads to insights which produce conclusions that are distinctive. Such a dynamic makes sustained and coordinated policy action challenging. The Food and Agriculture Organization of the United Nations (FAO) generates the most significant attempt at developing a set of core food security indicators. Organizations such as the Economist Intelligence Unit (EIU) draw upon some FAO indicators based on the four pillars of food security conception of availability, access, utilization, and stability; while also developing their own unique approaches. The existence of national data for particular indicators varies widely and adds to the challenge.

Benchmarking, a method which is increasingly being used in large studies, has not been applied to a large international food security and nutrition study. This paper performs a process benchmarking exercise. Results show that FAO data, albeit in a modified form, are the foundation of the EIU's study. The EIU draws upon qualitative observations to fill

conceptual gaps in aspects of food security (e.g., availability, access, and utilization). Additionally, the EIU generates and applies its own estimates to address data gaps. Partial information is common due to challenges present in disparate contexts. Further analysis of FAO and EIU data reveals a significant opportunity to develop indicators relevant to governance. Extensive discussion, leading to consensus and cooperation, is required from key actors situated at international, regional, national, state, and finer scales. It is essential that these actors establish and monitor the most accurate information possible.

4.1.1 Keywords: FAO, EIU, Food Security, Process Benchmarking, Governance

4.2 Introduction

This paper considers the question, ‘To what extent has the FAO’s conceptualization of food security helped or hindered international food security studies?’ It contributes to the literature by critically considering the impact of the FAO on other studies. Efforts are being made to consolidate approaches and achieve a consensus regarding salient food security indicators which include social and economic factors (FAO, 2015a). Significant gaps remain. International organizations use a variety of indicators in analysing food security. Some indicators are identical, others partially related, while many are unique in their particular approach. The FAO’s core indicators form a conceptual starting point towards a more complete capturing of food security (FAO, 2015a). The international study which draws on the widest palette of indicators is the ‘Global Food Security Index,’ (EIU, 2015) published annually by the Economist Intelligence Unit (EIU). The EIU combines FAO data with complimentary qualitative information of its own, and also adds a further number of indicators to capture the impact of governance on food security.

International food security is framed by an extensive and complex variety of inquiries. One group of studies focuses largely on capturing hunger through anthropometric data (Bassett & Winter-Nelson, 2010). Recent research considers the impact of environmental change (Lobell et al., 2011). International trade and economics are also represented (Diaz-Bonilla et al., 2006). Increasingly, researchers note the importance of engaging with phenomenon that cannot be captured by quantitative data (Poku & Whitman, 2011). For example, Action Aid links sustainable agriculture and climate agriculture with social, legal, and gender rights (Action Aid, 2011).

Capturing the impact of social and political factors on food security is based on a sound theoretical foundation. When reducing poverty and hunger, the most important measure of good governance is providing basic public goods to citizens (Paarlberg, 2002). Where national governments have performed well in the developing world, hunger has been significantly reduced (Paarlberg, 2002). Effective governance is connected to higher prosperity, better education, gainful employment, and freedom from hunger on a sustained basis (IFPRI, 2001). The FAO experiments with governance indicators, plotting the Worldwide Governance Indicator for *Rule of Law* against data on *average agricultural capital stock per worker* (FAO, 2012). The results show a direct correlation between governance and agricultural investment (FAO, 2012).

A more nuanced understanding of food security is possible if a common set of metrics is developed which effectively captures relevant environmental, health, and socio-economic information (Coates, 2013). The FAO's conceptualization of food security is currently the most extensive with respect to the breadth and scope of indicators. Other studies contribute to the debate by filling in gaps and refining models. Understanding this interaction could be beneficial in developing an independent and coherent cluster of critical literature. To effectively interpret the current dynamic, a brief review of the historical evolution of food security indicators used by the FAO is beneficial.

In the mid-1970s the FAO generated a set of indicators based on data in their food balance sheets (FAO, 1997). The analysis, international in scope, groups nations into categories based on import/export status of cereals, and the combination of low-incomes and food deficits (FAO, 1997). At that time food security was seen primarily as a national supply issue focusing on key grains such as wheat and rice (Maxwell & Smith, 1992). By the late-1990s, the FAO developed national food security indicators, with an emphasis on the nation-state as the central actor (FAO, 1999). It added availability and access indicators and moved the prime focus away from cereals (FAO, 1999).

The FAO does not produce a wide-reaching international food study. However, it publishes an annual 'FAO Hunger Map' based on the *percentage of undernourished in the population* (FAO, 2015b). This indicator is the traditional FAO hunger measurement (FAO, 2015b). Per capita dietary energy consumption is calculated from FAO food balance sheets to estimate energy availability in a country over an annual period (FAO, 2013). Minimum dietary energy requirements are estimated using FAO and World Health Organization (WHO) consultations (FAO, 2013). Information from The United Nations Population Division (UNPD) and United States Aid and International Development (USAID) is also considered (FAO, 2013). The procedure creates an *average individual* in a population which functions as an estimator (FAO, 2013). It focuses on the amount of food energy required to maintain a minimum body weight, basic body composition, and a minimum level of sedentary physical activity (Haen et al., 2011). Including measurements which address micronutrient deficiencies and obesity is encouraged by experts (Johnston et al., 2014). Quality of food is not considered (UNMDG, 2012b).

Indicator data contain methodological challenges, since the collection and analysis process integrates information from a variety of sources. Results from household surveys are linked with macroeconomic data sources such as food balance sheets, censuses, and demographic surveys (UNMDG, 2012b). For many countries the reliability of data and measures of inequality are uncertain. There are also inconsistencies between national and international estimates (UNMDG, 2012b). National data are derived primarily from food consumption in homes (UNMDG, 2012b). In contrast, international estimates, which include both private and public consumption, often incorporate food consumed outside of the home in venues such as restaurants, hospitals, and schools (UNMDG, 2012b). Estimates, based on national production and trade figures, are unable to fully capture geographic and socio-economic distinctions in countries (UNMDG, 2012b).

The FAO defines food security as having four dimensions: availability, access, utilization, and stability (Ecker & Breisinger, 2012). This is commonly referred to as the four pillars. Food availability refers to the sufficient quantity of appropriate quality food supplied through domestic production or imports (FAO, 2006). Food access occurs when individuals have adequate resources for acquiring appropriate foods for a nutritious diet (FAO, 2006). Utilization is present with an adequate diet, clean water, and satisfactory sanitation and health care (FAO, 2006). These three dimensions work collectively to achieve a state of nutritional well-being where all physiological needs are met. Stability requires access to adequate food at all times by a population, household, or individual. It should not be disrupted by sudden shocks or cyclical events (FAO, 2006). This *four pillar* approach differs from a food systems approach, which first emphasizes a number of activities that give rise to food security outcomes. The latter arranges outcomes into three components: availability, access, and utilization (Ingram, 2009). It proposes that three factors must be satisfied and stable over time to achieve success. Availability consists of production, distribution, and exchange; access involves affordability, allocation, and preference; utilization is comprised of nutritional value, social value, and food safety (Ingram, 2009).

The initial approaches by the FAO examined international food supply and price stability. These approaches evolved to include nation-states as the prime actors across availability, access, and utilization indicators. The next step was a slow evolution to include physical and economic access to meet dietary needs (Clay, 2002). The FAO chose the four pillar concept since research requires data across a variety of scales and political, socio-economic, and environmental contexts (Maxwell et al., 2008; Sachs et al., 2010; Sanchez & Swaminathan, 2005). The FAO recently developed a set of core food security indicators, including information obtained by partner organizations such as the World Bank, WHO, and the United Nations International Children's Fund (UNICEF) (FAO, 2015a). While the organization is able to identify key indicators, it is unable to draw wider conclusions due to a lack of complete and contemporary data availability across all indicators. The Economist Intelligence Unit (EIU) produces an annual food security index, combining its data with information from other large organizations (EIU, 2015). The EIU conceptualizes food security in three large categories: affordability, availability, and quality and safety (EIU, 2015).

The FAO's conceptualization of food security has been progressive over the years. However, an examination of the complimentary studies (Coates, 2013; EIU, 2015; Lobell et al., 2011) suggests that the organization might benefit from further development through the benchmarking of its indicators against international standards. The next section outlines the means for this comparison.

4.3 Methodology

In considering the question, 'To what extent has the FAO's conceptualization of food security helped or hindered international food security studies?' this paper developed concepts and suggestions using process benchmarking. The approach allowed for a direct comparison between the FAO's conceptualization, the EIU, and other relevant international partners.

Process benchmarking is an ongoing, systematic method which directly compares the activities of one organization with another recognized industry leader. It considers an entire system rather than individual functions or tasks (Tuominen, 2012). The process is well established for determining effective service provision under circumstances of scarcity (Grun, 2006). However, benchmarking for best practice in food and agriculture only occurs in a small number of cases. A clear and viable methodology is lacking and a move towards using process benchmarking on a wider scale is encouraged (Jack, 2009). The importance of benchmarking as a tool for analysing the level of political commitment to food and nutrition policies is emphasized (Fox et al., 2013). The method is gradually being adopted. For example, the Asia-Pacific region was recently considered in a study connecting food security and nutritional health to agriculture and wider policy decisions (Flaherty et al., 2013). The primary goal here is to explore how the FAO's conceptualization of food security, with its indicators acting as an industry benchmark, interacts with the EIU study. Information from other partner organizations (e.g., World Bank; WTO) is drawn upon when either organization does not independently generate the specific data.

The most rigorous conceptualization links benchmarking to healthy food environments. The International Network for Food and Obesity/non-communicable disease Research, Monitoring and Action Support (INFORMAS), is a global network of public interest organizations and researchers (Brinsden et al., 2013; Swinburn et al., 2013). This collective aims to monitor, benchmark, and support actions to create healthy food environments, reduce obesity, eliminate non-communicable diseases, and diminish inequalities (Brinsden et al., 2013; Swinburn et al., 2013). Particularly revealing, through a broad analysis of administrative performance, INFORMAS introduces a public sector module that determines how much progress international, national, state, and local governments have made towards good practice. The impact of this module is expected to strengthen over time as more evidence is gathered internationally (Swinburn et al., 2013). Furthermore, the expectation is that the benchmarking and ranking systems could provide inspiration for those countries lagging in policy implementation (Brinsden et al., 2013).

INFORMAS creates a Government Healthy Food Environment Policy Index (Food-EPI) and receives advice from the WHO and FAO. The index contains a set of domains comprised of indicators which are based on good practice, and benchmark statements concerning policy and infrastructure support (Swinburn et al., 2013). The domain of *food consumption* aims to maximize the consumption of fruits and vegetables (Swinburn et al., 2013). The domain of *food prices* is concerned with trade and investment agreements which protect both food sovereignty and healthy food environments (Swinburn et al., 2013). The *governance* domain strives for high levels of transparency and accountability, while encouraging community participation and inclusion in policy (Swinburn et al., 2013). A further *platform for interaction* domain is concerned with synergies between various government organizations and other relevant sectors (Swinburn et al., 2013). It is noted that some tools may be best constructed in the form of benchmarks for progress rather than absolute measures of achievement (Brinsden et al., 2013). The consumption of fruits and vegetables is generally low in absolute terms. In many instances this is temporary and rapidly expanding from a low starting point (Brinsden et al., 2013).

In contrast, higher levels of consumption may indicate a traditional diet that is being eroded by increased consumption of nutrient-poor processed foods (Brinsden et al., 2013).

EIU indicators were organized into three categories by a process of comparison with FAO benchmarks (as available) to determine if each was: 1) identical to the FAO - where the EIU drew on both FAOSTAT conceptualizations and data; 2) a variation - where there were only conceptual linkages between FAO and EIU variables; or 3) stand-alone indicators with no conceptual or data link to any used by the FAO. The first category briefly considers those indicators which are identical in both the FAO and EIU studies. The second identifies those which have conceptual similarities but differ in their data source (Table 1). The third includes indicators solely used by the EIU (Table 2). A discussion section compares and contrasts both FAO and EIU results with best practices in food security and nutrition research.

4.4 Results

The benchmarking exercise identified two indicators where the EIU drew on both the FAO conceptualizations and data. The *share of dietary energy supply derived from cereals, roots, and tubers*, along with the *diet diversification* indicators are identical (EIU, 2015; FAO, 2015a). The indicators are categorized differently, with the FAO's *availability* contrasting with the EIU's *quality and safety* (EIU, 2015; FAO 2015a). *Per capita food production variability* and *volatility of agricultural production* are identical. The FAO placed the indicator in its *stability* category while the EIU opted for an *availability* designation (EIU, 2015; FAO, 2015a).

The second step in the benchmarking exercise sought indicators which were conceptually similar despite not sharing the same data source. Eight pairs were identified: *food supply, protein, GDP, infrastructure, food expenditure, vitamin A, water sources, and* *political stability*. EIU data did not emphasize a timescale for two indicators: *agricultural infrastructure* and *food safety*. Each EIU indicator is complete while several FAO indicators remain incomplete (Table 4.1).

There are similarities between indicators and categorizations. *Average dietary energy supply adequacy* and *sufficiency of supply* are both in the availability category (Table 4.1). *GDP per capita* appear for each study. The FAO places it under the *access* category with a World Bank source, while the EIU conceptualizes it as *affordability* with its own calculations combined with World Bank and International Monetary Fund (IMF) information (Table 4.1). *Share of food expenditure of the poo*r is selected by the FAO in its *access* category, while *food consumption as a share of household income* is located in the EIU's *affordability* section. The EIU's data quality contains many elaborations while the FAO draws on its own data, which is largely complete, but does contain some minor data gaps (Table 4.1).

Prevalence of vitamin A deficiency in the population is situated in the FAO's *utilization* category and is derived from WHO data with sparse availability. In contrast, *dietary availability of vitamin* A is situated in the EIU *quality and safety* category, featuring complete data generated by the EIU (Table 4.1). Similarly, the FAO's *access to improved water sources* is derived from WHO and UNICEF sources and is largely complete. The EIU's *percentage of the population with access to potable water* is situated in its *quality and safety* section with its own calculations and inexact timescale (Table 4.1).

Table 4.1 Conceptual Linkages between FAO and EIU Variables. *Source:* Author analysis based on FAO (2015a) and EIU (2015) indicators.

Organization	Category of Indicator	Indicator	Source & Data Collection Method	Completeness & Timescale
FAO	Availability	Average dietary energy supply adequacy	FAOSTAT calculations	Largely complete from 1990-2015. Some omissions exist (particularly Africa)
EIU	Availability	Sufficiency of supply (partial) Average food supply in per capita calories	FAO	Complete. 2011
FAO	Availability	Average supply of protein of animal origin	FAOSTAT	Largely complete from 1990-2011
EIU	Quality & Safety	Protein quality	EIU calculation based on FAO, WHO and USDA data	Complete. 2005-2011
FAO	Access	GDP per capita	World Bank-World Development Indicators	Largely complete from 1990-2013
EIU	Affordability	GDP per capita	EIU; World Bank; IMF	Complete. 2014
FAO	Access	Percent of paved roads over total roads/ Road density/ Rail lines density	World Bank-World Development Indicators	Sparse availability, gaps exist for developing countries across years 1990-2012
EIU	Availability	Agricultural infrastructure	EIU	Complete. Timescale N/A
FAO	Access	Share of food expenditure of the poor	FAO Elaborations/ ILO/ National Statistical Offices Scoring	Considerable number of FAO elaborations for random and erratic data from 1999-2012
EIU	Affordability	Food consumption as a share of household expenditure	FAO	Complete from 1990-2014
FAO	Utilization	Prevalence of vitamin A deficiency in the population	WHO	Sparse availability from 1990-2012
EIU	Quality & Safety	Micronutrient availability (partial) Dietary availability of vitamin A	EIU	Complete. 2005-2007
FAO	Utilization	Access to improved water sources	WHO/UNICEF JMP	Largely complete with occasional gaps for years 1990-2012
EIU	Quality & Safety	Food safety (partial) Percentage of the population with access to potable water	EIU	Complete. Timescale N/A
FAO	Stability	Political stability and absence of violence/ terrorism	Brookings Institution, World Bank Development Indicators, World Bank Institute	Largely complete from 1996 to 2013
EIU	Availability	Political instability	EIU	Complete. 2015

The third stage of the benchmarking exercise yielded a group of nine EIU stand-alone indicators with no observable connection to the FAO (Table 4.2).

The four affordability indicators are categorized and based on the latest available annual data, and do not exhibit a uniform timescale for collection. Two are built on quantitative data: *proportion of population under the global poverty line* from the World Bank, and *agricultural import tariffs* from the World Trade Organization (WTO) (Table 4.2). The remaining two are derived from qualitative judgements by the EIU: *presence of food safety net programmes* and *access to financing for farmers* (Table 4.2).

The availability category is based on one qualitative and three quantitative indicators. *Corruption* is a qualitative observation. Quantitative examples from the FAO include: *public expenditure on agricultural research and development*; *urban absorption capacity* from the World Bank and EIU; and *food loss* (Table 4.2). Furthermore, the EIU chose *nutritional standards* for its quality and safety conceptualization, based on its own calculations, and with an unclear timescale (Table 4.2).

Table 4.2

EIU Stand-Alone Indicators. *Source:* Author analysis based on indicators (EIU, 2015).

Organization	Category of Indicator	Indicator	Source & Data Collection Method	Completeness & Timescale
EIU	Affordability	Proportion of population under the global poverty line	World Bank- World Development Indicators, UNDP	Complete. Latest available year 2001-2014
EIU	Affordability	Agricultural import tariffs	WTO	Complete. Latest available year 2009-2013
EIU	Affordability	Presence of food safety net programmes	EIU	Complete. Latest available year 2009-2015
EIU	Affordability	Access to financing for farmers	EIU	Complete. Latest available year 2006-2015
EIU	Availability	Public expenditure on agricultural research and development	EIU estimates based on OECD, World Bank, ASTII and EIU data	Complete. Latest available year 2001-13
EIU	Availability	Corruption	EIU	Complete. 2015
EIU	Availability	Urban absorption capacity	World Bank- World Development Indicators, EIU	Complete. 2013-2015
EIU	Availability	Food Loss	FAO	Complete. 2011
EIU	Quality & Safety	Nutritional Standards	EIU	Complete. Timescale N/A

4.5 Discussion

FAO core food security indicators are drawn on for ten of nineteen indicators used in the EIU study. They represent each aspect of the FAO's four pillars of food security. In some instances, the EIU took data directly from the FAO, and in other situations, partial data is augmented with the EIU's own analysis. Further instances resulted in an indicator displayed with a very strong conceptual link to an FAO counterpart. Process benchmarking research for specific indicators in each four pillar group is discussed in further detail.

4.5.1 Availability

The EIU selected indicators from the FAO's availability category. The FAO's *average dietary energy supply adequac*y and the EIU's *sufficiency of supply* indicator share conceptual similarities (Table 4.1). The FAO normalized its data to reflect different national energy needs measured in calories. The FAO and EIU both draw from FAOSTAT sources (Table 4.1). The EIU added a qualitative observation to their treatment by including a *dependency on food aid* aspect. To do so they drew upon World Food Programme (WFP) data from their *nutritional value of food aid deliveries* (WFP, 2015). As such, the organization has expanded the range of this indicator.

Findings illustrate both organizations draw on the FAO indicator *share of dietary energy supply derived from cereals, roots, and tubers* (EIU, 2015; FAO, 2015a). Food balance sheets determine starch carbohydrate consumption (FAO, 2015a). However, this is a limited view of dietary diversity needs and could be expanded in the future through the inclusion of required nutritional components (Pinstrup-Andersen & Watson, 2011). The FAO has done this partially in its treatment of protein, using the indicator *average supply of protein of animal origin* (Table 4.1). The consumption of animal proteins has been accepted by many as a sign of improved food security (Smil, 2008). Research suggests the

EIU's approach of measuring protein quality aims to expand this by recording the Protein Digestibility Corrected Amino Acid Score (PDCAAS). This is adopted by the FAO and WHO as the preferred method for the measurement of the protein value in human nutrition (Schaafsma, 2000). It takes into account that mixtures of plant proteins can serve as a complete and well-balanced source of amino acids for meeting human physiological requirements (Young & Pellett, 1994).

Findings illustrate the EIU has expanded the conceptual range of selected FAO availability indicators. In the instance of food aid relative to food supply, and in its recording of amino acid scores relative to dietary diversity, it builds on the foundation provided by FAO core food security indicators.

4.5.2 Access

The FAO's access category provides a framework for the EIU to add infrastructural and microeconomic information. The *share of food expenditure of the poor* indicator is based on FAO elaborations of International Labour Organization (ILO) and national statistical office publications (EIU, 2015). These are derived from various national household surveys (Table 4.1). There is no indication that the surveys are uniform, and multiple layers of elaboration damage the predictive accuracy of the data. Information is based exclusively on the lowest income quintile of a nation's population, rather than being more inclusive of a larger research sample. Some members of the larger group may be victims of uniquely distressing circumstances (EIU, 2015). Findings verify that the EIU modifies this indicator slightly, using FAO data to examine the entire population in *food consumption as a share of household expenditure* (Table 4.1). Both organizations evaluate poverty based on the expenditure point where households spend more than a given proportion on necessities (EIU, 2015; FAO, 2015a). However, it is a poverty rather than a food security indicator, and there are a series of cultural and relative biases regarding what an acceptable level of expenditure on food might be (Bradshaw et al., 1987). A more rigorous adaptation of this indicator could be beneficial. A further microeconomic indicator used by both studies is *GDP per capita* (EIU, 2015; FAO, 2015a) The FAO draws upon World Bank figures while the EIU uses its own calculations in combination with World Bank and IMF information (Table 4.1). While this indicator is useful, future elaboration on the nature of inequality, perhaps by incorporating a GINI score of inequality might be illuminating (World Bank, 2015).

Both studies examine infrastructure. The FAO draws upon sparse data from the World Bank for *percentage of paved roads* (Table 4.1), while the EIU uses a combination of qualitative observations from its own research to evaluate the existence of *agricultural infrastructure* (Table 4.1). While the FAO is more specific regarding road and rail density, the EIU emphasizes roads, ports, and crop storage facilities (EIU, 2015; FAO, 2015a). Infrastructural controls on food distribution are complex, and can involve physical impediments to transport, such as steep gradients and tight road curves (Gregory et al., 2005). A particular weakness of the EIU's approach is the use of a binary score to rate crop storage facilities rather than examining their actual effectiveness. In the developing world, it is estimated that roughly 30-40% of food is lost to waste due to poor infrastructure and/or lack of investment in locally available storage technologies (Godfray et al., 2010). Some retail outlets also lack cold storage, and small-scale storage is often absent (Godfray et al., 2010).

In the access category benchmarking suggests the EIU uses and expands on the FAO's conceptualization of infrastructure. Advances in the food logistics discussion include crop storage facilities. However, the scoring system requires refinement to examine efficacy rather than existence. While the treatment of food expenditure has widened, it remains unclear how this knowledge can positively impact food security research.

4.5.3 Utilization

The FAO conceptualized utilization using a combination of anthropometric and health measurements. *Prevalence of vitamin A deficiency in the population* is recorded using WHO data from household surveys (Table 4.1). This method has limitations due to variance in sample sizes from year to year. Research reveals that the EIU's *micronutrient availability* indicator would appear to go further by first recording the availability of vitamin A as 1/3 of its score, and then including animal and vegetal iron (Table 4.1). However, there are additional micronutrients required for proper nutrition which are not included in either study (Gomez et al., 2013).

The FAO's *access to improved water sources* derive from the World Bank and UNICEF household surveys and census (Table 4.1). Critics note that improved water may not represent access to water services that meet international engineering and health standards (Montgomery & Elimelech, 2007). The source of the data, the WHO Joint Management Programme, acknowledges that improved sources are not necessarily free from contamination (WHO/ UNICEF, 2014). The programme creates a distinction within improved water sources in its *drinking water ladder* framework. Piped water on premises is placed higher than *other improved sources* (WHO/ UNICEF, 2014). Alarmingly, data suggests that 10% of improved water sources may be at high risk for faecal contamination (Bain et al., 2014).

Similar to the FAO, the EIU's *food safety* indicator makes *access to potable water* equal to 1/3 of a wider score (EIU, 2015). The remaining sub-indicators include *agency to ensure the safety and health of food* and *presence of formal grocery sector* (Table 4.1). The debate on the merits of a formal grocery sector suggests that this aspect of the indicator requires refinement. There is a question of livelihoods, as critics note that supermarkets can remove smallholders from fresh produce supply chains (Humphrey, 2007). The existence of retail chains does not address the possibility of a food desert, where low-income residents may not have access to affordable and healthy food (Donald, 2013). In addition, there is little empirical evidence to suggest that people will purchase healthy food if retail outlets are built (Wrigley et al., 2003).

Findings suggest the EIU builds on the FAO's treatment of utilization in a number of ways. It acknowledges more, but not all, essential micronutrients required for proper nutrition. The organization has also chosen *access to potable water* over *access to improved water sources*, as there is potential for significant differences in health outcomes.

4.5.4 Stability

The FAO conceptualizes stability using a series of long-term macroeconomic, political, supply, and production indicators (FAO, 2015a). Findings confirm that the majority come from FAOSTAT data and the information is complete and contemporary. The exception is the *political stability and absence of violence/terrorism* indicator (Table 4.1). Here, the Worldwide Governance Indicators (WGI) use data sources to compile and summarize views and experiences. This is accomplished through surveys of households and firms, commercial business providers, NGOs, and public sector organizations (Kaufmann et al., 2011). The authors acknowledge possible subjectivity, contrasting perceptions, and economic halo effects (Kaufmann et al., 2011). Benchmarking results suggest the need for more objective and detailed data, and reveal the unreliability of comparing governance data with different sources over time (Apaza, 2009). The EIU similarly tracks *political instability* and draws upon its own risk briefing (Table 4.1).

Each of the studies reflects on food production using the FAO's *per capita food production variability (*Table 4.1). This is calculated by FAOSTAT and takes the standard deviation of net food production value over the past two decades. While important, this indicator could be strengthened if it included information on possible variations in food access and nutritional quality (Barrett, 2010).

Analysis shows that the EIU is conceptually similar to the FAO with respect to stability indicators. The FAO's treatment of economic and political factors considers relatively few indicators on stability, while the EIU uses more indicators.

4.5.5 Governance

The four pillars concept of food security does not place governance in a central position within its framework. This is an unfortunate flaw. The benchmarking exercise demonstrates that the EIU is attempting to capture the impact of governance related issues which are not covered by the FAO's core group. This paper suggests that the *allocation* component of the food systems approach, comprised of *economic, social and political mechanisms governing when, where, and how food can be accessed by consumers,* could be a more effective in approaching governance issues (Ingram, 2009). In contrast, the four pillars place governance and political issues as minor components connected with the conception of *stability* (FAO, 2006). This treatment minimizes the role of governance and does not consider its potential to generate a more thorough research profile. This situation requires additional research.

Six of nine stand-alone EIU indicators listed on Table 4.2 have governance implications. However, data quality and depth are lacking. The two indicators, *proportion of population living under or close to the global poverty line* and *public expenditure on agricultural research and development*, both suffer from data inconsistency in the form of 12 and 13 year variance (Table 4.2). Conceptually, exploring the connection between wider rural infrastructure and agricultural research and development is important as it links to the advancement of rural economies (Tutwiler & Straub, 2007). This is not considered by the EIU.

Findings illustrate the EIU includes a series of indicators which are exclusively scored using binary methods: *presence of food safety net programmes*; *access to financing for farmers*; *corruption*; and *nutritional standards* (Table 4.2). Crucially, the requirement of government to support the development of the agricultural sector and to reduce corruption is encouraged (McKeon, 2011). Including these indicators has some validity, however they simply record whether such plans exist, and not their efficacy. To elaborate on this disconnect, *government commitment to national standards* is based on a mixture of quantitative and qualitative sub-indicators. These depend on whether a government does, or does not have a national strategy or guidelines for monitoring nutrition (EIU, 2015). A binary score of 0-1 is used and cannot explain potential differences in quality. Ideally, this might be better explained by a quantitative model, which would be based on accurate, adequate, and timely information required for effective planning and evaluating of nutrition programmes and policies (Slining et al., 2015).

4.6 Conclusion

This paper demonstrates that the FAO's core group of food security indicators has positive and negative components, which both help and hinder international food security and nutrition studies. Major international food study constituencies draw on FAO core group indicators. However, the benchmarking exercise reveals some conceptual disconnects between the indicators and best practice. For example, the EIU draws upon FAOSTAT data before making further qualitative contributions. These FAO indicators are incomplete and often flawed, but function as a starting point for continued debate on capturing food security.

The EIU report refines the following FAO indicators: 1) availability - *amino acid scores for protein*s; 2) access - *crop storage facilities*; and 3) utilization - *expanding the range of key micronutrients covered*. Conceptual advances have not occurred in the stability category. As previously indicated, the four pillars approach appears to be ineffective in capturing governance. This limitation is confirmed by the EIU through experimentation with a multitude of governance indicators. In contrast, a food systems approach places governance in a central position due to its attention to food access allocation.

Governance indicators specific to food security can be created and strengthened through surveys. In the short-term, questionnaires on how effective food and nutrition programmes have been in improving lives are advisable. In the long-term, information can be obtained through comparative 'before and after' anthropometric and dietary recall information. Capturing the impact of corruption might be improved through electronic governance tools. While expensive to implement worldwide, representative test cases could monitor programme results and compare them against past benchmarks to determine possible leakage gaps.

Further criticism of the FAO reveals a reliance on quantitative results and the various methodologies used to compile data. Many indicators feature incomplete or sparsely populated data sets, and thus cannot act as effective tools for holistic and nuanced modelling. This results in a clear hindrance to both accuracy and transparency in research. Increased attention to rigorous data collection, resulting in complete data sets and more refined analysis by the FAO, its partner international organizations, and international food security and nutrition studies, would be extremely helpful. The FAO's conceptualization of food security is best viewed as a work in progress, valuable as a resource, but limited in depth and accuracy.

This paper encourages the construction of a much fuller and more accurate picture which reflects the multifaceted nature of food security. Benchmarking in food and nutritional studies is still in its early stages of development. The method could be more rigorously applied in order to collect best available information and set progressive standards. The refinement of benchmarking, as part of the ongoing discourse on global food security indicators, is desirable in generating more robust data. Furthermore, the inclusion of governance as a core component offers potential for more insightful and relevant policy, in both the short and long term. Evidence suggests that a holistic treatment could facilitate more accurate food security and nutrition studies.

4.6.1 Paper 1 in Context of the Thesis

This paper links to the conceptual framework by using scale to situate the debate on the nature of food security at the international level. It forms a direct link through the application of a process benchmarking methodology to maximize insights developed using nutrition, trade, and governance as analytical lenses. As the global standard-bearer for food data resources and research, the FAO functions as a reference point for many researchers and organizations seeking theory and data. The research critically interrogates the indicators and corresponding data selected by the FAO through comparison with a complimentary study by the EIU. Results offer insight to data compilation by the FAO and EIU and aim to improve the conceptualization of food security. Linkages to the framework include refinement in the recording of proteins to include plant proteins, and a significant reference to the position of governance. Trade receives minimal reference in this paper.

The use of nutrition as an analytical lens in the benchmarking exercise revealed that the FAO should more rigorously pursue statistics on micronutrients. Furthermore, the conception of dietary diversity is limited to animal proteins and requires a more inclusive protein digestibility amino acid score. Trade statistics, not extensively explored by the FAO, tend to be limited to infrastructure and are open to future conceptual development beyond the benchmarking exercise. Governance results suggest that best-practice communication of information detailing the success of food and nutritional programmes would enrich the understanding of global food security.

Findings illustrate that the accepted data measurements for nutrition and governance require improvement. This fact provides the conceptual foundation for the three following papers which apply the conceptual framework in unique ways to national, state, and district contexts.

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Chapter 5. Paper 2: Many at the Table Suffer from Malnutrition – Why? Food Group Research to Improve Global Nutrition

(Submitted to *Food Policy*)

This paper supports the central aim of this thesis by interacting with FAO data to reveal relationships that exist between the food system and nutrition. It accomplishes this by re-organizing food balance sheet data into nutritional food groups. This research engages with nutrition, trade, and governance in a significant manner. It expands the discourse on nutrition by focusing on using food groups to understand malnutrition beyond hunger. Essential to the discussion are trade strategies which range from direct WTO reform to the strengthening of regional initiatives. Opportunities for strategic nutrition-centric governance in the form of alternative development pathways are discussed.

5.1 Highlights

- Only 6 of 145 countries studied have adequate WHO designated food group supplies for medium activity diets.
- Fruit & vegetable supplies for medium activity diets are globally inadequate with few exceptions.
- Developed Mediterranean countries have high protein consumption from plant sources.
- Some developing countries could increase plant protein consumption if exports reduced.

5.2 Abstract

International food security and nutrition studies frame nutrition and dietary diversity in a narrow manner. There is a misplaced focus on the supply of carbohydrate starches and proteins, and these items can either be costly or limited in supply deficit countries, due to international trade. Dietary diversity constructs, devised by academics and used by international organizations, contain conceptual gaps. This paper contributes to the literature by drawing upon the Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT) food balance sheets, to supplement the lack of rigorous nutritional information at the comparative international level. It notes food balance sheets and commodities have not been divided into nutritional food groups and used in large cross-national food security and nutrition studies. An international food group dietary supply model is created using WHO food groups to categorize FAOSTAT data. Selected data illustrates the allocation of food group supply in relation to essential dietary requirements. A modified version of International Food Policy Research Institute's (IFPRI) Global Hunger Index is used to map the results into country groupings. Findings show that many developed Mediterranean countries with low levels of hunger and urbanization have a strong supply of fruits & vegetables. These countries derive a high proportion of protein supply from plant-based sources. Information on international trade surpluses in fruits & vegetables indicates that many non-industrialized nations have the potential to gain protein sources from plants. Evidence suggests that rapidly urbanizing and developing countries should pursue alternatives to red meat for the poor segments of their population. Including nutritional information in international food security and nutrition studies has significant potential to influence policy.

5.2.1 Keywords**:** Dietary Diversity, Food Groups, Plants, Proteins, Regions, Trade

5.3 Introduction

The world suffers from a triple burden of malnutrition, in that individuals can be overweight and obese, hungry, or affected by micronutrient deficiency (Gomez et al., 2013; Johnston et al., 2014). Particularly in the developing world, micronutrient malnutrition, due to deficiencies in essentials such as vitamin A, iodine, and iron is associated with the condition of anaemia (Leathers & Foster, 2004). Protein-calorie malnutrition commonly results in wasting (Mann & Truswell, 2007). Although healthier diets are readily available to wealthy consumers, a significant obstacle exists for many who are vulnerable since processed foods are more likely to be consumed by poorer populations (Dixon, 2009). Similarly in developed nations, the nutritional transition from plant-based diets towards consumption of animal protein, oils and fats, sugars and carbohydrates, is associated with increased affluence (WHO & FAO, 2002). It is here that the over consumption of meat and dairy products is consistently linked to obesity, cancer, and cardiovascular diseases (WHO & FAO, 2002). Despite these issues, the consumption of animal proteins has been designated by many as being the most salient measure of dietary richness (Smil, 2008). Access to inexpensive food of poor nutritional quality has led to an explosion of obesity-related problems (Eshel & Martin, 2006). Post-obesity diets are a reaction to this and emphasize the reduction of red meat and processed foods (Eshel & Martin, 2006). Research is particularly necessary in developing nations to create healthy food strategies (McMichael, 2007), and to understand regional dynamics relative to the triple burden (Gomez et al, 2013).

There are challenges to understanding whether national agricultural and food systems provide the correct balance of nutritious foods, and if populations consume recommended dietary requirements (Dangour et al., 2012). Unfortunately, contemporary food security and nutrition studies do not address balanced diets robustly. This is mainly because food requirements are not homogeneous, and the relationship between food intake and nutrition varies greatly depending on social and economic factors (Dreze & Sen, 1989; Nabhan, 2004). Increasing urbanization modifies food purchasing habits and is a major factor driving global obesity. This challenge occurs disproportionately among the poor in the developing world (Popkin et al., 2012). Strikingly, inequality in many low and middle income nations has resulted in populations that are underweight, micronutrient deficient, or obese. These conditions occur simultaneously in countries, communities, households, and individuals (Popkin, et al., 2012). This dynamic will likely be compounded by continued population and consumption growth. Research projects global demand for food will continue to increase while competition for land, water, and energy will negatively affect the ability to produce food (Godfray et al., 2010).

Evidence indicates that the international trading regime has a significant influence on nutrition. Trade in fruits & vegetables has expanded at a higher rate than other agricultural commodities from the 1980s to the mid-2000s (Huang et al., 2004) and more than doubled from the year 2000 to 2008 (Fernandez-Stark et al., 2011). Developing countries have actively pursued the production and export of horticulture due to increased global demand from rising incomes and an expanding middle class (Fernandez-Stark et al., 2011). Fruits & vegetables are essential to nutrition, and a distinctive pattern of trade in these commodities has been largely, but not exclusively, established around a south/north dynamic (Friedland, 1994). Much of the production takes place in less developed nations of the global south, for consumption in the capitalist north (Friedland, 1994). While trade reform to mitigate inequalities between nations is desirable, a long-term solution remains elusive due to conflicting visions of how to resolve negotiations on the proposed Special Safeguard Mechanism (SSM) (WTO, 2008). In the meantime, alternative strategies are being implemented. Trade and investment have been increasing between developing countries (UNCTAD, 2009) and there has been a proliferation of regional trading blocs which interact with the global system to advance common interests (Nielsen, 2006).

This paper recognizes that a combination of limited data and changing socio-economic developments will demand that more robust methodologies are used to conceptualize, capture, and apply nutritional information in large international food security and nutrition studies. An awareness of dietary diversity could assist policy makers in addressing the unique nutritional needs of individuals. This paper contributes to the literature by considering the question, ‘To what extent might more rigorous nutritional information positively impact food policy?’

The recommendation to consume diverse types of foodstuffs is an internationally accepted means for achieving a healthy diet (Ruel, 2003). Despite this general agreement, there is a lack of consensus on how to measure and operationalize dietary diversity. In particular, healthy food diversity is often debated in the literature (Drescher et al., 2007; Ruel, 2003). Dietary diversity is usually measured by counting foods or food groups consumed over a reference period. However, a number of contrasting groups, unique classification systems, and diverse reference periods are used (Kant, 1996). Approaches for measuring overall diet quality include those which focus on examining the intake of nutrients, food groups, or a combination of both (Kant, 1996). There is a strong argument for measuring diets through micronutrients since many are essential to proper nutrition (Gomez et al., 2013). However, only vitamin A, iron, and iodine are routinely and robustly monitored to allow for country comparisons (Gomez et al., 2013). Nutritional status is recorded infrequently, the demand for data is low, while coverage varies and is difficult to assess (Haddad, 2013). The FAO’s *prevalence of undernourishment* indicator is based on the mean quantity of available calories, the inequality in access to those calories, and the mean minimum amount of required calories (Haen et al., 2011). This approach is problematic as dietary energy needs are based on the assumption of an aggregated minimum dietary energy requirement (MDER). The MDER refers to the amount of food energy needed to maintain an acceptable minimum body weight, body composition, and level of minimum sedentary physical activity, consistent with long-term good health (Haen et al., 2011). The MDER monitors minimums, rather than monitoring the ability of populations to live more active, dynamic lives. This information is useful in combating the hunger component of international food security, but does not assist in addressing the triple burden (Headey & Ecker, 2012). Unfortunately, methods which go beyond calories and incorporate dietary diversity, do not contain rigorous cut-offs to identify moderate or severe dietary inadequacy (Headey & Ecker, 2012). Further research could expand the literature by illustrating these nuances.

A popular approach encourages counting of the 12 groups used to construct the FAO's food balance sheets (Hatloy & Oshaug, 1998). Some studies encourage the counting of each food item separately (Drewnowski et al., 1997; Hatloy & Oshaug, 1998; Krebs-Smith et al., 1987). Researchers then group food into various arranged categories. The International Dietary Quality Index records five main food groups, noting variety within protein sources (Kim et al., 2003). Some indexes have been developed using a more simplified model. The Healthy Eating Index (HEI), is based on a ten component system of five food groups, four nutrients, and a measure of variety in food intake (Kennedy et al., 1995). Similarly, an index was created by Drescher et al. (2007) which focused on three key aspects of healthy food diversity: number, distribution, and the health value of consumed foods (Drescher et al., 2007). Unfortunately, none of these methods are consistently applied. Notably, the FAO recently selected three nutrition-specific indicators based on food groups, for its core set on food security: *energy supply derived from cereals* *and roots & tubers*; *average protein supply*; and *supply of proteins of animal origin* (FAO, 2012). The indicators are limited by their exclusive focus on starch carbohydrates and proteins.

The FAO and World Food Programme (WFP) attempt to meet this challenge by using information on dietary diversity to inform food security analysis. The organizations use different data collection methods and analytical approaches (Kennedy et al., 2011; WFP, 2008). The FAO uses a one day Household Dietary Diversity Score (HDDS), based on guidelines produced by the Food and Nutrition Technical Assistance Project (Kennedy et al., 2011), while the Food Consumption Score (FCS) is used by the WFP (WFP, 2008). The FAO solely collects quantitative information, while the WFP incorporates both quantitative and qualitative information (Kennedy et al., 2011; WFP, 2008). The HDDS provides a clear picture at the population level, and is favoured when time and the resources for data collection are limited (Kennedy et al., 2011). The FCS offers a richer consumption profile and is more useful over a longer reference period, as it requires more time for data collection (WFP, 2008). The FCS and HDDS each focus on the number of food groups consumed, rather than portion size or the proportions of each food group consumed. Both studies award points for the consumption of food such as sweets, which are not required for a healthy diet (Kennedy et al., 2011; WFP, 2008).

These studies implement data collection and use analysis methods which do not incorporate a sophisticated treatment of nutritional requirements. Most strikingly, numeric weights are assigned to food groups rather than recording required nutrients. In the case of the WFP, critics note that positive associations observed in the results of the FCS, do not necessarily equate to favourable nutrient intakes (Jones et al., 2013). It weighs fruits & vegetables lower than staple foods (Jones et al., 2013). The HDDS weighs all food groups equally (Kennedy et al., 2011). The HDDS records the quantitative dietary recall of all food/drink consumed by any household member within a 24-hour window. A score is calculated based on the sum of 12 food groups (Kennedy et al., 2011). In contrast, the FCS is a list-based recall of frequency of household consumption over the past seven days (WFP, 2008). Food items are grouped into the eight food groups. Values for each food group are multiplied by the respective food group weight and the sum of the weighted scores is the FCS (WFP, 2008). The studies are summarized in Table 5.1.

Table 5.1

HDDS and FCS Food Group Items. *Source:* (Kennedy et al., 2011; WFP, 2008).

HDDS Food Group	Weight (Score)	FCS Food Group	Weight (Score)
Cereals	1	Cereals, Tubers and Root Crops	2
White Root and Tubers	1	Meat and Fish	4
Meat	1	Milk	4
Fish	1	Oil/Fats	0.5
Eggs	1	Fruits	1
Milk and Dairy	1	Vegetables	1
Oils and Fats	1	Pulses	3
Fruits	1	Sugar	0.5
Vegetables	1		
Pulses, Legumes and Nuts	1		
Sweets	1		
Spices, Condiments and Beverages	1		

Food groups and dietary diversity are recorded in a variety of ways. Unfortunately, a lack of consensus means that this measure is not adequately captured in most food security and nutrition studies. A solution would have significant potential to positively inform food policy.

5.4 Methodology

The International Food Policy Institute (IFPRI) produces a global hunger index (IFPRI, 2013) which ranks low and middle development nations. A modified global hunger index (120 nations from the global hunger index with available FAOSTAT data plus 25 additional industrialized nations with available data) of 145 countries was created to facilitate a global inquiry (see Figure 5.1).

FAOSTAT food balance sheets present a country's food supply during a specified reference period, showing food item information on availability for human consumption in grams/capita/day (FAO, 2015a). This paper placed FAOSTAT food balance sheet information into four food groups determined by the World Health Organization (WHO) as being essential for nutrition: starch carbohydrates, fruits & vegetables, dairy, and proteins (see Table 5.2). A food group dietary supply model was created. The model was fused with the modified global hunger index to identify the availability of food groups essential to nutrition across nations. In order to expand upon hunger to capture all aspects of the triple burden of malnutrition, the availability of food groups for medium levels of physical activity were calculated based on WHO standards of recommended dietary consumption (see Table 5.3 and Table 5.4).

Further application of food balance sheet information was required to explore the nuances of global protein consumption. Calculations were made to determine: the average supply from protein sources for hunger groups (see Figure 5.2), largest supply of plant based protein sources for industrialized countries (fruits & vegetables along with pulses and treenuts, see Table 5.5), and the hunger groups of fruit & vegetable exporting countries (Figure 5.3).

FAO food balance sheets have strengths and weaknesses. On the positive side, the data indicates shortages and surpluses for each food item and distinguishes between supply from domestic production and trade (FAO, 2001). Critically, the data are assembled from a variety of sources across many countries, and since quality and coverage vary considerably, there is room for inaccuracies and errors (FAO, 2001). The challenges of recording subsistence food crops, accurately predicting food waste, and accounting for seasonal commodity yield variations, are limiting. Furthermore, food balance sheets are unable to explain food consumption patterns; however, the data can be used to speculate on consumption from a supply perspective (FAO, 2001). Information obtained through household and food consumption surveys are the preferred source (FAO, 2001). Since food balance sheets tend to overestimate consumption (Kearney, 2010), it can be generally assumed that worse case scenarios are not omitted. However, without comprehensive international data on consumption, food balance sheets are the sole source facilitating cross country comparisons (FAO, 2001). The possibility for cross-referencing is not present. Despite the drawbacks, international food and nutritional studies acknowledge the reality, and have referenced food balance sheet data when making consumption inferences (Popkin et al., 2012).

5.4.1 Hunger and Food Group Model Development

A total of 145 countries were selected for analysis based on 2010 FAOSTAT data availability. Of these, 120 were taken from the IFPRI 2013 Global Hunger Index (IFPRI, 2013), in addition to 25 industrialized countries. This paper created five distinct hunger groups (Hunger Group 1 to 5) which modified the IFPRI study:

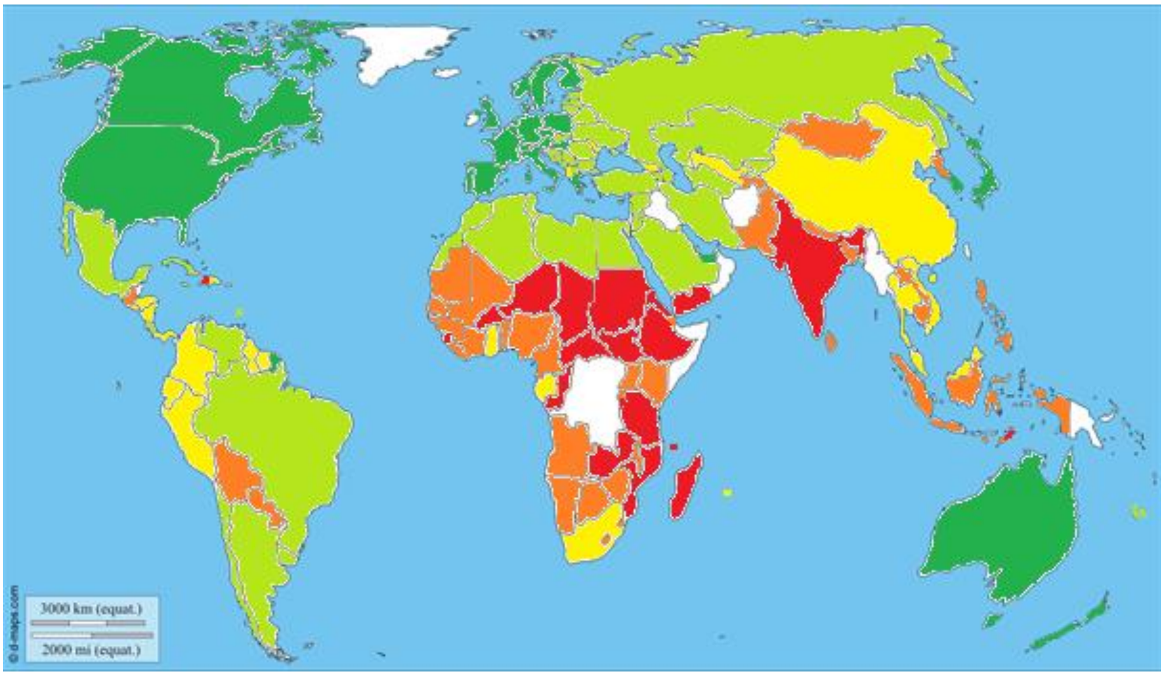
25 Industrialized Countries (Hunger Group 1. Abbreviated HG1. See Appendix 2a.
42 Upper Middle Countries (Hunger Group 2. Abbreviated HG2. See Appendix 2b.
22 Lower Middle Countries (Hunger Group 3. Abbreviated HG3. See Appendix 2c.
37 Upper Developing Countries (Hunger Group 4. Abbreviated HG4. See Appendix 2d.
19 Lower Developing Countries (Hunger Group 5. Abbreviated HG5. See Appendix 2e.

Hunger Group 1 is comprised of the 25 industrialized countries not present in the Global Hunger Index. Hunger Group 5 combine the two lowest ranking groups in the IFPRI study. Hunger Groups 2, 3, and 4 consist of nations which are placed in groups identical to IFPRI. All hunger groups are presented on a colour coded world map presented in Figure 5.1 (See Appendix 1a and Appendices 2a-e for a listing of specific countries in each of the five hunger groups).

Figure 5.1

Hunger Groups in the World. *Source:* Author calculations based on a modification of the Global Hunger Index (IFPRI, 2013) country groups (Appendices 1a and 2a-e).

(map modified from: http://d-maps.com/carte.php?num_car=13180&lang=en)



Legend: ■ HG1; □ HG2; □ HG3; ■ HG4; ■ HG5; □ No Data

FAOSTAT food balance sheet supply information facilitated this study. The reference year of 2010 has the most recent information, and grams/capita is the unit of measurement. Table 5.2 outlines how the FAOSTAT data are categorized into new WHO food groups for computations. Computations produced surplus/deficit of national food group supply results, and are presented in Table 5.4.

Table 5.2

Essential Food Groups. Calculated using FAOSTAT Data. *Source:* Author calculations based on the WHO CINDI pyramid methodology (WHO, 2000).

Nutritional Food Group Name	Components of Calculation using FAOSTAT (2010)
Starch Carbohydrates	Result derived by adding the categories of cereals and starchy roots.
Fruits & Vegetables	Calculated using data under the headings of fruits and vegetables, respectively.
Dairy	Result from the milk category in the database.
Proteins	Calculated by adding the cumulative results for eggs, fish, meat, pulses, treenuts, and aquatic products.

5.4.2 Model Application

The food group computations were used to compare the gap between daily dietary needs and available food group supply. The average supply for all countries in each hunger group was subtracted from the WHO CINDI recommended dietary consumption totals for medium activity individuals. The unit of measurement was grams/ per capita. Table 5.3 outlines the recommended consumption levels suggested by the WHO. The data used to generate the computations are available in Appendices 2a-e.

Table 5.3

WHO CINDI Food Group. Recommended Dietary Consumption (grams/per capita/day). *Source:* (WHO, 2000).

Food Item	Model 1 Low Activity	Model 2 Medium Activity	Model 3 High Activity
Bread, Pasta, Rice & Potatoes	300g	450g	600g
Fruits & Vegetables	500g	700g	900g
Milk & Dairy	200g	250g	300g
Meat & Alternatives	100g	200g	300g

Protein source supply information in grams/per capita/day for each of the hunger groups were calculated by the author from information found in the FAOSTAT database: red meat (bovine & pork), seafood (fish & aquatic products), poultry (chicken & eggs), pulses & treenuts, and fruits & vegetables. Empirical findings are presented for the five nations with the highest amount of protein from the plant-based sources of fruits & vegetables and pulses & treenuts. Also included are levels of urbanization and the overall level of urbanization found in the G1 collection of industrialized nations. Findings are presented in Table 5.5 and data are included for all countries and food groups selected for use in the study (Appendices 3a-e).

The relationship between trade surpluses in fruits & vegetables and hunger groups was investigated. 2010 FAOSTAT food balance sheet data on national trade for fruits & vegetables was used. Countries which have a trade surplus were selected and assigned a percentage share of international trade in the food group. Those with >2% or <2% of the total trade surplus are distinguished in a map (Figure 5.3; Appendix 1b).

5.5 Results

5.5.1 Dietary Diversity

The food group dietary supply model indicates that only six of 145 selected countries have adequate supplies of all essential food groups required for nutrition. HG1 countries Greece, Italy, and Portugal are joined by HG2 countries Cuba, Lebanon, and Montenegro since they enjoy surpluses across all food groups (Table 5.4; Appendix 2b). Remaining countries experience varied supplies of essential food groups. Starch carbohydrates are abundant across all groups but HG4 had the largest surplus (Appendix 2d). Fruits & vegetables are insufficient across all groups, with HG1 and HG2 recording lower relative deficits. Dairy deficits are present from HG3 through to HG5, while proteins have deficits in HG4 and HG5. Hunger groups which have urbanization levels under 50% experience deficits for all food groups with the exception of starch carbohydrates (Appendices 2c-e).

Table 5.4

Essential Food Group Supply: Surpluses/Deficits (grams/capita). *Source:* Author calculations using food group dietary supply model and 2010 FAOSTAT food balance sheet data (Appendices 2a-e).

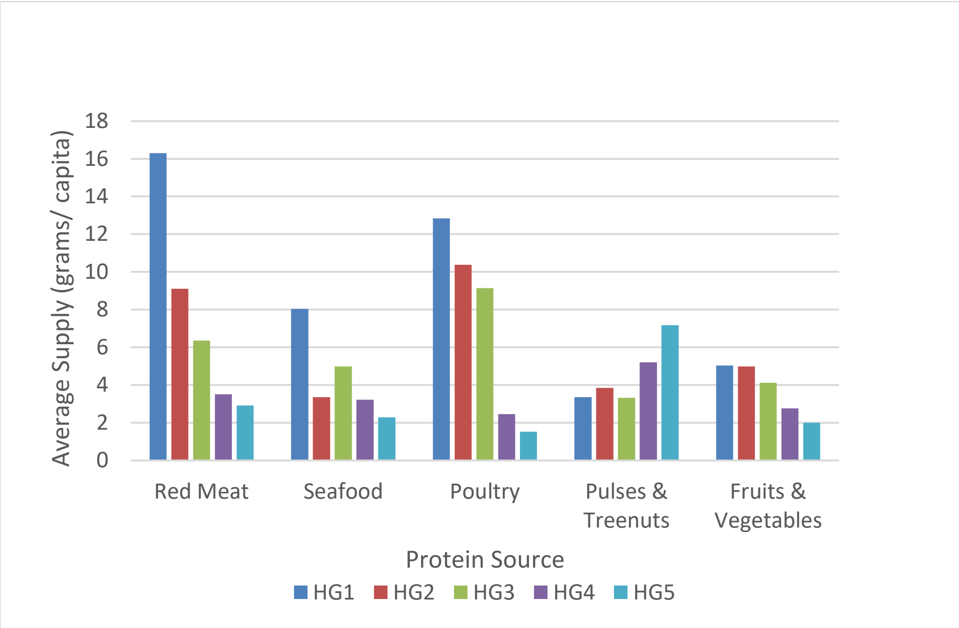
Hunger Group	Starch Carbohydrates	Fruits & Vegetables	Dairy	Proteins	Urban (%)	Deficit free countries
HG1	47.79	-119.50	363.41	160.20	78.48	Greece, Italy, Portugal
HG2	150.78	-120.02	160.30	29.28	66.31	Cuba, Lebanon, Montenegro
HG3	94.04	-221.77	-2.77	1.86	56.68	-
HG4	204.32	-419	-137.35	-81.21	40.73	-
HG5	101.84	-540	-151.37	-73.05	30.95	-

5.5.2 Plant-based Protein Sources

Hunger groups differ in their main protein source (Figure 5.2, Appendices 3a-e). HG1 draws mostly on red meat. HG2 and HG3 have a greater reliance on poultry. HG4 and HG5 depend on pulses & tree nuts (Figure 5.2). The average consumption of red meat protein sources increases with improved hunger scores; while conversely consumption in pulses & tree nuts decline. The largest single increase in red meat consumption occurs between HG2 and HG1. If the supply of pulses & tree nuts were maintained at average HG5 levels, more than half of this increase (3.81g/7.29g) could be mitigated (Author calculation). Similarly, if pulses & tree nuts were supplied at lowest hunger group levels, they could replace between 20-25% of red meat consumption in industrialized nations (Author calculation).

Figure 5.2

Average Supply from Protein Sources (grams/capita). *Source:* Author calculations based on 2010 FAOSTAT food balance sheet data (Appendices 3a-e).



A significant number of countries which draw high amounts of protein from plant-based resources are located in the industrialized European Mediterranean region (Table 5.5, Appendix 3a). Greece, Portugal, Italy, and Spain are close to the top in the consumption of fruits & vegetables. Similarly, pulses & treenuts feature Spain, Italy and Greece at the top. These countries all share urbanization rates under the average HG1 rate of 78.48%. A comparison shows that Greece with a cumulative score of 12.8g, Spain at 12.4g, and Italy at 11.8g, are significantly above the HG1 average of 8.4g for plant-based protein supply.

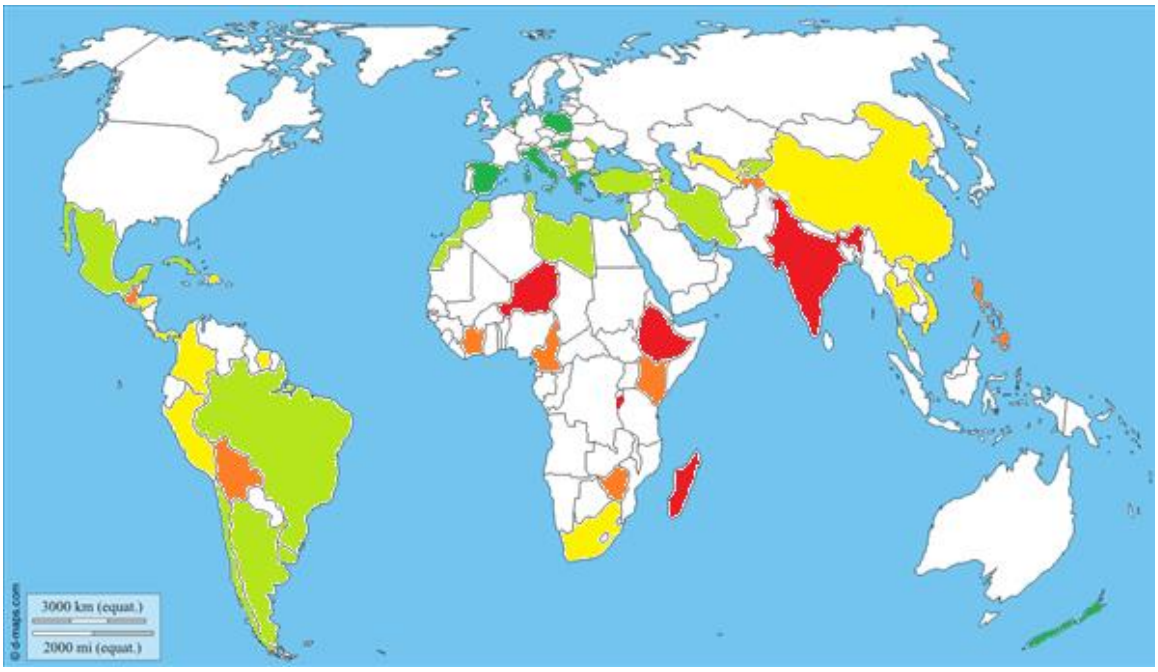
Table 5.5

Largest Supply of Plant-based Protein Sources (grams/capita) **for HG1 Countries.** *Source:* Author collection of 2010 FAOSTAT food balance sheet data on fruits & vegetables and pulses & treenuts (Appendices 3a-e).

HG1 Country	From Fruits & Vegetables (g)	Urban %	HG1 Country	From Pulses & Treenuts (g)	Urban %
South Korea	8.9	83	UAE	16.1	84
Greece	8.3	61	Canada	7.5	81
Portugal	7.8	61	Spain	6.7	77
Italy	7.2	68	Italy	4.6	68
Spain	5.7	77	Greece	4.5	61
Average HG1	**5.04**	**78.48**	**Average HG1**	**3.36**	**78.48**

Figure 5.3

The Hunger Groups of Fruit & Vegetable Exporting Countries. *Source:* Author collection based on the correlation between hunger group membership and status as a fruit & vegetable exporter (2010). See Appendix 1b for full listing of specific countries. (map modified from: http://d-maps.com/carte.php?num_car=13180&lang=en)



Legend: Share of Trade Surplus (%) HG1- 18.5; HG2- 39.5; HG3- 30; HG4-7; HG5- 5; No Data

5.5.3 Trade

Evidence suggests the majority of international fruit and vegetable exports originate from HG2 and HG3 hunger groups (Figure 5.3). Regional dynamics are present which largely correlate to hunger groups. Middle Eastern and Latin American nations are prevalent in HG2, Latin American and southeast/east Asian in HG3, and African in HG4 and HG5. India is the sole HG5 nation at present with a greater than 2% trade surplus share.

5.6 Discussion

5.6.1 Dietary Diversity

Food security studies focus on the challenge of capturing food supply and availability when comparing nations (Pinstrup-Andersen, 2009), emphasizing caloric minimums to draw conclusions (FAO, 2014). Dietary diversity indicators are stronger within countries, but often struggle to make cross-country comparisons. There is a lack of coordination, dissemination of data is incomplete, and many inconsistencies exist between sundry culinary cultures (Jones et al., 2013). Conclusions draw on nationally aggregated data on food supply. Sources include food balance sheets, which cover the total amount of food produced and imported, along with utilization figures, which include statistics on food exports (Jones et al., 2013).

The food group dietary supply model supports the argument for the use of more rigorous nutritional information to inform food policy. It illustrates that food balance sheets can be processed into food groups which provide insights into dietary energy supply at the international level. The groups reveal food supply deficits when medium dietary requirements are considered (Table 5.4, Appendices 2a-e). This paper suggests that food security and dietary diversity should be measured beyond the minimum standards currently employed by food security indicators (Haen et al., 2011). Through applying the standard of *medium activity levels* across four key food groups required for nutrition (WHO, 2000), this study identified large deficits of food supply for all hunger groups in fruits & vegetables. Conversely, there is a general abundance of starch carbohydrates. Dairy experiences a transition from deficit to surplus in HG2 and similarly, proteins are adequate beginning in HG3 (Table 5.4, Appendices 2a-e). Only six of 145 countries studied show sufficient supply across all essential food groups for nutrition, and five of these are Mediterranean countries (Table 5.4, Appendices 2a-e). Findings confirm that the global agricultural system produces enough food to feed the planet, but access to and consumption of sufficient amounts of nutritious food continues to be a challenge (Johnston et al., 2014). Food balance sheets often result in overestimation of food consumption (Kearney, 2010). The findings in this paper reveal that significant supply shortages of key food items make a balanced and healthy meal difficult for a large number of citizens across many nations. A modification of food security and nutrition studies is strongly encouraged.

5.6.2 Plant-based Proteins

The ability of rapidly urbanizing nations to maintain a balance between socio-economic development and nutritious diets is crucial. The results of this paper show that specific hunger groups each have a unique protein source that is dominant (Figure 5.2, Appendices 3a-e). Evidence suggests that countries could benefit by prioritizing their dominant protein source while monitoring the nutritional transition in urban areas. This would help identify points of intervention. India belongs to HG5 and derives its main source of proteins from plant-based sources of pulses and fruits & vegetables (Author calculation: Figure 5.2, Appendix 3e). Despite this, many higher income members of the population, primarily situated in urban areas, are consuming a more substantial percentage of their diets from animal products, sugars, and fats (Shetty, 2002). Findings indicate that the largest single transitional leap to animal-based protein consumption occurs from HG2 to HG1 during the final stage of industrialization (Figure 5.2, Appendices 3a-b). This could be partially mitigated by maintaining levels of plant protein supply, found in lower hunger groups, as nations develop (Author calculation: Figure 5.2, Appendices 3d-e).

However, exceptions exist. A number of developed Mediterranean countries have significant protein supply from plant-based sources despite relatively lower levels of urbanization (Table 5.5, Appendix 3a). Findings indicate that a standard nutritional transition is not essential. With expanding global incomes increasing the consumption of animal-source foods, many traditional or local foods, have been viewed as inferior goods or *foods of the poor*, rather than nutritious, sustainable options (Seale et al., 2003). In contrast, many traditional and local foods provide plant-based protein to those who are unable to afford more costly red meat protein sources that are increasingly dominant. This intersection creates the opportunity for intervention.

Increased consumption of plant proteins and fruits & vegetables, in both the developed and developing world, will have a direct positive effect on dietary health. This paper advocates in favour of a broad, multi-sectoral policy approach integrating nutrition into smallholder agriculture (World Bank, 2010). It can be accomplished by encouraging home production of those fruits & vegetables that are nutrient rich, in addition to promoting education regarding nutrition and health (World Bank, 2010). Urbanizing countries exhibiting deficits in fruits & vegetables, should explore peri-urban agricultural solutions thus incorporating a mosaic of urban and rural worlds which are inspired by home gardens (Lerner & Eakin, 2011; Tornaghi, 2014).

The development of educational programmes to mitigate the negative impacts of a possible nutritional transition could yield positive outcomes. Research indicates that the consumption of fruits & vegetables in adults can be increased by a variety of approaches, and those involving a personalized, face-to-face component in the intervention, are the most successful. Viable strategies include individual counselling through religious institutions, or in collaboration with workplaces (Pomerleau et al., 2005). In instances where these approaches are not feasible for entire populations, individually tailored information in either print or digital form is a reasonable alternative (Pomerleau et al., 2005). Additional research shows that a community intervention approach is the only cost-effective means to target an entire community. Furthermore, all intervention programmes have limitations, and even the most successful initiatives have been shown to impact approximately 5% of the population (Cobiac et al., 2010). Further gains could be realized through market interventions to secure availability and access.

Results and supporting disciplinary research suggest that maintaining the supply levels of plant-based protein for urbanizing non-industrialized nations, could mitigate the severity of the shift to a diet which consists of significant amounts of animal-proteins. This strategy is potentially beneficial as the literature suggests agricultural market power moves away from individual producers, to a limited number of large trade, retail, and agribusiness companies (IAASTD, 2009). The modernization of the food system contributes to increased food security, yet this has not resulted in the production of more nutritious foods for all (Chicago Council on Global Affairs, 2011).

5.6.3 Trade

Analysis indicates the vast majority of fruits & vegetables originate from countries which are still battling hunger. There should be a simultaneous re-evaluation of how countries with significant dietary challenges interact with the international food trade regime. Policy strategies for fruit & vegetable exporters should not be identical, but based on unique features of hunger groups and geographical regions.

An emergent corporate environmental food regime of governments, the private sector, collective organizations, and privileged individuals, is evident (Friedmann, 2005). This results in consolidation of inequality between the rich and poor, expressed in the retailing of food supply chains subdivided by class diets (Friedmann, 2005). A strong argument exists that the current food regime is corporate in nature, and politically constructed around the division of agricultural labour. Northern staple grains (surpluses) are traded for southern high-value products, in the form of protein from animal meat and fruits & vegetables (McMichael, 2009). WTO negotiations have preserved farm subsidies for the global north alone, while the global south has been forced to reduce agricultural protections, import staples, and export high-value foods (McMichael, 2009).

The fruit & vegetable exporters of the developed Mediterranean (Italy, Spain, and Greece), are members of HG1 (Figure 5.3, Appendix 1b). The proximity of the Mediterranean Middle East exporters in HG2: Turkey, Egypt, Lebanon, Morocco, Jordan, and Tunisia provides an opportunity for new policy initiatives (Figure 5.3, Appendix 1b). Regional trade liberalization in the wider Mediterranean, could take advantage of existing logistical agro-food flows of fruits & vegetables from the southern shore of the Mediterranean into Europe, improving efficiency, and reducing wastage (Malogio & Hertzberg, 2007). Recent investment trends in agricultural and agro-food projects by European firms in the region are palpable. However, political divergences have prevented the emergence of an economically linked regional entity (Cheriet & Rastoin, 2014). This could make additional resources available for addressing those affected by food concerns in HG2 Middle Eastern countries.

A closer analysis reveals that the North African nations of Egypt, Morocco, and Tunisia contrast with one another with respect to food expenditure. The United States Development Agency (USDA) Economic Research Service, records food group expenditure to show that Tunisians pay only 35.95% of their total household expenditures on food while fruits and vegetables make up 28.19% of their total food expenditure (Rakotoarisoa et al., 2011). In contrast, Morocco records scores of 45.61% of total expenditures on food and 18.41% for fruits and vegetables (Rakotoarisoa et al., 2011). Egypt is even further removed with 48.08% food expenditure and 12.53% of food expenditure on fruits and vegetables (Rakotoarisoa et al., 2011). Furthermore, Tunisia enjoys the lowest income elasticities for all major food groups and its agricultural GDP per worker is the highest among the three nations (Rakotoarisoa et al., 2011). This republic is in the strongest position of the trio to consider large-scale fruit and vegetable exports. Its strengths come from the high consumption rates of the food group, relatively low food expenditure, income stability, and a comparatively prosperous agricultural workforce.

The approach taken by countries situated in lower hunger groups should improve positioning in relation to structural inequalities found in the global trade regime. The G-33 group of developing countries are led by India in opposing restrictions on public stockholding of food resources, particularly in the context of running programmes that target the poor (FAO, 2014). Current WTO *Amber Box/Aggregate Measurement of Support* (AMS) thresholds, stipulate that trade distorting support is constituted when 10% of the total value of production is procured by government price supports (FAO, 2014). The potential gains in modifying this are significant. Among 100 developing countries with membership in the WTO, only 14 have recourse to the AMS. Furthermore, the most populous developing countries with food security issues such as India, Pakistan, Turkey, and Egypt are excluded (FAO, 2014).

India is a large HG5 country with a National Food Security Act (NFSA) that guarantees the Right to Food, and requires extensive state stockpiling for the implementation of this programme (Kishore et al., 2014). A recent agreement between India and the United States prioritizes moving forward on trade reform with the condition of protecting the right to public stockholding programmes for food security (WTO, 2015). However, the details are interim and a viable solution has yet to be found (WTO, 2015). Notably, a peace clause is in place at the WTO, which allows India to continue grain procurement in breach of the 10% subsidy cap without triggering action from other member states (The Economic Times, 2015). India has tremendous food consumption deficits for fruits and vegetables (Deaton & Dreze, 2009) yet in the context of trade, India is one of the world's largest exporters of fruits & vegetables (Figure 5.3, Appendix 1b). A review of national trade policy is advisable in light of this consumption deficit.

5.7 Conclusion

This study contributes to food policy by reorganizing food data to better illuminate nutritional challenges. It has the potential to influence conceptual and methodological improvements, educational development, cultural change, and collaborative multinational action. The concept of dietary diversity is continually being refined in the literature. It is illuminating to consider dietary requirements in the context of medium dietary energy needs. There is potential for processing food balance sheet data into a dietary food group model, thus providing detailed information regarding national food supplies. Results indicate that almost all countries in the world have a deficit in at least one major food group deemed essential for healthy nutrition. Also, there are insufficient fruits & vegetables to meet medium activity dietary energy needs in each global hunger group. Developed Mediterranean nations demonstrating high levels of protein consumption from plant sources, stand as viable and successful models for rapidly urbanizing, developing countries with food challenges.

It is recommended that the food group dietary supply model might undergo a sensitivity test by using time-series analysis. A multi-year average of FAOSTAT data would be able to reflect possible fluctuations caused by social, economic, and environmental impacts. Furthermore, an examination of data at the level of individual food items which are used to make the four food groups is desirable.

A further possibility is to conduct research on population distribution and dietary energy requirements for each nation in the model. This would create a more nuanced picture of the food supply and consumption relationship for various population groups in society. It would also inform whether the average universal individual estimate, as used in the current model to explain energy requirements, is representative.

As data is often collected in increments of three years, it is recommended that all available information from that period should be taken to ensure multiple observations are considered. The sample would ideally be taken from the most recent three years available, which is currently 2009-2011. This is possible as 2011 data was recently released.

Preliminary findings indicate that developing countries which have the resources for significant plant-based protein consumption, could adopt a broad, multi-sectoral approach incorporating educational, cultural, and economic policy intervention to improve nutrition. It appears international exports of fruits & vegetables largely originate from medium hunger group countries. However, there is the potential for regional alliances and trade reform to mitigate this pattern. Nations such as India and Tunisia find themselves in advantageous positions to act as regional and global leaders. Overall, the regional and hunger group trends presented in this study can lead to more in-depth research to impact national level policy makers.

Results could serve as a harbinger for further conceptual and methodological engagement within the wider food, nutrition, development research, and policy communities. Developing more rigorous dietary diversity and nutritional information is essential to lighten the triple burden of malnutrition. While this study has begun the process the adoption of various approaches is suggested. Stakeholders (e.g., government policy makers, corporations, non-profit organizations, academics, and individuals) could engage in dialogue and socially responsible decision making with the potential to more fully address the challenges of global hunger and malnutrition.

5.7.1 Paper 2 in Context of the Thesis

Paper 2 considers the potential of nutritional information to positively impact food policy. It builds upon analysis generated in Paper 1 and considers dietary diversity at the international level while also exploring how FAO food balance sheet data can be used. Functioning at the national scale, Paper 2 contemplates food security and nutrition at the national level across the nation states of the world. This paper forges direct links to the conceptual framework through the consideration of nutrition, trade, and governance to understand national food supplies and nutritional requirements.

Nutrition information, functioning as an analytical lens to organize FAOSTAT national food group data, enables the creation of essential food groups. This re-organization allows for a more critical examination of malnutrition beyond hunger, and dietary diversity beyond animal protein consumption. Results place the use of plant proteins at the centre of the discussion.

By employing trade as an analytical lens, the paper records deficits and surpluses in major food groups which exist among various hunger groups. It suggests alternative development strategies, which favour pulse production and consumption, could be adopted for nations undergoing a nutrition transition. It further advises potential benefits from regional trade initiatives in the southern Mediterranean and more rigorous WTO reform in the case of large fruits & vegetable exporting nations such as India.

Paper 2 highlights the need for relevant governance structures which prioritize policies to increase plant-based protein supply and consumption to improve nutritional health. Findings suggest that a broader treatment of dietary diversity, as previously advocated in paper one, when also applied to national level data, produces conclusions relevant for improved nutrition.

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Chapter 6. Paper 3: Maximizing India's Vast Resources for Improved Nutrition: Reforming the National Food Security Act

(Submitted to *Food Security*)

This paper supports the central aim of this thesis by interacting with Indiastat data to uncover linkages between India's food system and the nutritional well-being of its citizens. It facilitates this by constructing a holistic model based on key drivers of India's food system and uses the results to inform the strategic distribution of plant proteins at the state level. The analytical lenses of nutrition, trade, and governance from the conceptual framework interact with one another prominently. The expansion of the 2013 National Food Security Act (NFSA) to include plant proteins, development of inter-state relationships in pulse production and import/export, and collaboration between the central and state governments to facilitate strategies and reduce corruption, are encouraged.

6.1 Abstract

India is presently struggling with significant levels of malnutrition. In order to cope with the challenge, in 2013 a national food distribution programme known as the NFSA was created to distribute essential grains (rice, wheat, millet) to those in need. Due to many shortcomings in conception and implementation, the NFSA is currently undergoing a process of reform to potentially increase the supply of pulses and make use of e-governance mechanisms. This paper critiques the existing approach to food security in India by taking a holistic approach to food security and nutrition studies. A state food potential model for India was created based on five indicators representing key drivers: Economic, Nature, Nutrition, Development, and Governance. These indicators were analysed to identify the Indian states that require the most intervention. This information

was then compared against crop cultivation and storage resources, technological connectivity, and climate impacts reported on those states. This represents a nutrition-sensitive agriculture approach to reforming the NFSA. Findings suggest that the states in greatest need are located in the north and east of the country. In addition, a series of pulse producing states adjacent to these areas have surplus resources for export. These findings are relevant to domestic and international scholars who are investigating ways to connect India's public distribution programmes to the wider food system and to policy makers situated at national and state scales. This research has wider application in positioning developing countries and their resources in relation to the international food system, and will inform food policy research in similar contexts.

6.1.1 Keywords: Communication Connectivity, Food Potential, Indian States, Improved Nutrition, Pulse Production

6.2 Introduction

Recent research notes that there is a lack of information with respect to the links between agriculture and nutrition in India (Gillespie et al., 2015). The nation, largely self-sufficient in food grains, is emerging as a global food exporter (Ramachandran, 2007). Endemic pockets of hunger remain, seasonal shortfalls are common, and malnutrition is widespread especially for women and children (Ramachandran, 2007). Infrastructural challenges and food waste broadly contribute to the problem, and even those states with the best cold storage facilities for fresh produce (Rajasthan, Madhya Pradesh, & Chhattisgarh), are not immune. These three states contain villages which experience hunger for a minimum of two to a maximum of eight months per annum (Barme & Ramachandran, 2002). Within this context, the *Right to Food* movement draws from the

Right to Life in Article 21 of the Indian Constitution, and supports freedom from hunger and undernutrition for all of India's citizens (Kishore et al., 2014). Demands include an active universal public distribution system (Swaminathan, n.d.). The NFSA grew out of this movement and aims to provide food and nutritional security by ensuring access to food at affordable prices. It builds on the Targeted Public Distribution System (TPDS), by providing subsidized food to 75% of rural and 50% of urban households (Kishore et al., 2014; Kumar et al., 2014; Joshi, 2013; Rai et al., 2015). The TPDS is the main policy instrument used by the government to address food needs (Rai et al., 2015). Critics note that the procurement system is flawed, with a few prosperous regions being favoured and individual states lacking influence in the process (Karmakar & Mukhopadhyay, 2014). Despite constraints, the literature in the field has noted the potential impact of the NFSA. This paper asks 'In what ways does the National Food Security Act in India need to be reformed to enhance its programme efficacy?' This question is pertinent to the current context in India and leads to the expansion of related literature that has national and cross-national relevance. The relationship between large public distribution systems and the wider food system is not rigorously explored. The rapid development of India's economy alongside persistent food and health challenges makes it a salient case study.

Research supports the production and consumption of micronutrient rich foods which are essential for improved food security in India (Nandi & Bhattacharjee, 2005). The current structure of the programme, heavily based on rice and wheat, cannot provide critical vitamins and minerals (Rai et al., 2015). Unfortunately, because market prices exceed minimum support prices, the government only procures pulses and oilseeds for release into the TPDS on a limited basis (Jacoby, 2013). A modest inclusion of these food items is significant to diets and health. Nutritional priorities are questioned in light of changing food baskets (Joshi, 2013). Economic development and urbanization are increasing the size of the middle class and result in a dietary shift which influences a traditionally vegetarian population to consume more meat (MacDonald & Iyer, 2012). Dietary changes occurring with the shift from rural to urban lifestyle contributes to an obesity epidemic (Yadav & Kishnan, 2008). At present the reality of this nutritional transition continues across much of the country. Government surveys indicate that consumers are rapidly increasing their consumption of animal products, vegetables and fruits while reducing their consumption of cereals (Basole & Basu, 2015a; Gandhi & Zhou, 2014). Managing this transition will be a significant challenge but the NFSA could play an important role.

Currently, a research and policy environment favours experimenting with providing pulses, instead of and in addition to, cereals in the NFSA. Such an action could have a significant impact on health benefits since general protein consumption by poor consumers is declining and grains are too expensive for many (Kishore et al., 2014). There are also potential ramifications for the agriculture sector. Farmers in India are switching to rice and wheat production for better prices from the government, despite the fact that other items provide essential nutrition (Rai et al., 2015). Demand for pulses and edible oils is not met by domestic production and an increase in the production of these items would improve food security (Kumar et al., 2014).

The TPDS defines the central government as responsible for ensuring availability, acceptability, and affordability of food, while the state is responsible for ensuring accessibility (Karnaker & Mukhopadhyay, 2014). The country has suffered from significant leakages in its supply chain with food loss estimated between 45-55% (Joshi, 2013). The literature suggests the incorporation of e-governance (Masiero, 2015), whereby market corruption would be eliminated by selling food directly to traders who deal with consumers. This might significantly improve programme delivery and could be facilitated using a voucher with a smartcard or direct banking connected by mobile phone (Basu, 2010). In states where the TPDS functions especially poorly there is a desire for alternatives. For example, in Bihar, roughly 20% of consumers prefer direct allocations of food while over 50% choose cash transfers (Narayanan, 2015).

The recent actions of the central government suggest that these realities are under consideration (Gillespie et al., 2015). Research illustrates that the majority of civil society, industry, and government officials recognize that the contribution of agriculture and the food system to nutrition is limited due to an emphasis on wheat and rice rather than pulses and other foods (Gillespie et al., 2015). Supportive of change, a panel appointed by Indian Prime Minister Narenda Modi, recommended the NFSA increase cold storages and more directly target distribution to those below the poverty line (Gupta & Dash, 2015). The political climate for reform appears to be favourable. Dietary shifts due to rapid development and urbanization, alongside significant shortcomings in current TPDS architecture, suggest that reform of the NFSA needs to be both significant and strategic to respond to food and nutritional challenges.

6.3 Materials and Methods

In considering the question, ‘In what ways does the National Food Security Act in India need to be reformed to enhance its programme efficacy?’ this paper employed Indiastat data to create a model which is able to determine the food potential of Indian states. While there are many studies which explore aspects of food and nutritional issues in India, there are none which make use of data to explore the many factors which contribute to capturing the food system at the state level. This research establishes the food potential of Indian states and uses additional data to inform availability, access, and utilization issues. Results inform a national food strategy and the NFSA, by identifying their strengths and weaknesses.

In a previous study, five key drivers, Economic, Environment, Socio-Cultural, Infrastructure, and Political were conceptualized as impacting the food system in India (Dame & Nüsser, 2011). The model used has its root in the food systems approach, which broadly considers political, socio-economic, and ecological drivers (Ingram & Brklacich 2002; Ericksen, 2008) for use in complex food policy (Lang et al., 2009). Its chosen drivers are multi-scale in nature, and are able to link local food system realities to government policy and interventions such as the Public Distribution System. As the model explores the impact of a development intervention programme to the wider food system, a modified version of it can be used to illuminate the links between state food system characteristics and the NFSA. This paper's use of the model is limited to a consideration of the quantifiable aspects of established drivers which can be supported by state level data: employment opportunities, climatic variability, marginality/limited accessibility, policies/intervention programmes, and socio-cultural evaluations (Indiastat, 2011a-c; Indiastat, 2012a-b; Indiastat, 2013a).

This model provides a foundation for the current research and generates the source material for a slightly modified version. Indicators, functioning as data sources and representatives for each of these drivers, were chosen based on the availability of information and are most precisely labelled as: Economic, Nature, Nutrition, Development, and Governance. Together they generate a model for determining the food potential of 28 administrative units (27 states, 1 territory - Delhi).

These five key indicators are used to create a model which frames the analysis of NFSA reform possibilities across India. Specific policy interventions are suggested as they relate to: a) availability - the relationship between cold storage capacity and requirements for pulse producing states; b) access - connectivity to internet and mobile services; and c) utilization - the consumption gap of pulses to cereals. Interventions are applied to states in groups reflecting their similarities and differences, strengths and weakness, in the comparative national food landscape. To develop the most complete understanding possible, best available data was drawn from 2011-2015 resources.

Part 1 employed data across five indicators for food security to construct a model. 1) Economic: data was captured by reports on state-wide daily rates of minimum wages for unskilled agricultural workers as consistent with the national Minimum Wages Act of 1948. The minimum wage level for unskilled agricultural workers was reported in rupees (Rs) per day (Indiastat, 2011a). 2) Nature: data was generated by referencing the state-wide percentage of land area which was deemed to be affected by natural calamities (extreme weather events) (Indiastat, 2011b). 3) Nutrition: data captured the rate of malnutrition for children as revealed by the percentage of those who were underweight under the age of three (Indiastat, 2012a). 4) Development: measured by the road length (in kilometres) per 100 square kilometre of area (Indiastat, 2011c). 5) Governance: measured by the proportional number of convictions in the public distribution system (Indiastat, 2012b; Indiastat, 2013a). The data for each indicator can be found in the Appendices.

Each indicator, extracted from various reporting agencies, originally existed as a measurement defined by unique characteristics. Therefore, data were not directly comparable. To remedy this challenge, the units underwent a normalization procedure to enable comparative analysis. Linear algebra was used to create a common measurement range (Abdi, 2010). This method normalized the data to create scores which generated measurements from 0-1 for each indicator. Data was normalized by using the following equation:

(Raw Score - Lowest Score in Sequence) / (Highest Total in Sequence) - 1 = Final Result.

The scores for each of the five indicators were added together to generate food potential totals for each of 28 administrative units. They were separated into five groups: >3.5 (High), 3-3.5 (Good), 2.5-3 (Moderate), 2-2.5 (Low) and <2 (Severely Low). The results are displayed in Fig. 6.1 and the indicator data and totals for each state are found in Appendix 4.

As the state of Telangana was formed after the most recent data was made available, its results were calculated as part of Andhra Pradesh, the state to which it belonged previously. However, to reflect the current political map of the country, it is shown as a separate state in Fig. 6.1.

Part 2 made use of data (Indiastat, 2012c; Indiastat, 2012d) which recorded the consumption of pulses and cereals across 28 administrative units. As the relationship between pulse and cereal consumption in India had been discussed in the relevant literature (Kumar et al., 2014; Gillespie et al., 2015; Rai et al., 2015), this part used a consumption gap. This approach is justified from a nutritional perspective as pulses consist of roughly 20-25% protein, which is double the content of wheat and triple that of rice (FAO, 2016). There is an indication that combining pulses and cereals can provide a balanced diet and diversify cereal-based systems (FAO, 2016; Narasimhan et al., 2010). Pulses have higher amounts of the essential amino acid lysine while cereals have higher amounts of methionine and cysteine. Thus, blending pulses with cereals or nuts results in higher quality protein that contains all essential amino acids in appropriate amounts (Pulse Canada, 2016). As such, working to balance the consumption of pulses and cereals improves nutrition, especially in low income areas where animal proteins are limited (FAO, 2016).

In order to generate the results, the rural consumption of pulses (monthly kg per capita) was subtracted from the rural consumption of cereals (monthly kg per capita). This process was repeated with data which captured the character of urban consumption. The rural and urban totals were averaged to produce a hypothetical state-wide score. This score is the best possible record of the gap in consumption between pulses and cereals, but is imperfect as most recent census data on urban/rural population distribution in India is not available. Cumulative results for each state are displayed in Table 6.1 and explained by the following categories: <7.5, 7.5-10, 10-12.5 and >12.5. States which are pulse producers are distinguished by italics (Table 6.1). Data and resultant calculations are available in (Appendix 5).

Part 3 considered data for cost of cultivation and production yield for the 14 pulse growing states of India (Indiastat, 2012e-i; Appendices 6-10). Five pulse varieties were reviewed and are listed here in Scientific (Latin), Hindi, and English. 1) *Lens culinaris*, masoor, red lentil; 2) *Cicer arientinum*, gram, brown/white chickpea; 3) *Vigna radiata*, moong, green chickpea; 4) *Vigna mungo*, urad, black chickpea; 5) *Cajanus cajan*, tur, pigeon pea.

In order to further apply the food potential model to agricultural realities, this paper then recorded absolute productive efficiency, noting when a crop can be cultivated at the lowest cost per unit, relative to other states. Relative productive efficiency was also recorded to capture when a crop can be cultivated at the lowest cost per unit (Fried et al., 1993). An absolute productive efficiency was taken for each crop based on a comparison between state totals. Relative productive efficiency totals were taken based on the best total for all crops together within each state. Results revealed how strategic pulse cultivation could maximize nutrition in a reformed NFSA.

Calculations were made for each crop by dividing the yield by the cost of cultivation to produce a result. The capacity of each state to preserve food was recorded by calculating the cold storage gap. This total was calculated using data (Indiastat, 2012j) to divide the number of required cold storages by the current amount to produce a percentage which represents infrastructural capacities (Appendix 11). The cold storage results are displayed in Table 6.2 alongside information on all absolute and relative productive efficiencies for 14 Indian states.

Part 4 made use of telecommunications data (Indiastat, 2014; Indiastat, 2015). The number of mobile phone subscribers and internet users was recorded for most administrative units. Totals were also recorded for state pairs as follows: Maharashtra and Goa; Madhya Pradesh and Chhattisgarh; Uttar Pradesh and Uttarakhand; plus Bihar and Jharkhand. A group of states in the northeast (comprised of Mizoram, Meghalaya, Nagaland, Manipur, Tripura, and Arunachal Pradesh), were placed together. Mobile phone and internet totals were first added together. The total was then divided by state/territory population estimates from the most recent census (Indiastat, 2011d). For multi-state regions all population figures were combined. These calculations generated per capita connectivity totals (Appendices 12-14). Results are presented in Fig. 6.2, with food potential groups clustered together, and multi-state regions distinctively grouped.

6.4 Results

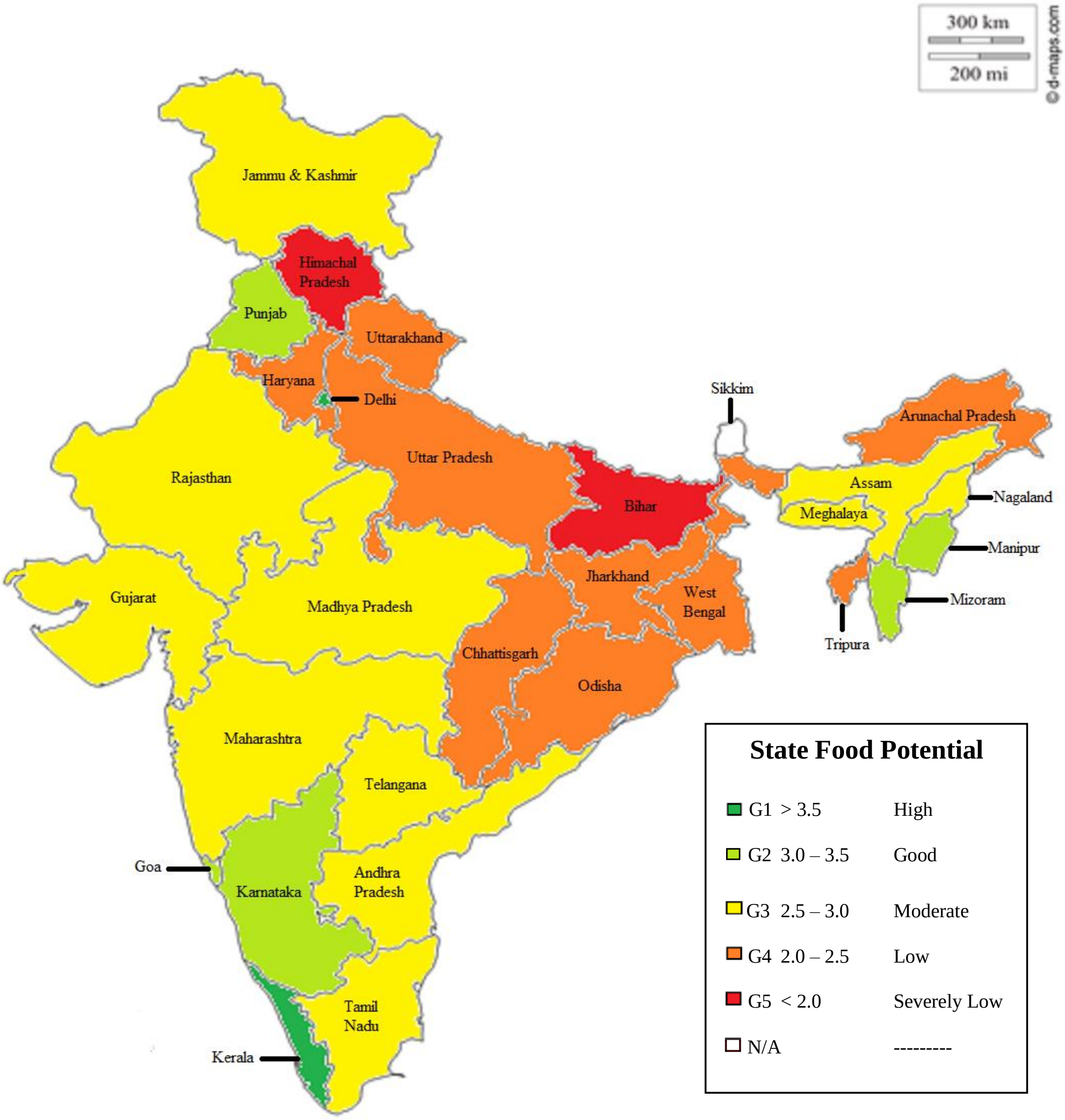
6.4.1 Part 1: State Food Potential

Fig. 6.1 maps the data totals from Appendix 4 to illustrate the food potential of 28 administrative units. Results are generated by equally weighting five indicators (Economic, Nature, Nutrition, Development, and Governance) which act as proxies for key aspects of the food system. The economic indicator is measured by *average minimum wage per agricultural worker*. Concerns regarding nature are represented through the *amount of land area impacted by extreme weather events*. Nutrition is represented by the *percentage of malnourished children under three*. Development is shown via the *percentage of paved roads*. Governance is captured through the *number of corruption cases in the public distribution scheme*.

The southwest states of Kerala, Karnataka, and Goa, along with the Delhi region and Punjab in the northwest, enjoy high and good levels of food potential. Most of the remaining western and central portions of the country, north from Tamil Nadu through Maharashtra to Rajasthan and up to Jammu and Kashmir, record moderate scores. The low and severely low cases are located in a belt which contains the majority of northern and eastern states. These include: Himachal Pradesh and Bihar at the most severe extreme, and the low, but slightly better cases, of Haryana, Uttar Pradesh, Chhattisgarh, Jharkhand, Odisha, West Bengal, and Assam. The far eastern region contains a mix of food potential categories.

Figure 6.1: **Indian States and Their Food Potential** (based on data from Appendix 4)

(map modified from: http://d-maps.com/carte.php?num_car=24853&lang=en)



6.4.2 Part 2: The Relationship between Pulse and Cereal Consumption in Indian States

Table 6.1 (supported by Appendix 5) illustrates the consumption gap between pulses and cereals for 28 administrative units. Two main findings are evident. First, a number of states enjoy relatively high pulse consumption despite having wider food potential constraints. These include: Gujarat, Maharashtra, Meghalaya, Tamil Nadu, Haryana, and Uttar Pradesh. Second, the majority of higher ranking states enjoy more favourable rates of pulse consumption (with Karnataka as a pulse producer). This information indicates pulse producers from moderate, good, and high food potential states are in a more favourable position to export pulses to parts of the country exhibiting low and severely low rates of consumption.

Table 6.1: Difference in Consumption between Grains and Pulses (kg) (Pulse producers in bold italics)

(see Appendix 5).

kg	G1	G2	G3	G4	G5
<7.5	Delhi				
7.5-10	Kerala	Goa	***Gujarat***	***Haryana***	
		Karnataka	***Maharashtra***	***Uttar Pradesh***	
		Punjab	Meghalaya		
			Tamil Nadu		
10-12.5		Mizoram	***Andhra Pradesh***	Arunachal	***Bihar***
			Assam	Pradesh	Himachal
			Jammu &	***Chhattisgarh***	Pradesh
			Kashmir	Jharkhand	
			Madhya Pradesh	***Odisha***	
			Rajasthan	Uttarakhand	
				West Bengal	
>12.5		Manipur	Nagaland	Tripura	

6.4.3 Part 3: Policy Intervention to Increase Pulse Consumption

Table 6.2 illustrates which states most effectively cultivate pulses: brown/white chickpea, green chickpea, black chickpea, pigeon pea, and red lentil. Geographically, there are four cases where absolute productive efficiency is linked to a state which is directly in a lower ranking food potential group, or neighbouring one. Pigeon pea in Uttar Pradesh, red lentil in Madhya Pradesh, and black chickpea in Chhattisgarh, are pulses grown in states shown to be national leaders in cold storage requirements. Conversely, brown/white chickpea is best produced in Bihar, a state with poor storage facilities; while green chickpea is best grown in Tamil Nadu, which has the worst facilities. Rajasthan has cold storage facilities at 82% capacity, the second highest in the country. Rajasthan's relative productive efficiency is also in brown/white chickpea, making it an ideal for production.

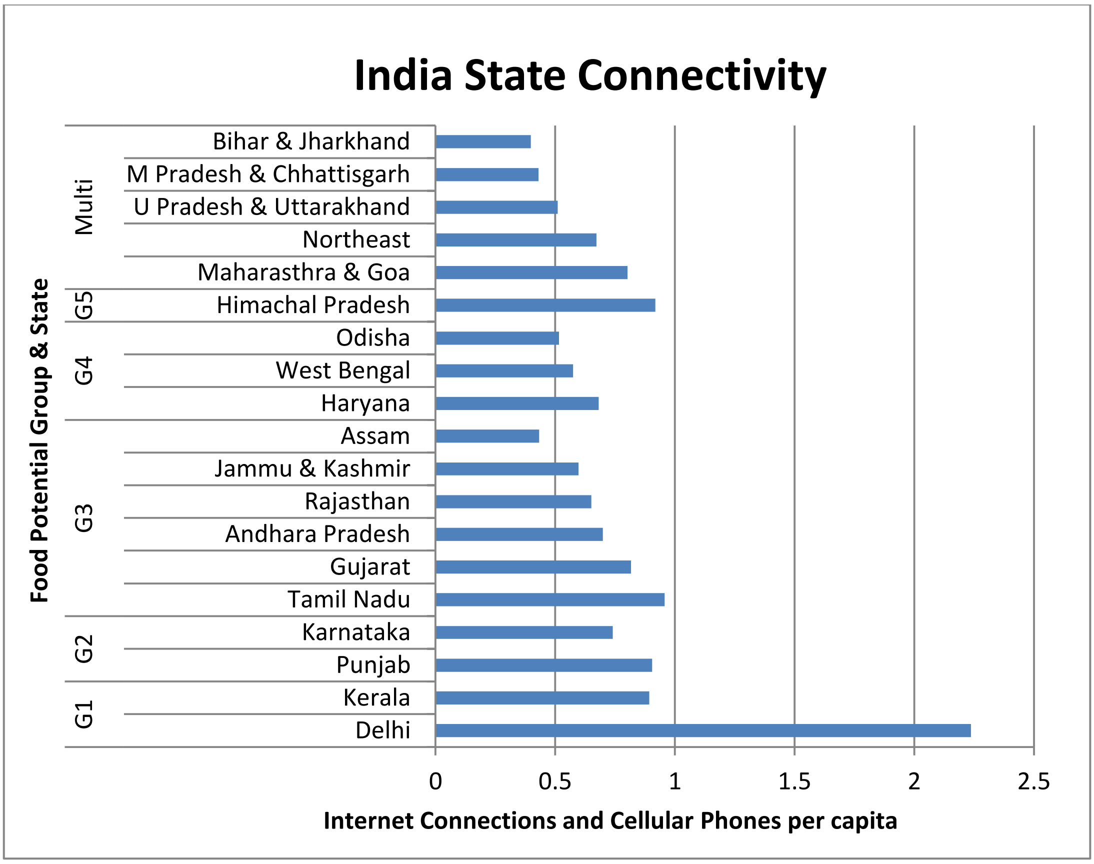
Table 6.2: Pulse Production and Cold Storage Capacity (See Appendices 6-10; 11)

State	Cold Storage	Absolute Productive Efficiency	Relative Productive Efficiency
Uttar Pradesh	83%	*Cajanus cajan* (Pigeon Pea)	*Cajanus cajan* (Pigeon Pea)
Rajasthan	82%		*Cicer arientinum* (Brown/White Chickpea)
Madhya Pradesh	66%	*Lens culinaris* (Red Lentil)	*Lens culinaris* (Red Lentil)
Chhattisgarh	62%	*Vigna mungo* (Black Chickpea)	*Vigna mungo* (Black Chickpea)
West Bengal	53%		*Lens culinaris* (Red Lentil)
Haryana	48%		*Cicer arientinum* (Brown/White Chickpea)
Gujarat	46%		*Cajanus cajan* (Pigeon Pea)
Andhra Pradesh	38%	*Vigna radiata* (Green Chickpea)	*Vigna mungo* (Black Chickpea)
Bihar	27%	*Cicer arientinum* (Brown/White Chickpea)	*Cicer arientinum* (Brown/White Chickpea)
Karnataka	16%		*Cicer arientinum* (Brown/White Chickpea)
Odisha	15%		*Cajanus cajan* (Pigeon Pea)
Maharashtra	8%		*Cicer arientinum* (Brown/White Chickpea)
Tamil Nadu	3%		*Vigna radiata* (Green Chickpea)

6.4.4 Part 4: India State Connectivity

Fig. 6.2 (Appendices 12-14) illustrates the potential of technology to integrate e-governance into NFSA reform. It reveals the number of internet connections and mobile phones per capita across Indian states and regions in March of 2014 (Indiastat, 2014). Results indicate that states with larger urban areas, and most of those with higher food potential scores, enjoy more favourable levels of connectivity. Delhi, Karnataka with Bangalore, Maharashtra with Mumbai, Tamil Nadu with Chennai, Gujarat with Ahmedabad, Punjab, and Kerala, are examples of this. Of the states with the greatest food challenges, Bihar and Himachal Pradesh are polar opposites with respect to connectivity. The latter enjoys a slightly greater level of connectivity than Punjab, which has good food potential. There is an unfortunate scenario in many low food potential states experiencing a poor connectivity ratio of slightly above or below 50% of the population. Along with the most severe case of Bihar, the cases of Jharkhand, Chhattisgarh, Uttar Pradesh, Uttarakhand, Odisha, and West Bengal are also noteworthy.

Figure 6.2 India State Cellular Phone & Internet Connectivity (Appendices 12-14)



6.5 Discussion

While exploring possibilities for reform of the NFSA, the five indicators of the state food potential model are reviewed under two rubrics: a) Mitigating concerns which explore economic factors and challenges of nature; b) Policy interventions which consider nutrition (utilization and consumption gap); development (availability and pulse production); and governance (access and technological connectivity). Together, they represent an opportunity to implement a holistic, nutrition-sensitive agriculture approach to food policy (Jaenicke & Virchow, 2013).

6.5.1 Mitigating Concerns

6.5.1.1 Economic

India is the largest producer, consumer, and importer of pulses in the world, accounting for approximately 33% of the global area under cultivation and 20% of total production (NCAER, 2014). Pulses are a primary source of protein in India, and while production has increased due to price supports given by the National Food Security Mission, fluctuating prices do not ensure stable consumption (NCAER, 2014). Recently, India became an importer of pulses from Canada and Australia with an import to production percentage of 17.8 (NCAER, 2014). Increases in productivity and production are required to reduce imports (Reddy, 2004).

The national government acts on two fronts. In the international arena, it has been strident in its defence against WTO restrictions on national agricultural investment plans, as it directly impacts the NFSA (WTO, 2015). Domestically, it champions the development of contract farming, resulting in a large-scale transfer of responsibility for food from the individual farmer to contracting companies (Gill et al., 2010). Organic farming, most of which takes place under contract arrangements, emerged as an important niche sector for markets exporting fruits and vegetables to developed nations (Gill et al., 2010). The commercialization of agriculture has led to the promotion of export-oriented activities (Karmakar & Mukhopadhyay, 2014). In contrast to contract farming, a family unit can cultivate its own or rented land thereby positively impacting their food security (Rao, 2006).

To navigate this dynamic, the Indian government introduced a national anti-poverty programme in 2005 known as the ‘Mahatma Gandhi National Rural Employment Guarantee Act’ (Azeez & Akhtar, 2015). The programme offers up to 100 days of unskilled manual labour per year on public works projects for a rural household member at the stipulated minimum wage rate (Azeez & Akhtar, 2015). Research shows that participation in the act has reduced the variability of household incomes, and is an effective tool in income stabilization in the poorest districts. Higher ratios of the *employment guarantee scheme wage* to the *agricultural wage* result in a greater probability of participation (Scandizzo et al., 2009a). The minimum agricultural wage captured in the model is relevant in revealing overall economic stability. This determines the level of incentive that low-skilled workers have in participating in the regular labour market, as opposed to remaining in farm activities (Scandizzo et al., 2009b). It also provides insight to the dynamic of links between local economies to state, national, and international food commodity markets.

6.5.1.2 Nature

Climate change affects the food system through changing temperatures, shifting rainfall patterns, and greater volatility in weather patterns (Pinstrup-Andersen, 2011). Impact on specific crops varies. In the case of pulses, only 15% of the production area has assured irrigation causing farmers to opt for safer cash crops (NCAER, 2014). Studies show improved irrigation is the most significant factor in increasing pulse yields (Reddy, 2004). In response to changing temperature and water regimes, the Government of India identifies improved productivity potential, and water use efficiency for agricultural crops, as priority areas of research (Planning Commission, 2008).

Research suggests that crop revenues can increase or decrease with higher temperatures and greater precipitation (Sanghi & Mendlesohn, 2008). Future losses are predicted across the majority of the country, with the exception of the east. The west coastal provinces, the far north, and central portions of the country stand to experience losses. Devastating losses would occur in Gujarat and Maharashtra (Sanghi &

Mendlesohn, 2008). In contrast, gains are expected from the eastern half of Uttar Pradesh down to the southern coast of Tamil Nadu. Very significant gains are predicted for West Bengal and Odisha.

Scholars present a composite of climate sensitivity and adaptive capacity which indicates climate change vulnerability is greatest in the centre of India (O'Brien et al., 2004). This includes states with moderate food potential such as Rajasthan, Gujarat, Maharashtra, and Madhya Pradesh (Fig. 6.1; O'Brien et al., 2004). States with low food potential: Haryana, Uttar Pradesh, Chhattisgarh, and Jharkhand, (Fig. 6.1) also experience high vulnerability (O'Brien et al., 2004). Bihar stands in the lowest category of food potential (Fig. 6.1) and also has a high level of climate change vulnerability (O'Brien et al., 2004). Other parts of the country are low risk, particularly in the northern states of Punjab and Himachal Pradesh (O'Brien et al., 2004). This positioning is advantageous for Himachal Pradesh, which faces challenges independent of climate-related ones (Fig. 6.1). The southern states of Kerala, Goa, and Tamil Nadu are low risk also (O'Brien et al., 2004), and are in the high, good, and moderate food potential groups (Fig. 6.1). There is a general pattern where coastal sections of high, moderate, and low food potential states (respectively Karnataka, Andhra Pradesh, and Odisha) are low-risk to climate change vulnerability, while their interiors (Fig. 6.1) are high risk (O'Brien et al., 2004). West Bengal is in a low food potential group (Fig. 6.1) but experiences low-risk to climate change (O'Brien et al., 2004).

Evidence suggests that the central and state governments should collaborate to improve irrigation and water infrastructure. Action must be broad but focused in states which have both low food potential and are at high risk for climate vulnerability or other trials of nature.

6.5.2 Policy Interventions

6.5.2.1 Nutrition: Utilization and Consumption Gap

The consumption of cereals, the largest source of protein in India, is declining in both rural and urban areas. Pulses, a major source of high quality proteins and micronutrients, are also declining in consumption in favour of milk, meat, and processed foods (Kumar & Joshi, 2014). Pulses are a major source of protein amongst poorer segments of the population, but consumption is very low. In particular, rural populations consume more cereals, fewer pulses, and less oil and fat compared with urban populations (FAO, 2006). In India there is not a significant difference among income classes with respect to pulse intake. However, there is a need to increase consumption of pulses among the poor to compensate for the lower consumption of proteins from meat and milk products (Reddy, 2004). Overall, sufficient quantities of pulses are not consumed when compared with the standards prescribed by the Indian Council of Medical Research (Reddy, 2004). Pulse demand is significantly more responsive to changes in income than food grains such as wheat and rice, but is less responsive than other foods such as milk and meat (Price et al., 2003). Pulse substitution for middle and lower income consumers does not typically occur between pulses and other protein-rich foods such as meat, milk or fish; but rather most commonly with cereals, vegetables, and fruits (Price et al., 2003).

In the post-WW2 period, the net availability of pulses decreased (as determined by production figures), while those of rice and wheat increased (Reddy, 2004). The per capita consumption of pulses dropped while those for rice increased. This has meant that prices of pulses have increased (Reddy, 2004). Table 6.1 (Appendix 5), illustrates that generally the relative consumption of cereals to pulses is lowest in states with higher food potential. These largely correspond to the more prosperous areas of Kerala, Goa, and Punjab, in addition to regions with large urban metropolises such as Delhi, Karnataka, Tamil Nadu, Maharashtra, and Gujarat. This occurs whether or not pulse production takes place in these states which are also experiencing a nutrition transition. Citizens are consuming more meat and smaller portions of grains (Basole & Basu, 2015b). Pulse producing states with moderate or low food potential have lower consumption of the crop (e.g., Andhra Pradesh, Madhya Pradesh, Rajasthan, Chhattisgarh, Odisha, and West Bengal). Evidence suggests government policy could address the largely rural challenge by encouraging locally grown pulses at competitive prices.

6.5.2.2 Development: Availability and Pulse Production

Promoting the production and strengthening usage of potential micronutrient rich foods is invaluable to improve food security and nutrition (Nandi & Bhattacharjee, 2005). Vast areas of India are subtropical and well suited to the cultivation of vegetables, fruits, and plantation crops. They provide higher yields per hectare, higher sale prices, and sustain agro-industries. This is also the case for various pulse varieties. Nevertheless, with the exception of urban regions, per capita consumption is low (Swaminathan, n.d.). Losses of vegetables and fruits during packaging and transportation are estimated at 30% (Swaminathan, n.d.). Table 6.2 (Appendices 6-10) indicates that each pulse producing state has a crop which they can grow most effectively. While cold storage facilities are limited in many instances, it is plausible that investments by governments could be advantageous. This would increase the ability of smallholders to produce the most efficient pulse crop, enable increases in pulses on a small-scale level in rural communities, and increase markets close to production sites.

Long-term projections often assume that Indian crop yields will not make progress towards matching world averages or domestic benchmarks. This assumption is based on historically poor performance and low rates of public investment in the agricultural sector

(Landes & Hjort, 2015). Evidence supports broad investments in infrastructure for preservation, cold storage, refrigerated transportation, rapid transit, grading, processing, packaging, and quality control (FAO, 2006). These measures could help the horticultural sector achieve its full economic potential and achieve the micronutrient needs of the population (FAO, 2006). Findings suggest that developing infrastructure is essential. The food miles concept (food transported over great distances consumes more energy than food grown locally), confirms that effective roads and highways are essential to avoid spoilage and waste (Carolan, 2012). Table 2 (Appendix 8), reveals that India has two states, Uttar Pradesh and Rajasthan, with greater than 80% storage capacity and two states, Madhya Pradesh and Chhattisgarh, with greater than 60%.

Stagnant and poorly located pulse production is the central obstacle. This is the result of considerable pulse cultivation, moving from favourable, to marginal, to poor resource endowed regions. A set of processing, marketing, and resource constraints has compounded the issue creating further obstacles to the improvement of agricultural yields and nutrition (Shukla, 2015). Table 6.2 illustrates that each state can produce a different pulse crop at absolute efficiency. These states are also geographically positioned to export surplus pulse crops to neighbouring states in the north and east, which are distinguished by low potential and food insecurity (Fig. 6.1). Evidence from this study suggests a national policy decision could create four specialized centres of production: pigeon pea in Uttar Pradesh; brown/white chickpea in Rajasthan; red lentil in Madhya Pradesh; and black chickpea in Chhattisgarh. Coupled with modest investments in cold storages, these four states have the potential to become nationally-focused pulse producers.

6.5.2.3 Governance: Access and Technological Connectivity

Electronic connections linking small farmers and consumers to policy environments and markets should be improved, and there is a need to experiment with new supply chain models (Gandhi & Jain, 2011). Mobile phones offer an option and have been championed as the solution for farmers in remote areas, to receive updates on weather, markets, and technical information (Lumpkin, 2013). Suggestions to capitalize on this trend include using an e-cash transfer system for the NFSA. This would aim to increase programme usage by cardholders which currently stands under 50% (Svedberg, 2012). It is estimated that India has about 600 million unique cell phone users, of which approximately 370 million live in rural areas (Landes & Hjort, 2015). However, mobile phones cannot be the only instrument connecting consumers to the NFSA. Although its position in the discussion is more nuanced, the internet also has a potential role to play as a method to increase communication and improve equitable distribution.

Fig. 6.2 (Appendices 12-14) illustrates that connectivity strongly correlates with urbanization. States which contain large cities such as Delhi, Tamil Nadu (Chennai), Maharashtra (Mumbai) and Goa, Karnataka (Bangalore), and Gujarat (Ahmedabad), have the most promising figures (Fig. 6.2). However, the urban/rural divide is not finite with respect to connectivity. West Bengal contains the metropolis of Kolkata but has poor connectivity (Fig. 6.2). Conversely, Punjab and Kerala enjoy high levels of connectivity (Fig. 6.2) and good and high food potential, respectively (Fig. 6.1). Himachal Pradesh has high connectivity (Fig. 6.2) with poor food potential (Fig. 6.1). These areas of high connectivity would benefit if all of their delivery systems were digital, with a small, on-site option for those lacking a personal connection. Expanding the Common Service Centres (CSCs), public internet access areas found in each Gram Panchayat (a finer administrative scale) for the delivery of government services, could assist in mitigating this challenge (Department of Electronics and Information Technology, 2015).

Unquestionably, the quality of internet connections in India is poor. This makes any large-scale transition of the NFSA transfer through the internet challenging. Bandwidth, even for wired connections is expensive and often comes with data limits (Anwer, 2015). Furthermore, internet speed is frequently slow and it often fluctuates arbitrarily on a day-to-day basis. The servers are prone to malfunction and breakdown, meaning downtimes are typical for most connections (Anwer, 2015). Statistically, India has the second slowest average connection speed in the world at 2.3 in megabytes per second (mbps). Only 9.9% of connections are above 4 mbps (Akamai, 2015). Again, these challenges could be approached within the framework of the *Digital India* programme, a central government led e-governance initiative with a vision to provide governance and services on demand (Department of Electronics and Information Technology, 2015). Within the programme, the development of broadband highways to encourage coverage for all would assist. However, quality issues should be resolved for the development to be of practical use to the NFSA (Department of Electronics and Information Technology, 2015).

Most of the poor and severely challenged states have limited connectivity totals, with the most extreme case being Bihar. Evidence supports considering the following policy options: a) an effort to increase the number of 'previously owned' mobile phones from the developed world made available to the poor; b) a commitment to expand the digital India initiative to provide reliable and affordable mobile and/or internet access for those accessing their NFSA account; and c) instituting short to medium term pilot programmes which maximize community and family resources and counter sparse connectivity.

6.6 Conclusion

This paper demonstrates that a food potential model effectively identifies Indian states which require specific policy interventions to mitigate food challenges. The reform of the NFSA provides an opportunity for these interventions to be established in collaboration with the central and state governments.

Delhi, Kerala, Goa, Karnataka, and Punjab have the highest food potential and higher levels of pulse consumption relative to cereal intake. Each enjoys high technological connectivity rates in the 75-100%+ range. Evidence supports the distribution of second-hand mobile phones to rural areas in these states to extend programme reach.

The moderate food potential group is found in the belt from Tamil Nadu to Maharashtra and Rajasthan. The states in this group are both pulse producing and have larger urban areas - Ahmedabad, Mumbai, and Chennai have higher consumption of pulses to cereals. Rajasthan is best positioned for producing and exporting brown/white chickpea while Madhya Pradesh is suited for red lentil. Gujarat, Maharashtra, and Tamil Nadu have high connectivity scores while other members of this group lag behind. With some additional government investments, Madhya Pradesh and Rajasthan have the potential to increase the production and export of red lentil and brown/white chickpea to nearby states with lower food potential. Investments might include added irrigation infrastructure to secure pulse growth, as the area is highly vulnerable to climate change and shifting rainfall patterns. The urban/rural and income divides are relevant, and connectivity rates enable NFSA programmes to be widely distributed via mobile phones. Internet connection speed and price could also be improved, and the central and state governments might collaborate in expanding the digital India initiative in realizing this goal. Findings suggest increasing connectivity through the procurement of second-hand equipment would be beneficial, particularly in rural areas.

In the low food potential group, Haryana and Uttar Pradesh have higher consumption and production of pulses. Chhattisgarh, Odisha and West Bengal are pulse producing but have lower consumption. Uttar Pradesh has absolute productive efficiency for pigeon pea and 83% cold storage capacity, the highest in India. Chhattisgarh has absolute efficiency in black chickpea and 62% of cold storage capacity. Uttar Pradesh and Chhattisgarh are each highly vulnerable to the effects of nature through climate change, thus a long-term state government commitment to irrigation is essential. The entire group experiences a connectivity gap. Evidence supports the transport of pulses from Uttar Pradesh and Chhattisgarh to areas of need by joint national and state government collaboration. The connectivity gap could be partially mitigated by importing second-hand mobile phones and maximizing usage by families and friends.

Each of the severely low food potential states have large pulse to cereal consumption gaps, however, only Bihar is a pulse producer. Bihar holds absolute productive efficiency in brown/white chickpea, but has poor connectivity and inadequate cold storage capacity and is at high risk for climate change and shifting rainfall patterns. Policy action in Bihar should increase mobile phones while maximizing usage. National and state investments in the production and storage of brown/white chickpea, along with irrigation infrastructure would have a positive impact on Bihar's population. In contrast, Himachal Pradesh's main asset is technology and as such is an excellent test case for wireless NFSA.

Additional field work is recommended for the State Food Potential Model prior to any active policy action. As data is sparse and often unavailable beyond one particular year, proxy indicators might be improved by targeted survey-based questions and collection initiatives. Nature, Economic, Governance, Infrastructure, and Nutrition information could be collected for a three year period similar to the process used for the second paper, and then processed into a time-series model for comparison.

Individual indicators could be substituted for sensitivity testing. Information regarding rainfall patterns might be included in the model, rather than area under threat from extreme weather, to provide an interesting contrast for exploring crop yields. Information on the amount of household income spent on food (currently unavailable) would allow for a more nuanced understanding of the relationship between income and nutrition. Governance and corruption in the NFSA might be elaborated on through questionnaires. While interesting results would be possible, a considerable potential for error exists which would need to be taken into account. For infrastructure, access of potable water information could be collected and compared with paved roads. Anthropometric information could be extended to include information on vulnerable groups such as pregnant women and anaemia.

This paper uses a food potential model to explore modification of the NFSA. Evidence suggests opportunities for further study and reform including: investing in infrastructure such as cold storages and irrigation; improving dietary awareness; initiating incentives for growth and distribution of pulses; reducing leakages through significant investments in quantity and quality of communication technology; and strengthening ties between state and national levels. The state food potential model and its findings are useful in guiding future research and policy. The model suggests that resources are present to significantly reduce food issues and hunger through adopting a nutrition-sensitive approach to agriculture which could work towards maximizing the country's immense food potential.

6.6.1 Paper 3 in Context of the Thesis

Paper 3 concentrates on analysis of scale at the state level in India. The paper makes use of a broader data spectrum than available in international comparative studies to gain insights into how the Indian food system links to nutrition. It critically engages data from Indiastat to select proxy indicators for five key drivers of the food system (Economic, Nature, Nutrition, Development, and Governance). Collectively these directly engage with the conceptual framework of the thesis. The paper connects India's food system potential to the reform of the NFSA.

The paper first re-imagines nutritional goals by building on the exploration of plant protein supplies across countries as revealed in Paper 2. It encourages greater consumption of pulses in a sub-national state context, and searches for the means to achieve this within food systems and policy frameworks. Secondly, a solution is found in the potential of inter-state and international trade to manage redistributing specific pulse varieties. This further supports the concept introduced in the second paper of pursuing favourable positioning vis-a-vis the international trade regime. An understanding of the relationship between the domestic production of pulses and dietary needs is valuable due to interactions between the NFSA and the international trade system. As more information concerning the food system is accessible at the state level, governance has a more prominent role as a lens from the conceptual framework than for papers situated at international and national scales. This builds on the suggestion of the first paper, and is addressed through the monitoring of corruption in public food distribution programmes and a potential remedy through e-governance mechanisms. The national/state nexus is an appropriate venue for discussing policy suggestions which include investments in cold storages, improved irrigation, and communication technology recommendations.

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Chapter 7. Paper 4: Within Reach? Creating Multi-Scale Nutritional Policy for Rural Karnataka

(Submitted to *Economic & Political Weekly*)

This paper supports the central aim of this thesis by interacting with district level data in Karnataka to link the food system to nutrition. It constructs a nutritional HDI model which frames the use of pulse and cereal resources. This research engages with each of the analytical lenses from the conceptual framework. Nutrition is approached through the development of the nutritional HDI and through recommendations for increased pulse production and consumption. The possibilities for collaboration between districts in the trade of required food items, and the potential emergence of a governance opportunity which engages administrative decision makers at district, state, and national levels, are emphasized.

7.1 Abstract

The Government of India is experimenting with the idea of an increased role for pulses in the NFSA. In order to effectively manage this, information in Indian food security and nutrition studies needs to be utilized to facilitate district level comparisons. This paper modifies a United Nations Human Development Index (HDI) and creates a triple-themed framework with specific nutritional indicators for Karnataka. It makes use of district level data to produce a nutritional HDI comprising absolute household expenditure on food (income), the adult literacy rate (education), and the percentage of pregnant women with anaemia (health). District level consumption expenditure results for proteins and cereals are transformed to produce estimates of food consumption quantities in relation to national dietary requirements. Production yield statistics are compared against district consumption. Climate and weather conditions are considered. Results suggest that

almost all rural districts in Karnataka have unsatisfactory nutritional HDI scores. Karnataka can strategically distribute pulses and cereals through the NFSA into northern districts which have poor nutritional HDI scores and low consumption and production. In contrast, an opportunity exists to develop a production agglomeration in the South, which has the yield potential and climate conditions for production of pulses and cereals. Findings also suggest horticulture can be expanded along parts of the coast. Collaboration between district, state, and national governments could potentially improve nutrition.

7.1.1 Keywords: India**,** Karnataka, HDI, Nutrition, Rural

7.2 Introduction

Recent data from India indicates that consumers are rapidly increasing their consumption of animal products and fruits & vegetables, while reducing their consumption of cereals (Gandhi & Zhou, 2014). Despite this general trend, distinctions between urban and rural areas are difficult to capture. Closer scrutiny reveals a more complex food and nutritional picture. The 2013 National Food Security Act (NFSA) is oriented towards more efficient distribution of subsidized food grains to those who are in need. It also seeks to remedy disparities in food production between states through its distribution network (Shirur & Gowdan, 2014). The current debate has noted the need to more properly identify vulnerable groups and geographic disparities. To elaborate, the current version of the act has an arbitrary subsidy figure of 75% for rural and 50% for the urban population (Shirur & Gowdan, 2014). Policies do not reflect the nuances of food and nutritional insecurity in India or its states. Developing more targeted regional strategies has been discussed for quite some time (Gaiha, 1999). Karnataka, which is rapidly urbanizing and experiencing significant disparities between its urban and rural populations (Ghori, 2015) functions as a good bellwether case study.

The NFSA has begun to incorporate pulses in addition to grains. This policy has gained traction as pulses are supplementary to staple Indian diets when they are combined with rice (chawal) or wheat (roti) foods (Chandrashekhar, 2013). While India's per capita protein consumption is not significantly below recommended nutritional protein requirements, widespread disparities in income are present that impact vulnerable groups, particularly women and children in rural areas (Pavaskar, 2014). Given these realities, a more nuanced understanding regarding food systems and nutritional outcomes of states and their districts, will be required to ensure the NFSA is successful. This paper notes the complexity of India's food and nutritional profile. It acknowledges that leading Indian academics have suggested the importance of analysing Indian states individually (Gopalan, 1995). It considers the question, 'To what extent can relevant survey information be used in the reform, and subsequent implementation of district level food policy in rural Karnataka?'

Karnataka is an interesting case study as it is a rapidly urbanizing state in India characterized by inequality between its urban and rural areas. The state serves as a viable bellwether for the rest of the country since it is involved in economic and social development which closely parallels Karnataka. Situated on the western coast of India, the state has an area of 191,791 square kilometres and a population of 61,130,704 as of 2011 (Encyclopaedia Britannica, 2015). Agriculture engages the majority of the population; however, the pace of urbanization is accelerating with increasing industrialization (Ghori, 2015). The principle city, Bangalore, known as the Silicon Valley of India, has a population of 8,520,435 in its urban agglomeration (Encyclopaedia Britannica, 2015). The latest NSS results for Karnataka reveal that expenditure on food is 51.3% of total household expenditures in rural areas as opposed to 40.1% in urban areas (NSS, 2014). At 18%, the state has the highest consumption of pulses, nuts & oilseeds in India (NSS, 2014). Despite this favourable statistic, increases in overall protein intake per person between 1993-94 and 2011-2012 were lacking (NSS, 2014). Furthermore, there is no indication that economic development is resulting in nutritional gains. In the rural areas of the province, the proportion of pulses as a source of overall protein is consistent between food expenditure groups (NSS, 2014). Conversely, consumption of cereals decline while meat consumption rises with increases in food expenditure (NSS, 2014). State food consumption information is intriguing and demands further study at the district level where a finer examination of inequalities between rural and urban is possible.

M. S. Swaminathan (1987) wrote that a crucial development in food systems evolution is nutrition security, which realizes physical and economic access to balanced diets and safe drinking water for all people at all times. This idea, now over 25 years old, remains accurate and relevant today and is especially important since malnutrition is an established challenge. Karnataka is comprised of policy webs which contain disparate groups that aim for improved nutrition. The state has responded to the challenge by situating itself as the first Indian state with a nutrition mission in 2010 (Paarlberg, 2012). Furthermore, the Karnataka Comprehensive Nutrition Mission is linked to the Karnataka Department of Agriculture, and participates in its decision making. Its goal is to work towards nutrition security by targeting vulnerable groups (Paarlberg, 2012).

The National Sample Survey (NSS) takes place across all of India inclusive of rural and urban communities. It records monthly per capita consumption expenditure (MPCE) for food in households (FAO, 2006) across states and districts. The National Nutrition Monitoring Bureau (NNMB) provides data on dietary intake (by 24 hour dietary recall), and nutritional status (based on anthropometry and nutritional deficiencies), for ten major

Indian states including Karnataka (NNMB, 2013). The fourth District Level Household and Facility Survey (DLHS) provides information on general population and health characteristics of Indian districts and also Karnataka (MHFW, 2013). Further information on the production and productivity of agricultural crops is available through the Directorate of Economics and Statistics (2012) of Karnataka located in Bangalore.

7.3 Methodology

7.3.1 Overview

This paper made use of two datasets containing district level information. First, data was taken to build a nutritional HDI model constructed using proxy indicators for income, health, and education for each district in Karnataka. Secondly, information on *expenditure allocation* was employed to gain insights into food group consumption (Gaiha et al., 2013). NSS (2014) data for the *total expenditure on food* was taken to represent income. DLHS (MHFW, 2013) data for *percentage of anaemic pregnant women* was used as a proxy for health, and its information on the *literacy rate* was taken as the best proxy for education. Second, NSS (2014) district level data were placed through a set of calculations in order to estimate pulse and cereal consumption. Household food expenditure across each district for pulses and cereals were divided by state level prices to produce an estimate of the overall quantity consumed. The following discussion explains the reasoning for using each indicator and data source, along with their strengths and weaknesses.

Household food expenditure surveys were used twice in this paper. First, absolute food expenditure was used to estimate income. In addition, pulse and cereal data was used to estimate overall food item consumption (NSS, 2014). In food security and nutrition studies, food expenditure surveys have been used to inform: household food energy deficiency, depth of energy deficiency, dietary diversity, and the percentage of food expenditure in relation to total household expenditure (Smith & Subandoro, 2007). Drawbacks do exist. Two such examples include the lack of data on the access of food by individuals within households, and the reality that estimates may be biased owing to systematic, non-sampling errors (Smith, 2002). A further weakness is present since important nutritional and energy information which correspond to individual needs (Hoddinott, 2001) are not captured by food expenditure surveys.

Due to the shortcomings of food expenditure surveys, it is important to consider other information on food availability using survey data containing anthropometric measures that accompany undernourishment (Tandon & Landes, 2012). The incorporation of sources employing diverse methodologies benefits more robust food security conclusions. For example, at the national level researchers note a variety of assessment methodologies have produced significantly different estimates in the size of India's food insecure population (Tandon & Landes, 2012). The approaches were comprised of aggregate food production and consumption, household expenditure surveys, and surveys of direct responses to questions on household food security (Tandon & Landes, 2012).

DLHS data aids in understanding the complex nature of nutritionally vulnerable groups through direct health based surveys. It contains information which captures long-term impacts on the general population and vulnerable groups (MHFW, 2013). In this paper, it provides district level health data for pregnant women with anaemia, and education information represented by the literacy rate of individuals over seven years of age (MHFW, 2013).

Pregnant and lactating women consistently have the most significant protein deficiencies among vulnerable groups in India (NNMB, 2013). In contrast to quantitative findings, the United Nations Children's Fund (UNICEF) has suggested that the nutrition of lactating mothers and children be specified qualitatively based on scientific assessment (UNICEF/UNU/WHO, 2001). Acknowledging individuals at different ages require different diets varying in proteins, vitamins and minerals (UNICEF/UNU/WHO, 2001); district information for Karnataka provides an intriguing compliment to state level results. Complimentary to the findings of the NNMB, the DLHS identifies pregnant women with anaemia (MHFW, 2013). This indicator functions as a proxy, since low dietary intake and deficiencies of iron, vitamin B12, and vitamin C, are among the central causes of anaemia (Ramachandran, 2014). The use of anaemia as a nutrition proxy is valid due to the link between iron and anaemia. Amongst all micronutrients iron deficiency is the most common (UNICEF/UNU/WHO, 2001).

The DLHS contains a further indicator on the literacy rate of individuals over seven years of age (MHFW, 2013). This indicator is directly used in related Indian food security and nutrition studies in addition to years of schooling to represent education (Gopalan, 1995). Poor nutrition is linked to unsatisfactory learning outcomes and a loss of productivity (Spears, 2013).

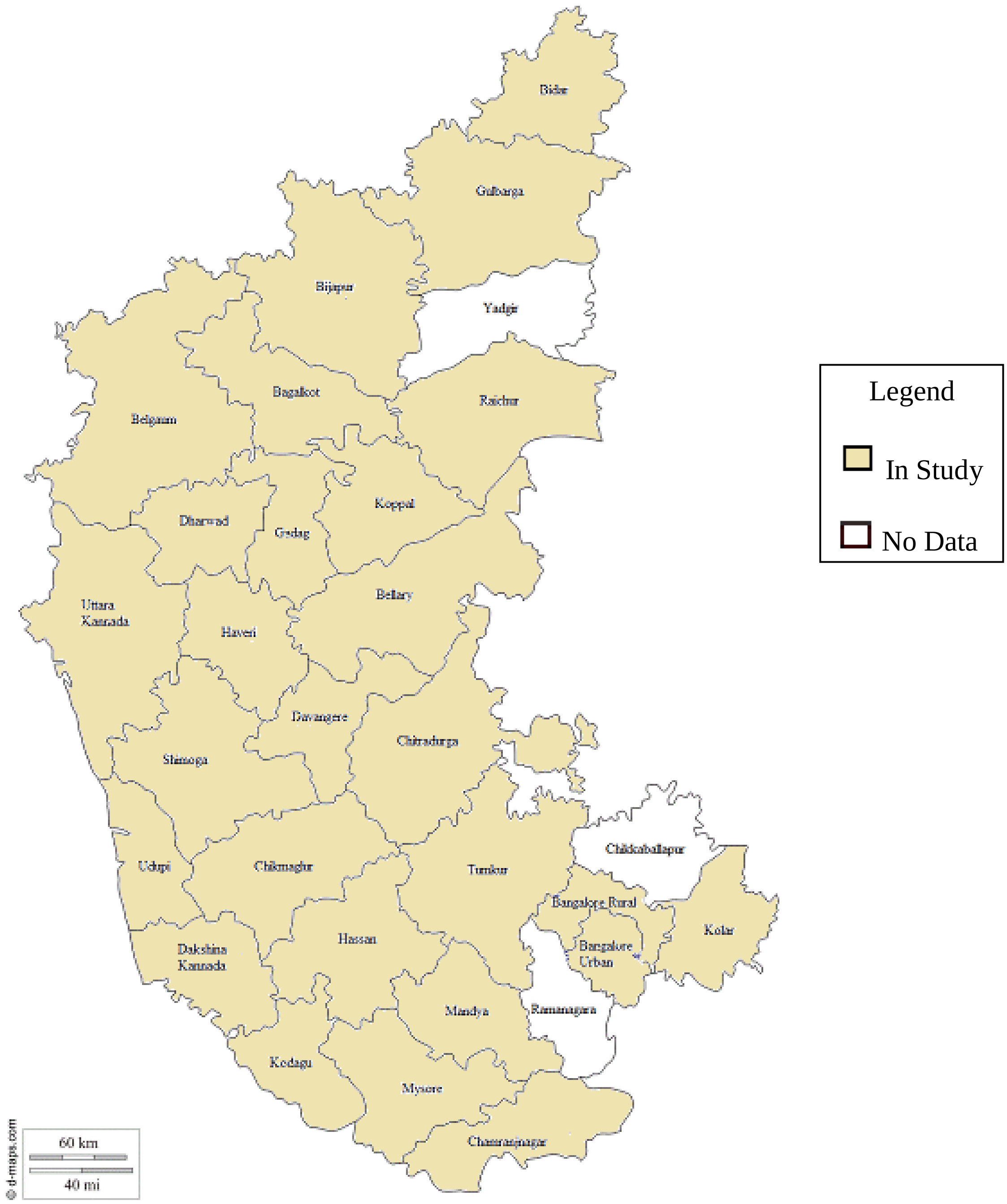
7.3.2 Calculations

7.3.2.1 Part 1: The Creation of a Nutritional HDI

The two datasets were used to create a food centred nutritional HDI model for 27 of the 30 districts since data was not available across all sources for three districts in the state: Chikkaballapur, Ramanagara, and Yadgir (Figure 7.1).

Figure 7.1 Districts of Karnataka

(map modified from: http://www.d-maps.com/carte.php?num_car=8763&lang=en).



The process drew upon the United Nations Development Programme (UNDP) Human Development Index (HDI) for India’s states (UNDP India, 2011). The three dimensions of HDI are defined by the UNDP as income, health, and education. Data opportunities at the district level were explored and the most suitable proxy indicators to capture the three thematic components were selected. The first step involved drawing relevant raw data for each theme and processing it into the formula that follows. The minimum and maximum totals were derived from international standards which were elaborated for each respective nutritional HDI component. The symbol ‘*’ represents multiplication and ‘^’ designates the cubed root.

Nutritional HDI component (e.g. income/health/education): *Karnataka district level data - Minimum/Maximum - Minimum* = Resultant nutritional HDI for specific component.

Income was captured by the absolute yearly household expenditure on food. The percentage of food expenditure in relation to total household expenditure represents income and economic factors and is an established metric (FAO, 2015a). This paper takes an absolute figure due to two key factors. First, exploratory research by the author using NSS data revealed relative parity between districts with wide income disparities. This was manifest in the percentage of food expenditure versus total household expenses. Second, researchers have recently noted that greater discrepancies are present for non-food relative to food spending in Indian households (Basole & Basu, 2015b).

The income calculation accessed NSS information on monthly average household consumer expenditure across various categories. Food items (with the exception of tobacco and related products), were included in the calculation. The average 2012 exchange rate for rupees (Rs) to United States Dollars (USD) of 53.37 was used (X-Rates, 2015). The

Purchasing Power Parity (PPP) figure of 17.53 between Indian Rs and USD was inputted (World Bank, 2015). The following formula was used:

*Monthly Food Item Expenditure * 12 Months * Rs to USD Exchange Rate * Rs PPP in International Dollars (USD)* = Yearly District Income.

Second, the *Yearly District Income* was converted into the nutritional HDI formula. The district level calculation made use of the highest and lowest yearly food expenditures in the world. The maximum expenditure figure was taken from Switzerland at 4080 USD (United States Department of Agriculture, 2015) and multiplied by a PPP of 1.37 (World Bank, 2015) for a total of 5589.60 USD. The minimum figure was taken from Liberia (African Development Bank, 2012) at 41.12 USD (converted by both measures) and employed to create the following formula:

Yearly District Income (District Income Figure) - 41.12/5589.60-41.12 =

Result (Income Formula)

Specific examples, using data figures for Belgaum (see Appendix 15) are presented.

Yearly Belgaum Income: .1571.65 - 41.12/ 5589.60-41.12 =

Result (Income Formula for Belgaum: 0.243603)

The Health component was captured by creating the percentage of pregnant women with anaemia as revealed by DLHS data for 27 districts. The percentage representing the number of anaemic women is inversely proportional to the number of non-anaemic women thus data results are inverted since larger numbers in the index correspond to positive results. Districts with fewer pregnant women with anaemia produce higher ‘health’ scores. Each district level calculation made use of the instance with the lowest number of pregnant women with anaemia. The number of non-anaemic pregnant women (from the USA) was recorded as the maximum (94.3%). At almost the exact opposite end of the scale Bangalore Urban exhibited the highest number of anaemic pregnant women (94.7%) and thus generated the inverted minimum figure of healthy, non-anaemic expectant females of 5.3%. This latter figure, the worst result from all districts observed in this study, generated a functional value of (5.2%) to facilitate the mathematical process.

District Health (Belgaum: 53.6) - .052/ .943- .052 =

Result (Health Formula for Belgaum: 0.540782)

Education was captured by the literacy rate of people over seven years of age. The DLHS recorded this figure across 27 districts. Each district level calculation was inputted relative to the maximum level of literacy recorded from Lithuania (100%) and a minimum level noted in Niger (19%). The following formula illustrates the process:

District Education (Belgaum: 69.28) - .19/ 100-.19 =

Result (Education Formula for Belgaum: 0.620741)

The second step calculated the cubed geometric mean for each of the indicators to produce a final district score. This calculation was made by taking the cubed root of the product of the three indicators:

3^ Income Result (.243603) Health Result (.540782)* Education Result (.620741) =*

HDI Nutrition Score (Belgaum: 0.434049)

Final HDI Nutrition scores were summarized in Table 1 (Appendix 15). Scores were recorded across the following categories of increasing severity: >.48 = Adequate; .45-.499 = Slightly Inadequate; .40-.449 = Moderately Inadequate; .35-.399 = Significantly

Inadequate; .30-.349 = Severely Inadequate; and <.30 = Alarmingly Inadequate. All HDI scores <.48 are considered low by the UNDP (UNDP India 2011, 22).

7.3.2.2 Part 2: Food Consumption and Production

The next section used NSS data to illuminate district level food consumption. Unfortunately, district level information only pertains to consumption expenditure and does not capture quantity. Therefore, a series of author calculations to illuminate consumption quantity were necessary. Academics have noted this constraint, and have devised a system for calculating metric quantities from raw food data known as the *monetary value* method (Smith & Subandoro, 2007). This occurs by converting food expenditure data to metric food quantities. The procedure uses one metric weight unit consistently for all conversions. Expenditures reported by households are matched with corresponding information on food prices and target geographical area. The figures are then divided by one metric weight unit to produce quantities (Smith & Subandoro, 2007).

An initial calculation created a theoretical baseline, by estimating the quantity of pulses and cereals to be obtained per 1 Rs. The next calculation modified NSS consumption expenditure scores. These were based on a 30 day recall for each district and food item, by converting them to a daily per capita scale, with equivalent consumption quantity. The system for realizing the calculations is further explained in the material to follow. It should be noted that actual district level nutritional consumption can only be estimated, as there are inevitable market distinctions which cannot be captured.

The calculation was based on information from the NSS, 'Details of consumption of selected pulses & pulse products in Karnataka.' This was derived from the NSS state report, Table 4, Page 11 (Directorate of Economics and Statistics, 2012). The information was used to determine roughly how much per capita quantity of pulses in (g) can be obtained by one consumer expenditure unit (Rs). In order to do this the *pulses & products* total provides a figure found in the column *per capita qty. (kg) consumed in 30 days* under the *modified multiple reference period (MMRP)* with a rural total of .684 (Directorate of Economics and Statistics, 2012). The column *value per 30 days (Rs)* provides a corresponding figure of 39.92 (Directorate of Economics and Statistics, 2012). The first calculation is interested in converting both 30 day totals into daily totals. In order to do so both were divided by 30:

Quantity (.684) / Days (30) = Daily Quantity (.0228)

Value (39.92) / 30 = Daily Value (1.330666667)

Kilograms were converted to grams to show 22.8 g of pulses are consumed. Quantity was divided by price to indicate amount of pulse purchasing power of 1 Rs.

Daily Quantity (22.8) / Daily Value (1.3306666667) = 17.13

This calculation is necessary as district level information is solely available in Rs and there is no other mechanism for estimating consumption quantity. It shows that 17.13g of pulses can be purchased with 1 Rs.

The second calculation was derived from Statement 6, Page 235 of the NSS (Directorate of Economics and Statistics, 2012). The *Monthly per capita value of consumption* was accessed from this page. The statement which included the sub-group *pulses* under *MMRP* showed monthly rural consumption of pulses in Belgaum had a value of 33.72 Rs (see Appendix 2 Rs data column). This total was divided by 30 to produce a daily expenditure result in Rs. That result was then multiplied by 17.13 to capture the estimated quantity of pulses consumed in grams. This process was repeated for all remaining districts.

*Pulses Expenditure (Belgaum: 33.72) / 30 * 17.13* = Result (19.25412)

Both calculations were generated for cereals (first at the state and then the district levels) using NSS data and the procedure outlined previously. Table 3, Page 10 of the state level NSS report showed that 74.34 g of cereals are consumed per Rs (Directorate of Economics and Statistics, 2012).

A series of district level calculations made use of the data provided in Statement 6, Page 235 (Directorate of Economics and Statistics, 2012). The result listed below the sub-group *cereals* under *MMRP*, showed monthly rural consumption of cereals in Belgaum had a value of 102.7 Rs (Directorate of Economics and Statistics, 2012). This total was divided by 30 to produce a daily expenditure result in Rs. It was then multiplied by 73.34 (grams) to generate an estimate of the quantity of cereals consumed in grams. This process was repeated for all remaining districts.

*Cereals Expenditure (Belgaum: 102.7) / 30 * 73.34* = Result (254.4906)

Results for both pulses and cereals were compared against the Indian Council of Medical Research paper entitled, ‘Nutritive Value of Indian Foods daily recommendations for pulses and cereals’ (Gopalan, 1991). Recommended daily consumption for cereals is 400 g and 35 g for pulses. Surpluses and deficits were recorded (Appendix 2) and results capture consumption relative to recommendations. Consumption figures correspond to six levels of nutritional adequacy which indicate the relative consumption deficit in a percentage (>0; 0 to -.09; -.10 to -.19; -.20 to -.29; -.30 to -.39; and <-.40) for both food items (Table 7.1).

Consumption Pulses (Belgaum: 19.25412) – 35 = -15.7459

Consumption Cereals (Belgaum: 254.4906) – 400 = -145.509

Production yield figures for pulses and cereals were taken from the ‘Report on Area, Production and Prices of Agricultural Crops in Karnataka 2009-10’ (Directorate of Economics and Statistics, 2012). These yield figures, corresponding to six levels of productivity, are based on kilogram/hectare yield levels for pulses (1 = >700; 2 = 600 to 699.99; 3 = 500 to 599.99; 4 = 400 to 499.99; 5 = 300 to 399.99 and 6 = <300) and kilogram/hectare yield levels for cereals (1 = >3000; 2 = 2500 to 2999.99; 3 = 2000 to 2499.99; 4 = 1500 to 1999.99; 5 = 1000 to 1499.99; 6 = <1000 (Table 7.1; Production Ratings: Pulses and Cereals).

7.4 Results

Table 7.1. Summary of Karnataka Rural District Ratings Information: Nutritional HDI; Pulse/Cereal Consumption; and Pulse/Cereal Production Yield (Appendices 15, 16).

District Nutritional HDI Ratings		Nutritional HDI Score	Consumption Ratings		Production Ratings	
			Pulses	Cereals	Pulses	Cereals
1	Uttara Kannada	**>.48**	**1**	**2**	**5**	**3**
2	Kodagu	**.45-.479**	**5**	**2**	**5**	**2**
	Belgaum		**5**	**5**	**5**	**5**
	Chitradurga		**5**	**3**	**3**	**4**
3	Gadag	**.40-.449**	**2**	**3**	**6**	**5**
	Haveri		**2**	**2**	**5**	**4**
	Shimoga		**3**	**4**	**5**	**2**
	Bellary		**4**	**1**	**5**	**3**
	Bijapur		**4**	**4**	**5**	**6**
	Chikmagalur		**3**	**3**	**2**	**3**
4	Davanagere	**.35-.399**	**4**	**4**	**1**	**1**
	Gulbarga		**5**	**5**	**4**	**5**
	Koppal		**5**	**5**	**5**	**4**
	Mysore		**5**	**5**	**3**	**2**
	Bagalkote		**6**	**5**	**4**	**5**
	Bidar		**2**	**5**	**4**	**6**
	Chamarajanagar		**3**	**2**	**2**	**4**
	Dakshina Kannada		**6**	**1**	**6**	**3**
5	Dharwad	**.30-.349**	**5**	**5**	**3**	**5**
	Hassan		**4**	**5**	**4**	**2**
	Kolar		**2**	**2**	**2**	**4**
	Raichur		**5**	**3**	**4**	**3**
	Tumkur		**3**	**5**	**3**	**4**
	Udupi		**6**	**2**	**4**	**2**
	Bangalore Rural		**2**	**3**	**1**	**2**
6	Bangalore Urban	**<.30**	**1**	**1**	**2**	**3**
	Mandya		**3**	**4**	**4**	**2**

Nutritional HDI Rating		**Consumption Rating**		**Production Rating**	
1	Adequate	**1**	Surplus	**1**	Highest
2	Slightly Inadequate	**2**	Slight Deficit	**2**	High
3	Moderately Inadequate	**3**	Moderate Deficit	**3**	Moderate
4	Significantly Inadequate	**4**	Significant Deficit	**4**	Low
5	Severely Inadequate	**5**	Severe Deficit	**5**	Very Low
6	Alarmingly Inadequate	**6**	Alarming Deficit	**6**	Lowest

The nutritional HDI data illustrated in Table 7.1 reveals that the rural areas of districts in Karnataka have generally poor scores when compared against global standards (HDI scores of <.48 are defined as poor.) Results create the possibility to craft policy solutions for groups of districts, or geographical sub-regions with similar characteristics within the state. Those districts which record the lowest scores are primarily located in the south of the province closest to Bangalore.

The grouping of districts by nutritional HDI scores is further complicated with data on pulse and cereal consumption and production. Table 7.1 provides a strong visual impact revealing the complexities of Karnataka. In general, the vast majority of districts across the state suffer from consumption deficits (Table 7.1). The districts which enjoy surpluses for pulse consumption are Uttara Kannada and Bangalore Urban. Similarly, cereal consumption surpluses can be found only in Bellary, Dakshina Kannada, and Bangalore Urban (Table 7.1). The need for nutritional intervention is immediately apparent, and some surprising results illuminate certain patterns and inconsistencies.

Uttara Kannada is the sole district with an adequate nutritional HDI (Rating 1) as illustrated in Table 7.1. Uttara Kannada enjoys a surplus in pulse consumption with a slight deficit in cereals (Table 7.1). It does not score favourably for productivity yield (Table 7.1).

Kodagu has a slightly inadequate nutritional HDI (Rating 2), a slight deficit in cereal consumption, and high productivity yields for the food item (Table 7.1). This contrasts with a severe deficit in its pulse consumption and very low yields (Table 7.1).

Table 7.1 further illustrates five districts (Belgaum, Chitradurga, Gadag, Haveri, Shimoga) with a moderately inadequate nutritional HDI (Rating 3). Comparatively speaking, Haveri has only slight deficits in consumption for pulses and cereals despite not having high production yields (Table 7.1). The district of Belgaum is largely an outlier as it has a moderately inadequate nutritional HDI score despite experiencing the most significant pulse and cereal deficits in the group and very low production yields (Table 7.1). While registering moderate production yields for pulses, the district of Chitradurga has a severe deficit in pulse consumption as well as a moderate deficit in cereals (Table 7.1). Shimoga records moderate deficits in pulse consumption and significant deficits in cereals yet has high productivity for cereals (Table 7.1). Gadag has a slight deficit in pulse consumption and a moderate one in cereals, yet exhibits very low and the lowest rating for production yields (Table 7.1).

The seven districts with significantly inadequate nutritional HDI (Rating 4) include Bijapur and Davanagere with corresponding significant deficit levels for both pulse and cereal consumption (Table 7.1). Davanagere has the highest production yield potential for both food items (Table 7.1). Gulbarga, Koppal and Mysore have severe consumption deficits in both food items while the latter contains higher production potential for both (Table 7.1). Bellary boasts a surplus in cereal consumption but a significant deficit in pulses (Table 7.1).

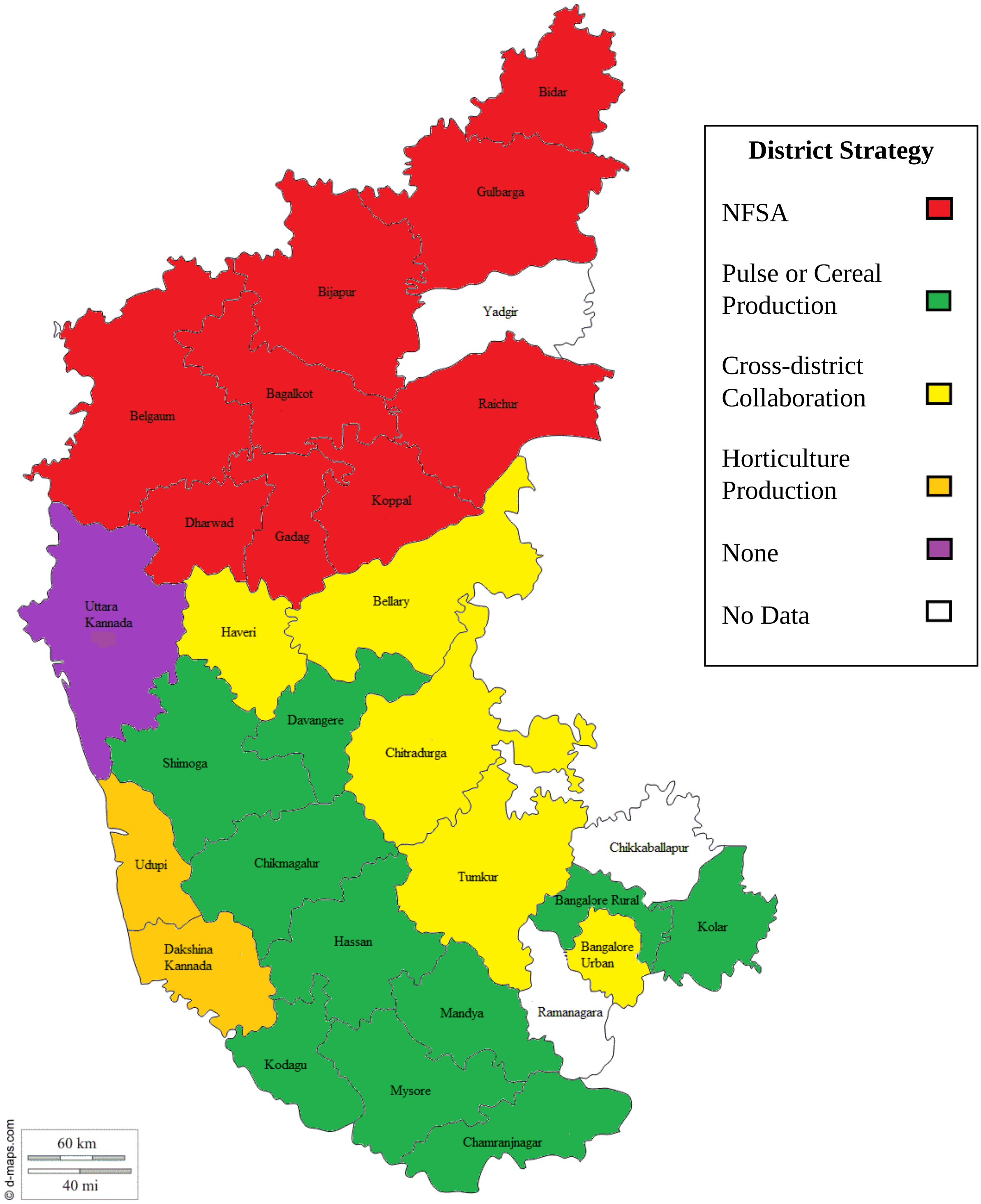
Nutritional HDI in the severely inadequate category (Rating 5) consists of ten instances. Pulse consumption deficits are alarming (Bangalkote, Dakshina Kannada, and Udupi) or severe (Dharwad, Raichur) in nature (Table 7.1). High pulse production yields are located in Chamaranjnagar and Kolar (Table 7.1). Hassan and Udupi have the potential for positive cereal yields (Table 7.1). The latter suffers alarming pulse consumption deficits (Table 7.1). Kolar has severely inadequate nutritional HDI despite relatively slight consumption deficits (Table 7.1). Dakshina Kannada scores a surplus for cereal consumption but an alarming deficit in pulses (Table 7.1).

Bangalore Rural, Bangalore Urban, and Mandya exhibit alarmingly inadequate levels (Rating 6) of nutritional HDI (Table 7.1). Consumption deficits for pulses and cereals in Bangalore Rural are not as disturbing as some other districts. The district has a slightly larger deficit in cereal consumption but exceptional pulse production yield and high cereal production yield (Table 7.1). Mandya has low yields for pulses and high ones for cereals (Table 7.1), while Bangalore Urban, somewhat of a statistical outlier, shows high yields for pulses and moderate yields for cereals (Table 7.1).

These results are particularly relevant in light of food and agricultural policy reform at the district, state, and national scales. There are a number of complex combinations which will better inform varied approaches to policy. The discussion section that follows explores similarities between districts in further detail.

7.5 Discussion

Figure 7.2 Recommended Strategies for Improving Food Security and Nutrition for Districts in Rural Karnataka (map modified from: http://d-maps.com/carte.php?num_car=31757&lang=en).



7.5.1 Targeted Need Based Interventions within the NFSA Framework

Prior to the passing of the NFSA, India administered the largest food security programme in the world (Sharma, 2012). Research recognizes the soaring costs of providing food subsidies, and notes that these have been ineffective in reducing the proportion of the population that is undernourished (Sharma, 2012). Bearing this in mind, a NFSA strategy which both targets those in greatest need, and conserves financial and material resources is expedient. The need for direct state government intervention, in combination with NFSA and public distribution resources, is most necessary in the northern districts of the province (Figure 7.2). The level of urgency is greatest for Bangalkot, Bidar, Dharwad, and Raichur which record severely inadequate nutrition (Figure 7.1). Bijapur, Gulbarga, and Koppal are significantly inadequate, while Belgaum and Gadag are moderately inadequate (Table 7.1). This group of districts corresponds to the North Interior Karnataka Meteorological Zone (Haveri excluded) as defined by the India Meteorological Department. The zone features a semi-arid and arid landscape with low rainfall totals of 529mm in 2012 (Government of India, 2013). Seven of nine districts suffer from nutritional HDI scores in the significantly and severely inadequate categories, and do not hold comparatively high production yields for either pulses or cereals (Figure 7.1). Most record various degrees of low production yield with the exception of: Bijapur (pulses), Dharwad (pulses), and Raichur (cereals) which are moderate (Figure 7.1). Currently, Indian states collect a significant share of their NFSA allocation from the central pool (Kishore et al., 2014), and due to severity, this paper recommends that the food which supports the NFSA in these districts, comes directly from the central government.

A debate in the literature considers the inclusion and/or preference for pulses in the NFSA, leading to some advocating further experimental policy and research to justify an appropriate measure of implementation (Kishore et al., 2014). The predecessor to the NFSA, the Targeted Public Distribution System (TPDS), had a history of reducing poverty through increases in consumption expenditure (Dreze & Khera, 2013). However, a desire to move beyond cereals in national nutritional programmes arises when questioning the link between access to subsidized grains and the improved nutrition of specific vulnerable groups (Desai & Vanneman, 2014). Critics favour strategies which identify undernourished districts and groups prior to intervention (Desai & Vanneman, 2014). Furthermore, a heavy reliance on cereal price reduction risks reducing the consumption of other essential food items and overall dietary diversity (Desai & Vanneman, 2014). In order to uncover nutritional specifics, the group of districts in the north identified by this paper should be more rigorously studied at finer scales, such as taluks (district subdivisions).

7.5.2 Strategic Increases in Food Production and Cross-Scale Linkages

The most salient link between agriculture and nutrition for undernourished families is the production of low-cost energy foods. Decreases in pulse production and subsequent price increases, have taken pulses out of the reach of many of the poor (Gopalan, 1995). A crucial element in the improvement of the nutritional status of India’s population includes improved shipping systems facilitating the rapid transport of food to needy areas. Specific challenges demand strategies which go beyond cereal procurement. Results provide a means for Karnataka to approach this challenge using state-wide resources.

Table 7.1 illustrates that pulse productivity yields are highest in a series of southern states which also record low nutritional HDI scores. In general, districts with the highest and high production yield ratings can be used strategically for the cultivation of pulses (Figure 7.2). This strategy might be used in districts with a similar combination of production yield characteristics and low ranking nutritional HDI scores. For example, many districts in the south have inadequate nutrition but favourable productivity (Figure 7.1). Examples include: significantly inadequate (Chikmagalur- high productivity, Davanagere- highest productivity), severely inadequate (Chamarajnagar- highest productivity, Kolar- high productivity) and alarmingly inadequate (Bangalore Rural- highest productivity) in the south (Figure 7.1). A similar cultivation strategy can be used for cereals in Bangalore Rural, Hassan, Kodagu, Mandya, Mysore, and Shimoga which experience high productivity yields, and Devanagere which again has the highest productivity (Table 7.1). Each district would be able to export in varying degrees, however very severe cereal deficits would need to be addressed by Mysore and Hassan prior to large scale export. While Devanagere shows excellent productivity for both pulses and cereals, it also experiences significant consumption deficits for both (Table 7.1). A strategy is required to rectify the district's significantly inadequate nutritional status.

These districts, located in the South Interior Meteorological Zone, had 832 mm of rainfall in 2012 (Government of India, 2013). The examples indicate that agricultural growth and rural development lag behind in India. The country has missed the opportunity for agglomeration economies that could increase the efficiency of the agricultural sector, lower food prices for the poor, and create employment in modernized food supply chains (Dulsrund et al., 2015). An agglomeration here would be driven by both industry and regional factors, as producers would be situated in close proximity to others in relevant industries. Localization of knowledge and a clustering of industry-specific skills would create a specialized labour pool (Lall et al., 2001). The presence of the urban centres of Bangalore and Mysore at the core of the South Interior Meteorological Zone provides access to complimentary services in the financial, transportation, and technology sectors (Lall et al., 2001).

7.5.3 Policy for Coastal States and Outliers

The results demonstrate that favourable nutritional HDI scores are realized when there is higher consumption of both pulses and cereals. This can be seen in the case of Uttara Kannada, where positive nutritional gains are slightly more attributable to the pulse surplus, rather than the slight cereal deficit (Table 7.1). The district has a favourable position in the Coastal Karnataka Meteorological Zone, which received an abundant 3395mm of rainfall in 2012 (Government of India, 2013). Dakshina Kannada and Udupi, also located in this zone (Government of India, 2013), do not enjoy favourable nutritional HDI scores and are categorized as being severely inadequate (Table 7.1). The former enjoys cereal surpluses while the latter records a slight deficit (Table 7.1). However, both have alarming deficits in pulse consumption and have low yield potential (Table 7.1). This paper recommends that increases in protein consumption should be focused on increases in horticulture (Figure 7.2). Research has shown that a lack of horticultural development has also meant that various micronutrient deficiencies have been compounded (Gopalan, 1995). The inclusion of low cost, nutritionally rich horticulture products is essential to improve the nutrition of the poorest families (Rao, 2013a). Chilli, onions, and tomatoes are ideally produced in high rain, moist environments (Rai & Yadav, 2015). The two coastal districts of Dakshina Kannada and Udupi have favourable conditions to produce these fruits & vegetables (Government of India, 2013).

The districts of Bangalore Urban and Bellary are unique in the state as they record surplus consumption for cereals with moderate production yields (Table 7.1). In the case of Bellary, low pulse consumption prevents it from enjoying positive nutrition, and defines it as significantly inadequate (Table 7.1). In contrast, Bangalore Urban has a consumption surplus in pulses but experiences a level of nutrition that is alarmingly inadequate (Table 7.1). The discrepancy between the nutritional HDI and the consumption results is very likely due to the significant poverty issues experienced in the vicinity of the city. Historically, most of Bangalore's slums have been located in the middle and peripheral zones of the city and comprise roughly 20% of the total population (Chowdhury, 2010). This is captured by the NSS data in the Bangalore Urban district. In Bangalore, significant non-nutritional interventions which simultaneously address poverty and inequality will also be required. However, as the research in this paper indicates, each district is strategically located to act as a node for production and distribution of both pulses and cereals (Figure 7.2). This paper further recommends action for districts which do not enjoy favourable productivity and rainfall. Chitradurga and Haveri, both moderately inadequate (Table 7.1), and Tumkur severely inadequate (Table 7.1), should aim to increase NFSA support while simultaneously importing required crops from those neighbouring districts which would have increased production (Figure 7.2).

7.5.4 Multi-sectoral Collaboration

Proponents of linking agriculture to nutrition have emphasized that the targeting of nutritionally vulnerable groups is necessary to design appropriate interventions (Herforth et al., 2012). For example, some food-based agricultural strategies have been successful in reducing iron deficiency in vulnerable areas (Ruel, 2001). In the absence of a national programme, Karnataka was the first state in India to launch an initiative to combat malnutrition, intervening in target groups such as children under the age of three, pregnant and nursing mothers, and adolescent girls (Rao, 2013a). While interventions targeting specific vulnerable groups are favourable, there are broader deficits, palatable in rural areas of most districts, which need to be addressed (Table 7.1).

Cross-sectoral coordination is required to ensure that proper incentives are introduced to motivate institutions, and to prioritize improved nutrition outcomes (World

Bank, 2010). At present, the Karnataka Nutrition Mission collaborates with state government organizations (Kadiyala et al., 2014); however, district and state linkages to a wider national effort are unclear (Rao, 2014). Fortunately, momentum for multi-sectoral action is gaining support (Kadiyala et al., 2014). The Karnataka Nutrition Mission has already worked on monitoring multi-sectoral programmes for malnutrition such as anaemia control (Rao, 2013b). The organization is well positioned to act as a bridge to communities during data collection. It can also advise districts and the state regarding nutritional deficits and corresponding production goals. Researchers advocate the collection of nutrition data at the district level to combat undernutrition and strategically prioritize programmes (Desai & Vanneman, 2014). This paper argues that DLHS district level data should be expanded to include more nutrition related indicators, particularly for food item intake and anthropometric information.

7.6 Conclusion

This paper discusses district level nutritional HDI and its implications in the rural areas of Karnataka, seeking to answer the question, ‘To what extent can relevant survey information be used in the reform, and subsequent implementation of district level food policy in rural Karnataka?’ Nutritional HDI is an effective measure for identifying the degree to which districts in Karnataka face food and nutritional issues. When combined with relevant food consumption expenditure and agricultural production statistics, the index is able to propose specific policy interventions. Limited data are available at the district level. However, there are adequate resources to influence current and future work. As such, this paper demonstrates that survey information from the NSS and DLHS, when combined with Ministry of Agriculture statistics, can make a significant impact in reforming district level policy.

It would be valuable to strengthen, diversify, and test each nutritional HDI indicator. Effort should be put into collecting more data to compare different vulnerable groups for the health component, particularly children from 0-36 months of age. It would be helpful to develop a metric which more closely approaches the amount spent on food items by examining expenditure on food groups required for nutrition. Rather than capturing literacy, recording employment requiring education would provide a useful metric of overall social development. In addition, the comparison of the nutritional HDI model to standard HDI index indicators would illuminate differences between the new and old models.

Recommendations include: more robust NFSA distribution into districts of Karnataka which experience both low nutritional HDI and poor pulse or cereal yields; the increase in production of pulses and cereals in those districts with high yield potential for distribution in both producing and neighbouring districts; and increases in collaboration and strategic planning among national, state, and district level actors. Uttara Kannada, the only district in Karnataka with a positive nutritional HDI, demonstrates that this condition is best realized when a high consumption of pulses is combined with cereals. The potential for an agglomeration economy centred on pulse and cereal production is possible among a group of districts in the south of the province. The Karnataka Nutrition Mission has both the position and responsibility to act as a multi-scale conduit between the central, state, and district governments in addition to the wider citizenry.

7.6.1 Paper 4 in Context of the Thesis

The fourth paper concentrates on analysis at the district level (finest scale) in the state of Karnataka, India. It builds on the conceptual framework evidenced in the first three papers and further connects the aim of linking the food system and nutrition by exploring the nexus between increased food production, district collaboration, and a more focused NFSA. District level data are sparse relative to national and state scales. The creation of a nutritional HDI frames the results of the three analytical lenses (nutrition, trade, and governance) presented in the conceptual framework.

Nutrition features prominently in the creation of a nutritional HDI model, which is a modification of the UNDP's poverty formula. The model provides a reference point for district cereal and pulse consumption information thus continuing the exploration of pulse protein as it impacts nutrition. Trade is directly relevant to the nutritional HDI. It is through the recording of pulse and cereal production information that a policy strategy suggests the development of a production agglomeration, which would be able to export to its immediate neighbours. The strong emphasis on the production and consumption of pulses relative to nutritional requirements continues the discussion from papers 1, 2, and 3. The strategic use of available resources builds on themes found in the second and third papers. Governance is situated in the most decisive position at this scale as this paper suggests the implementation of various strategies to improve nutrition in districts in Karnataka. In each instance, significant government involvement and collaboration is required, including those between districts, the district/state, and the district/state/nation. The type of collaboration advocated here, similar to Paper 3, requires considerable effort due to its location at a finer scale.

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Chapter 8. Discussion and Implications

This chapter outlines the policy implications of the four papers and sketches the advancement of the discourse within the four analytical lenses: scale, nutrition, trade, and governance. In addition, two complimentary themes: food security and nutrition indicators, and the link between agriculture and nutrition, are integrated in the discussion. Each lens is organized into an independent section which contains key findings and implications. A review of the research and findings with respect to the overall objectives and possible outcomes of the thesis is included.

8.1 Multi-scale Analysis

Multi-scale analysis allows for a linking of the thematic structure, the bridging of gaps, and the enriching of analysis. It can be used to improve understanding of conceptual, methodological, empirical, analytical, and policy aspects of food security and nutrition studies. The benefit of this is that unified and coherent policy positions might be more fluidly constructed when decision-making can be situated into specific, delineated spaces as suggested by foodsheds research. These are international, national, state, and district, along with possible new regional formations (Feagan, 2007). Multi-scale positioning illuminates India's interactions with the food system and provides insights which could be useful for actors in other developing nations or at international organizations. This is relevant for policy and the literature on foodscapes as it provides a blueprint for the provisioning of nutritious food (Goodman, 2010; Minewald & McCann, 2014), and specifically for pulses in India and for fruits & vegetables in other nations. The collective findings of the four papers encourage a nascent policy narrative to unfold and represent the beginning of a moral economy of food where health and well-being are the primary concern of policy (Jackson et al., 2009; Morgan et al., 2006).

Many nations, including India, are situated in a low hunger group while recording trade deficits in fruits & vegetables. Relevant stakeholders, interacting with the international system, might advocate for trade reform, create alternative development strategies, and refine the concept and indicators of food security. The incorporation of more nuanced nutritional information, a reduction in the impact of international trade on food and nutritional programmes and related agricultural strategies, and the benchmarking and quantitative scoring of governance, could be integrated into an internationally accepted analytical system.

The Indian government is encouraged to continue in trade reform and reduce pulse exports. It might engage in targeted programming by cultivating pulses in proximity to the less fortunate states in the north and east. Improvements in e-governance could be adopted as a strategy to reduce corruption in programme delivery. Districts in Karnataka might develop regional strategies, such as agglomeration, to maximize strengths, and provide assistance to areas of weakness through the NFSA. As a pulse producer with inadequate cold storage facilities, the state would benefit from investments in this area.

8.2 Nutrition

This thesis uses indicators and best available data to clarify the relationship between food security and nutrition. Evidence from the first paper suggests that food security requires a more rigorous conceptualization by the international research community and international organizations such as the FAO. Current studies are based largely on indicators which do not emphasize nutrition and are only partially effective in their attempts to capture the complexity of the food system (EIU, 2015; FAO, 2015a;

IFPRI, 2013; WFP, 2013). Food is consistently treated as a commodity by international and national data collection agencies, as shown in FAO food balance sheets (FAO, 2010) and National Sample Survey (NSS) consumption expenditure survey results (NSS, 2014).

Most contemporary research on malnutrition confirms that the world is faced with a triple burden (Gomez et al., 2013; Johnston et al., 2014; Leathers & Foster, 2004; Mann & Truswell, 2007), meaning that capturing all nutritional requirements in a single study is challenging. Results of the first paper suggest that a Protein Digestibility Corrected Amino Acid Score (PDCAAS) would be more valuable than recording data on animal protein consumption (Schaafsma, 2000; Young & Pellett, 1994). This finding enables later papers in the thesis to consider more robust dietary diversity conceptualizations and plant protein sources.

Paper two builds on paper one by placing FAO food balance sheet data (Hatloy & Oshaug, 1998) into nutritional food groups as recommended by the WHO (WHO, 2000). It investigates the potential use of plant proteins (particularly pulses) as a measurement for dietary diversity. This paper does not employ less effective Food Consumption Score (FCS) and Household Dietary Diversity Score (HDDS) measurements which can only be used at the household level (Haddad, 2013; Kennedy et al., 1995) or studies which provide dietary requirements beyond daily minimum sedentary activity requirements (Haen et al., 2011; Heady & Ecker, 2012). This captures dietary diversity with greater precision (Ruel, 2003) and is the best available short-term solution to poor quality and limited availability of data (Haddad, 2013).

Moving forward, it would be advantageous for surveys to function as windows for understanding nutritional requirements (Drewnowski et al., 1997; Ruel, 2003). At the international level, developing a consensus for recording the nutritional quality of food would better illuminate agricultural, economic, educational, and health challenges (Jones et al., 2013; WHO, 2000). Food, agricultural, and development policy could coalesce to meet the goal of nutrition-sensitive growth. Understanding the nutritional meaning of food availability (along with affordability and quality) is an essential step in this process (IFPRI, 2011).

The food group dietary supply model could play a viable role in understanding the relationship between food supply and nutrition, however it is recommended that the model undergo significant time-series sensitivity testing before results are considered. Further studies on the relationship between food supply and dietary needs might consider potential production trade-offs to improve nutritional status. Of relevance would be the pulse to cereal consumption gap referred to in the third paper (FAO, 2016; Pulse Canada, 2016). It would also be of interest to scale up indicators from the state and national levels to the international where the food group dietary supply model is situated.

Papers three and four suggest that in India, the National Food Security Act (NFSA) can best reform through a series of in-depth state and district level studies which consider the food system and impacts on vulnerable groups (MHFW, 2013). The third paper includes the indicator for the *prevalence of undernourished under the age of five*, which has typically been used at multiple scales (IFPRI, 2013). The fourth paper builds on this idea by considering the *percentage of pregnant women with anaemia* in the nutritional HDI. A possibility exists to further explore the impact of public food security programmes such as the NFSA by scaling this indicator up from the district (Karnataka) to the state, national, and international levels. In order for this to occur district level information would need to be enriched across India (NSS, 2014). Further inclusion of information concerning other vulnerable groups could inform the formation of a new FAO core food security indicator. It would be advisable to conduct surveys on the groups most vulnerable with respect to each aspect of the triple burden of malnutrition (Gomez, 2013; Johnston et al.,

2014) as it is important to identify and narrow the nutrition gaps by first assessing their locations (Thompson & Amoroso, 2011). This could provide a more nuanced understanding of food and nutritional inequalities for policy makers in developing and developed, urban and rural, contexts.

Possible implications for nutrition extend beyond conceptualization and data into the realm of development strategy. The second paper suggests the identification of plant proteins as the means of mitigating the nutritional transition for those developing countries with favourable resources (Dixon, 2009). The third and fourth papers note the NFSA may be further modified according to a series of strategies such as pulse production and the development of horticultural potential (Fernandez-Stark et al., 2011; Frieldland, 1994). It creates a nutritional HDI and employs it alongside production and consumption patterns of pulse varieties (Haen et al., 2011; Kearney, 2010; Popkin et al., 2012). It is critical to increase pulse consumption (Kishore et al., 2014) in order to mitigate nutritional transitions from urbanization in Karnataka (Seale et al., 2003; Shetty, 2002; WHO, 2002).

This thesis recommends building upon a wider policy shift concerning agriculture and nutrition. It is crucial that models which link agriculture to nutrition be tested and refined for robustness (Arimond, et al., 2013; Ruel & Alderman, 2013; Webb & Kennedy, 2012). The third and fourth papers each target pulse consumption increases. Such increases have a greater chance of making a positive impact than standard agriculture to nutrition strategies (Masset et al., 2011; Waterlander et al., 2013). In the international arena, a commitment to nutrition-sensitive growth (IFPRI, 2011, World Bank, 2010) through plant proteins could gain traction with an example of future programme success in the NFSA.

8.3 Trade

Countries, states, and districts might benefit by establishing further associations with one another to leverage strengths and minimize weaknesses within the context of the global trading system. The slow and contentious process of WTO reform (Anderson & Martin, 2005; Bhegin et al., 2003; FAO, 2012; WTO, 2015), and varied national interests in the international food system (Hawkes & Plahe, 2013; Knuth & Vidar, 2011; Toledo & Manzella, 2012) require innovative policies to improve food security and nutritional health. New trade and development arrangements could emerge to take advantage of regional strengths (Nielsen, 2006; Shaw, 2007). Future research could fit into the *moral economies of food* literature, which situates trade alongside health and development (Morgan et al., 2006). The second paper identifies international surpluses and deficits of key nutritional food groups. It recommends the increased movement of fruits & vegetables between northern and southern Mediterranean nations, particularly in the case of Tunisia and the European Union (Cheriet & Rastoin, 2014; Malogio & Hertzberg, 2007). This would link countries without economic partnerships (UNCTAD, 2009) and encourage further study.

The third and fourth papers build on this idea by encouraging India to explore trade links and agglomerations within the context of the NFSA. Collaboration is suggested between those Indian states and districts with the most favourable resources and conditions and others who are in need. This idea has significant potential for expansion in the Indian context by using domestic pulse varieties to maximize local competitive advantages (Desrochers & Shimizu, 2012; Lobell & Burke, 2010). Paper four recommends the creation of agglomerations where districts cooperate to strengthen mutually beneficial relationships (Dulsrund et al., 2015; Lall et al., 2001). An opportunity exists for such development in a collection of districts located at the periphery of Bangalore, Karnataka.

Ultimately, this discourse has implications for the first paper as trade indicators, which take into account nutritional requirements, could be constructed and included by the FAO. Currently, the only trade indicators in use are *cereal import dependency ratio* and *value of food imports over total merchandise exports* (FAO, 2015a). In addition, research which examines potential agriculture-nutrition linkages through production efficiencies in fruits & vegetables in deficit areas (Siegel et al., 2014), and analysis that considers the possibilities of intra-country trade could be useful for India (Karmakar & Mukhopadhyay, 2014) and other developing nations (Ruel & Alderman, 2013).

Microeconomic concerns are also important to note. International trade statistics are largely based on national level information (FAO, 2015), while availability of state and district level data is comparatively sparse (NSS, 2014; DHLS, 2013). The third and fourth papers use income indicators based on *minimum agricultural wage* and *consumption expenditure on food* to capture microeconomic realities which have often been ignored (with some exceptions) in food security and nutrition studies (Oxfam Australia, 2014). Consumption expenditure has been used by the FAO when addressing the poor (FAO, 2015a). The literature supports research which records the purchasing power of families relative to food consumption (Moron & Viteri, 2009). The next step would be to expand the indicator to emphasize consumption expenditure on food items or nutritional requirements. This would be linked to wider nutrition-sensitive research initiatives, and add affordability information to research regarding the value chain (IFPRI, 2011).

8.4 Governance

The process benchmarking exercise explored in paper one reveals that governance has not been thoroughly captured by the FAO. It is a rapidly evolving component of food and nutritional studies. The EIU is exploring its impact using qualitative assessment (EIU, 2015) and INFORMAS is applying benchmarking and good practice for obesity studies (Brinsden, 2013 et al.; Swinburn et al., 2013). The inherent qualitative and subjective nature of governance is a limitation. Results are more meaningful when the performance of food and nutritional programmes are captured (Barrett, 2002; Brooks et al., 2008; Kaufmann et al., 2011; McKeon, 2011).

International initiatives have begun to explore this impact. While the first paper notes that the FAO has been slow to integrate governance indicators into its core group, it still influences the development of the thesis which considers governance either solely through corruption or perception indicators when possible, or in tandem with programme delivery and effectiveness. The second paper focuses on the programme aspect of governance and makes reference to alternative development pathways. It emphasizes the production and consumption of plant proteins and thus enriches the existing literature on urban agriculture in developing nations (Guitart et al., 2012; Hardman & Larkham, 2014).

Paper three builds on the recommendations of the first paper and includes a corruption indicator in the food potential model: *proportional number of convictions in the public distribution system per state*. This indicator is salient in the case of the NFSA which suffers from numerous leakages largely due to corruption in the supply chain (Kishore et al., 2014). This analysis contributes to the field as it moves away from the current practise of integrating qualitative measures of governance into quantitative results. It comprises a measurable performance standard and could be scaled up into the first paper, or more generally into the FAO's group of core food security indicators.

Traditional responses place an emphasis on mechanisms such as subsidies and taxes (Brooks et al., 2008), domestic food assistance programmes (Barrett, 2002), or various rural development strategies (Tutwiler & Straub, 2007). These were broadly advocated in the EIU's group of indicators discussed in the first paper, for example crop storage facilities (EIU, 2015). The third paper applied this concept by exploring specific investments in infrastructure such as cold storages and e-governance to address distribution (Gupta & Dash, 2015) and leakage issues (Masiero, 2015; Svedberg, 2012) and irrigation to improve production (Reddy, 2004). Current data on cold storage and internet connectivity exist only at the national level and further information, scaled down to the districts, will be required to be relevant for policy. In addition, the development of benchmarks for key policy interventions in the food system could be scaled up to the international level. The FAO could include these as part of their core indicators in an expanded conceptualization of infrastructure and the food system.

Moving forward, capturing multi-scale environmental impacts on food systems will be particularly challenging for researchers. The dynamic is especially difficult to monitor at the international level. Some studies exist which scrutinize the impact of climate change on the yield of key crops due to changes in temperature and precipitation (Beddington et al., 2011; Birdlife, 2009; Easterling et al., 2007; Segre & Gaiani, 2012). Despite data limitations, state climate impacts (in the form of agricultural area affected by extreme weather events) are included in paper three (Indiastat, 2011b) and paper four factors in relevant aspects of Indian meteorological zones (Government of India, 2013). Again, the papers suggest strategies that make use of local production and resource strengths in light of environmental realities (Desrochers & Shimizu, 2012) which ideally may strategically maximize production in the highest yield locations and avoid production on land that is not suitable (IIASTD, 2009).

The diversity of climates and unique ecosystems found within specific nations make it difficult to measure and quantify a universal indicator (Action Aid, 2011). Despite the constraints, it would be advantageous to scale up and develop a single indicator, or a set of climate change/environmental indicators, for use in international studies (Beddington et al., 2011; Segre & Gaiani, 2012). For such an initiative to be successful there would need to be a broad international deliberation on the construction of a flexible means for measuring impacts. Integration into a wider governance framework could occur (Ericksen, 2008).

8.5 Thesis Objectives

The first objective sought to address knowledge gaps between the literature on food security and nutrition indicators and available data. The lack of rigorous data was noted and remains a serious stumbling block for further research. Subsequently, dietary diversity and the use of plants as a key protein source were explored. Similarly, the organization of tradable food items into nutritional food groups, and the potential for capturing effective and collaborative food system governance were analysed.

The second objective was to develop and apply quantitative models which take into account the complexity of the food system in unique spatial contexts. This was achieved through a series of approaches which attempted to maximize food resources and relationships for nutritional health. These worked to improve the FAO's conceptualization of food security following a process benchmarking exercise. The second paper involved the reorganization of FAO food balance sheet data into nutritional food groups. The third paper contained a state food potential model using Indiastat data in tandem with the potential for increased pulse presence in the NFSA. The fourth paper developed a nutritional HDI model to strategically target vulnerable rural areas in Karnataka with various intervention strategies.

The third objective aimed to create strategies for increased plant-based protein consumption. This was achieved through a series of policy recommendations at four scales. The recording of plant protein supply information by international food security and nutrition studies, supportive trade and development strategies for nations undergoing nutritional transitions, and the targeted production and distribution of these resources by national, state, and district authorities in India, were discussed.

The fourth objective was to suggest collaboration options for policy makers. Opportunities for collaboration are copious, and include cooperation between established administrative entities at the national, state, and district levels. Further to this, new assemblages for resource sharing and programme effectiveness were shown to be potentially advantageous.

8.6 Concluding Statement

Results of this thesis encourage further research relating to food security and nutritional health. The development of programmes which make use of or expand plant-based protein resources to target vulnerable populations is possible and recommended. Findings indicate, that cooperation across various scales is vital in facilitating these developments, and an increase in direct collaboration is desirable. Ideally, researchers will pursue improvements in the quality and breadth of relevant food and nutritional data and models. The opportunities for future work are substantial.

The FAO might use the findings of this thesis to reconceptualise their core group of food security indicators. Perhaps a large cohort of international experts and stakeholders should consider, debate, and discuss this concept. It would be timely for the FAO's head office in Rome, to host a special conference on the nature and structure of indicators. This process would benefit from significant attention to governance, dietary diversity, and vulnerable groups. A universal commitment to developing these indicators, along with extensive discussion regarding their measurement across contexts and cultures, would be essential. Furthermore, a reduction and simplification in the number of indicators due to extensive logistical challenges would greatly assist future research and facilitate the collection of complete and contemporary data. The influence of this thesis on the FAO, WFP, IFPRI, EIU, and other large food security and nutrition studies, should result in the publication of inclusive and representative work.

Similarly, national governments could draw from the results of this thesis to modify their trade and development policies and focus their data collection and policy intervention efforts. Further data collection on dietary diversity and vulnerable groups, targeting each component of the triple burden, could develop. The central, state, and district governments in India, in collaboration with the NFSA, might use the results of this thesis in the medium to short term, to aggressively pursue an agriculture-nutrition strategy increasing pulse consumption. Here, the engagement of the Karnataka Nutrition Mission in the role of policy facilitator, could be a precursor to the development of new nationwide structures. In the long term, the development of dynamic agglomerations and mutually beneficial trade between districts and states in India, is possible.

The implications of this thesis carry substantial conceptual, methodological, empirical, and policy possibilities. The four analytical lenses (scale, nutrition, trade, governance), and the two complimentary themes (food security and nutrition indicators, the link between agriculture and nutrition), provide a broad and inclusive conceptual foundation for further work in traditional (food supply, anthropometry) and emerging (climate change, e-governance) aspects of study. Research confirms that the current global environment presents a unique opportunity for leaders and all stakeholders to simultaneously address food security and nutritional health issues in developed and developing nations. In order for opportunities to transform into achievements, broad, multi-scale approaches will need to be adopted by all actors across the food system.

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Appendix 1a. Hunger Group Membership (see Figure 5.1 Hunger Groups on The World)

Hunger Group 1 of Industrialized Countries (25): Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Japan, Netherlands, New Zealand, Norway, Poland, Portugal, South Korea, Spain, Sweden, Switzerland, UAE, UK, USA.

Hunger Group 2 of Upper Middle Countries (42): Algeria, Argentina, Armenia, Azerbaijan, Belarus, Bosnia, Brazil, Bulgaria, Chile, Costa Rica, Croatia, Cuba, Egypt, Estonia, Fiji, Iran, Jamaica, Jordan, Kazakhstan, Kuwait, Kyrgzstan, Latvia, Lebanon, Libya, Lithuania, Macedonia, Mexico, Montenegro, Morocco, Romania, Russia, Saudi Arabia, Serbia, Slovakia, Syria, Trinidad & Tobago, Tunisia, Turkey, Turkmenistan, Ukraine, Uruguay, Venezuela.

Hunger Group 3 of Lower Middle Countries (22): Albania, China, Colombia, Dominican Republic, Ecuador, El Salvador, Gabon, Georgia, Ghana, Guyana, Honduras, Malaysia, Mauritius, Moldova, Nicaragua, Panama, Peru, South Africa, Suriname, Thailand, Uzbekistan, Vietnam.

Hunger Group 4 of Upper Developing Countries (37): Angola, Bangladesh, Benin, Bolivia, Botswana, Cambodia, Cameroon, Cote D'Ivoire, Djibouti, Gambia, Guatemala, Guinea, Guinea-Bisseau, Indonesia, Kenya, Laos, Lesotho, Liberia, Malawi, Mali, Mauritania, Mongolia, Namibia, Nepal, Nigeria, North Korea, Pakistan, Paraguay, Philippines, Rwanda, Senegal, Sri Lanka, Swaziland, Tajikistan, Togo, Uganda, Zimbabwe.

Hunger Group 5 of Lower Developing Countries (19): Burkina Faso, Burundi, Central African Republic, Chad, Comoros, Ethiopia, Eritrea, Haiti, India, Madagascar, Mozambique, Niger, Republic of Congo, Sierra Leone, Sudan, Tanzania, Timor-Leste, Yemen, Zambia.

Appendix 1b. Hunger Groups: Fruit & Vegetable Exporting Countries

Hunger Group 1: Spain, Italy, Greece, Hungary, Netherlands, Poland, New Zealand.

Hunger Group 2: Brazil, Mexico, Turkey, Costa Rica, Chile, Argentina, Azerbaijan, Cuba, Egypt, Iran, Jordan, Kyrgyzstan, Lebanon, Morocco, Macedonia, Moldova, Serbia, Tunisia, Uruguay.

Hunger Group 3: China, Ecuador, South Africa, Thailand, Colombia, Dominican Republic, Honduras, Panama, Peru, Suriname, Uzbekistan, Vietnam.

Hunger Group 4: Guatemala, Philippines, Bolivia, Cameroon, Cote D'Ivoire, Kenya, Tajikistan, Zimbabwe.

Hunger Group 5: India, Burundi, Ethiopia, Madagascar, Niger.

Appendix 2a. 25 Industrialized Countries (Hunger Group 1)

Country	Dairy	F and V	Carbohydrates	Proteins	D Sur/Def	FV Sur/Def	C Sur/Def	P Sur/Def
Australia	612	542	403	428	362	-158	-47	228
Austria	647	628	457	388	397	-72	7	188
Belgium	651	523	626	337	401	-177	176	137
Canada	548	671	541	386	298	-29	91	186
Czech Republic	529	391	491	302	279	-309	41	102
Denmark	709	606	560	331	459	-94	110	131
Finland	1038	464	501	335	788	-236	51	135
France	678	586	506	397	428	-114	56	197
Germany	707	455	479	332	457	-245	29	132
Greece	803	940	539	343	553	240	89	143
Hungary	456	364	435	256	206	-336	-15	56
Italy	705	783	535	384	455	83	85	184
Japan	199	405	366	344	-51	-295	-84	144
Netherlands	933	544	509	330	683	-156	59	130
New Zealand	267	635	434	393	17	-65	-16	193
Norway	716	548	495	386	466	-152	45	186
Poland	522	457	723	278	272	-243	273	78
Portugal	566	836	527	461	316	136	77	261
South Korea	62	723	461	418	-188	23	11	218
Spain	492	620	427	458	242	-80	-23	258
Sweden	960	566	438	360	710	-134	-12	160
Switzerland	829	566	413	310	579	-134	-37	110
UAE	356	425	449	349	106	-275	-1	149
UK	661	592	587	318	411	-108	137	118
USA	688	604	448	449	438	-96	-2	249
Average	**613.4167**	**580.5**	**497.7917**	**360.2083**	**363.4167**	**-119.5**	**47.79167**	**160.2083**

Appendix 2b. 42 Upper Middle Countries (Hunger Group 2)

Country	Dairy	F and V	Carbohydrates	Proteins	D Sur/Def	FV Sur/Def	C Sur/Def	P Sur/Def
Algeria	364	615	770	103	114	-85	320	-97
Argentina	546	387	458	324	296	-313	8	124
Armenia	518	921	515	156	268	221	65	-44
Azerbaijan	378	631	826	115	128	-69	376	-85
Belarus	399	611	812	327	149	-89	362	127
Bosnia	492	766	696	130	242	66	246	-70
Brazil	392	498	484	340	142	-202	34	140
Bulgaria	370	312	533	201	120	-388	83	1
Chile	260	368	543	291	10	-332	93	91
Costa Rica	467	435	352	227	217	-265	-98	27
Croatia	577	510	453	259	327	-190	3	59
Cuba	250	739	624	217	0	39	174	17
Egypt	177	874	784	176	-73	174	334	-24
Estonia	671	499	652	265	421	-201	202	65
Fiji	115	216	665	235	-135	-484	215	35
Iran	166	986	641	196	-84	286	191	-4
Jamaica	251	474	484	273	1	-226	34	73
Jordan	214	491	530	189	-36	-209	80	-11
Kazakhstan	767	615	693	222	517	-85	243	22
Kuwait	364	578	497	379	114	-122	47	179
Kyrgzstan	551	495	740	130	301	-205	290	-70
Latvia	615	431	562	300	365	-269	112	100
Lebanon	254	775	535	229	4	75	85	29
Libya	305	801	612	181	55	101	162	-19
Lithuania	876	377	674	376	626	-323	224	176
Macedonia	418	829	519	174	168	129	69	-26
Mexico	292	421	474	285	42	-279	24	85
Montenegro	888	1118	539	284	638	418	89	84
Morocco	134	589	817	170	-116	-111	367	-30
Romania	642	676	752	219	392	-24	302	19
Russia	482	467	701	291	232	-233	251	91
Saudi Arabia	198	477	467	218	-52	-223	17	18
Serbia	404	510	486	195	154	-190	36	-5
Slovakia	398	428	481	229	148	-272	31	29
Syria	247	435	527	111	-3	-265	77	-89
Trinidad & Tobago	279	301	440	289	29	-399	-10	89
Tunisia	295	938	664	168	45	238	214	-32
Turkey	418	953	721	181	168	253	271	-19
Turkmenistan	388	582	657	190	138	-118	207	-10
Ukraine	415	508	744	224	165	-192	294	24
Uruguay	565	383	600	270	315	-317	150	70
Venezuela	431	339	509	291	181	-361	59	91
Average	**410.3095**	**579.9762**	**600.7857**	**229.2857**	**160.3095**	**-120.024**	**150.7857**	**29.28571**

Appendix 2c. 22 Lower Middle Countries (Hunger Group 3)

Country	Dairy	F and V	Carbohydrates	Proteins	D Sur/Def	FV Sur/Def	C Sur/Def	P Sur/Def
Albania	800	1030	520	179	550	330	70	-21
China	85	1103	595	332	-165	403	145	132
Colombia	299	424	454	190	49	-276	4	-10
Dominican Republic	166	722	322	232	-84	22	-128	32
Ecuador	531	558	320	195	281	-142	-130	-5
El Salvador	313	341	420	160	63	-359	-30	-40
Gabon	93	594	768	263	-157	-106	318	63
Georgia	376	253	643	114	126	-447	193	-86
Ghana	22	563	1361	113	-228	-137	911	-87
Guyana	321	317	485	222	71	-383	35	22
Honduras	279	352	381	144	29	-348	-69	-56
Malaysia	96	308	435	360	-154	-392	-15	160
Mauritius	327	358	550	247	77	-342	100	47
Moldova	403	397	596	175	153	-303	146	-25
Nicaragua	216	158	419	149	-34	-542	-31	-51
Panama	176	317	409	234	-74	-383	-41	34
Peru	164	467	684	160	-86	-233	234	-40
South Africa	151	216	583	203	-99	-484	133	3
Suriname	141	422	438	219	-109	-278	-12	19
Thailand	72	428	436	186	-178	-272	-14	-14
Uzbekistan	369	769	648	98	119	69	198	-102
Vietnam	39	424	502	266	-211	-276	52	66
Average	**247.2273**	**478.2273**	**544.0455**	**201.8636**	**-2.77273**	**-221.773**	**94.04545**	**1.863636**

Appendix 2d. 37 Upper Developing Countries (Hunger Group 4)

Country	Dairy	F and V	Carbohydrates	Proteins	D Sur/Def	FV Sur/Def	C Sur/Def	P Sur/Def
Angola	30	408	963	146	-220	-292	513	-54
Bangladesh	58	141	648	88	-192	-559	198	-112
Benin	24	223	1071	124	-226	-477	621	-76
Bolivia	110	284	558	233	-140	-416	108	33
Botswana	231	242	450	115	-19	-458	0	-85
Cambodia	7	167	569	158	-243	-533	119	-42
Cameroon	40	550	720	145	-210	-150	270	-55
Cote D'Ivoire	26	316	1139	120	-224	-384	689	-80
Djibouti	92	236	486	91	-158	-464	36	-109
Gambia	134	131	558	105	-116	-569	108	-95
Guatemala	130	359	386	163	-120	-341	-64	-37
Guinea	45	408	680	69	-205	-292	230	-131
Guinea-Bissau	48	199	588	58	-202	-501	138	-142
Indonesia	35	266	678	127	-215	-434	228	-73
Kenya	273	340	564	97	23	-360	114	-103
Laos	8	521	602	115	-242	-179	152	-85
Lesotho	53	105	772	91	-197	-595	322	-109
Liberia	7	197	676	53	-243	-503	226	-147
Malawi	13	236	930	83	-237	-464	480	-117
Mali	348	243	663	125	98	-457	213	-75
Mauritania	403	81	475	150	153	-619	25	-50
Mongolia	297	193	509	214	47	-507	59	14
Namibia	177	144	643	140	-73	-556	193	-60
Nepal	132	427	736	72	-118	-273	286	-128
Nigeria	22	353	1020	123	-228	-347	570	-77
North Korea	11	540	576	106	-239	-160	126	-94
Pakistan	479	168	433	71	229	-532	-17	-129
Paraguay	206	365	644	208	-44	-335	194	8
Philippines	40	498	538	210	-210	-202	88	10
Rwanda	53	595	898	109	-197	-105	448	-91
Senegal	85	214	509	129	-165	-486	59	-71
Sri Lanka	99	201	450	125	-151	-499	0	-75
Swaziland	119	285	519	95	-131	-415	69	-105
Tajikistan	145	111	515	47	-105	-589	65	-153
Togo	10	76	909	87	-240	-624	459	-113
Uganda	90	485	661	120	-160	-215	211	-80
Zimbabwe	88	89	474	83	-162	-611	24	-117
Average	**112.6486**	**281**	**654.3243**	**118.7838**	**-137.351**	**-419**	**204.3243**	**-81.2162**

Appendix 2e. 19 Lower Developing Countries (Hunger Group 5)

Country	Dairy	F and V	Carbohydrates	Proteins	D Sur/Def	FV Sur/Def	C Sur/Def	P Sur/Def
Burkina Faso	57	66	616	154	-193	-634	166	-46
Burundi	-	0	0	0	-250	-700	-450	-200
Central African Republic	47	182	890	253	-203	-518	440	53
Chad	61	45	578	107	-189	-655	128	-93
Comoros	-	0	0	0	-250	-700	-450	-200
Eritrea	-	0	0	0	-250	-700	-450	-200
Ethiopia	135	72	584	99	-115	-628	134	-101
Haiti	48	240	580	146	-202	-460	130	-54
India	220	354	498	86	-30	-346	48	-114
Madagascar	72	178	769	110	-178	-522	319	-90
Mozambique	12	116	996	107	-238	-584	546	-93
Niger	167	198	604	204	-83	-502	154	4
Republic of Congo	35	273	922	207	-215	-427	472	7
Sierra Leone	16	263	673	178	-234	-437	223	-22
Sudan	469	321	375	162	219	-379	-75	-38
Tanzania	104	292	676	121	-146	-408	226	-79
Timor-Leste	23	114	617	228	-227	-586	167	28
Yemen	89	231	483	139	-161	-469	33	-61
Zambia	23	95	624	111	-227	-605	174	-89
Average	**98.625**	**160**	**551.8421**	**126.9474**	**-151.375**	**-540**	**101.8421**	**-73.0526**

Appendix 3a. Average Supply from Protein Sources (grams/capita) Hunger Group 1

Country	Red Meat	Seafood	Poultry	Pulses	F & V
Australia	19.5	6	15.8	2.9	18.7
Austria	26.3	3.7	12.1	1.3	13.4
Belgium	15.2	6.3	10.9	2.4	13.3
Canada	17.7	5.8	16.6	7.5	24.1
Czech Republic	14.6	2.9	11.9	2.1	14
Denmark	17.1	9.2	14.4	1.7	16.1
Finland	17.3	10.3	9.9	1.1	11
France	19.2	9.5	13	1.8	14.8
Germany	19.4	4.5	11.2	1.7	12.9
Greece	14.3	5.3	8.9	4.5	13.4
Hungary	11.8	1.5	13.6	1.9	15.5
Italy	20.3	7.1	10.9	4.6	15.5
Japan	9	18.7	12.5	1.3	13.8
Netherlands	17.9	7.1	11.1	1.4	12.5
New Zealand	11.7	7.1	14.1	4.2	18.3
Norway	13	15.2	10.4	3.9	14.3
Poland	18.2	5.8	12.1	1.6	13.7
Portugal	18.5	15.3	15.3	2.5	17.8
South Korea	13	17.4	8.6	1.3	9.9
Spain	18.5	13.1	14.6	6.7	21.3
Sweden	21.2	8.5	10.6	2	12.6
Switzerland	16.5	4.4	9.9	2.8	12.7
UAE	2.6	5.8	14.4	16.1	30.5
UK	13.9	5.4	15.7	3.3	19
USA	20.8	5.2	22.4	3.4	25.8
Average	**16.3**	**8.044**	**12.836**	**3.36**	**16.196**

Appendix 3b. Average Supply from Protein Sources (grams/capita) **Hunger Group 2**

Country	Red Meat	Seafood	Poultry	Pulses	F & V
Argentina	29.4	1.8	14.3	0.4	14.7
Armenia	8.8	0.8	8.3	0.3	8.6
Azerbaijan	5.1	0.6	5.1	0.6	5.7
Belarus	19.1	4.8	13.1	0.4	13.5
Bosnia	5.8	1.7	5.3	3.9	9.2
Brazil	17.8	0.4	14.6	10.1	24.7
Bulgaria	9.3	2	10.3	1.8	12.1
Chile	14.7	4.5	13.7	3	16.7
Costa Rica	9.7	3.2	9.3	6.8	16.1
Croatia	13.7	5.4	5.8	1.2	7
Cuba	8.6	1.6	7.2	8.6	15.8
Egypt	5	6.4	5.1	6.3	11.4
Estonia	11.5	3.9	10.5	4	14.5
Iran	2.5	2.4	10.9	8.8	19.7
Jamaica	2.7	7.3	18.3	2.1	20.4
Jordan	2.4	1.8	14	5	19
Kazakhstan	14.1	1.5	6.9	0.2	7.1
Kuwait	3.9	4.2	29	4.2	33.2
Kyrgzstan	7.1	0.6	4.1	1.5	5.6
Latvia	12	8.6	11.7	0.6	12.3
Lebanon	8.4	2.7	9.4	6.9	16.3
Libya	2.4	3.8	9.9	2.8	12.7
Lithuania	15.1	16.4	11.8	3	14.8
Macedonia	6.1	1.7	8.8	5.1	13.9
Mexico	10.9	3.7	13.1	6.9	20
Montenegro	18.3	2.9	7	4.3	11.3
Morocco	2.5	4.2	8.4	5.3	13.7
Romania	10.9	1.7	10.8	1.4	12.2
Russia	12.5	7.6	12	1.3	13.3
Saudi Arabia	2.4	2.2	17.7	3.8	21.5
Serbia	12.4	1.5	5	5.9	10.9
Slovakia	10.7	2.3	9.6	1.3	10.9
Syria	1.4	0.9	4	5.8	9.8
Trinidad & Tobago	5.1	5.7	17.1	6.2	23.3
Tunisia	2.3	3.8	7.7	6.8	14.5
Turkey	4.3	2.2	8.4	8.7	17.1
Turkmenistan	10.8	1	3.7	0.1	3.8
Ukraine	8.5	3.7	12.8	1.2	14
Uruguay	15.8	1.7	9.3	2	11.3
Venezuela	7.7	3.2	17.5	4.7	22.2
Average	**9.112195**	**3.356098**	**10.38049**	**3.853659**	**14.23415**

Appendix 3c. Average Supply from Protein Sources (grams/capita) **Hunger Group 3**

Country	Red Meat	Seafood	Poultry	Pulses	F & V
Albania	8.2	1.8	7.2	3.5	10.7
China	12.7	8.6	10	1.1	11.1
Colombia	7.5	1.7	10.3	4.2	14.5
Dominican Republic	7.2	2.6	12.6	5.2	17.8
Ecuador	10.1	2.2	9	1.6	10.6
El Salvador	4.7	1.9	7.6	8.3	15.9
Gabon	4.3	8.6	11.3	0.1	11.4
Georgia	4.5	2.3	5.5	0.4	5.9
Ghana	0.8	7.7	2.2	0.8	3
Guyana	1.6	8.6	10.9	4.2	15.1
Honduras	5	0.8	8.2	5.5	13.7
Malaysia	4.8	17.1	17.1	2	19.1
Mauritius	3.5	6.8	14.5	6.6	21.1
Moldova	6.4	4	8.5	1.4	9.9
Nicaragua	2.9	1.5	6.8	11.5	18.3
Panama	10.6	4.9	10	3.8	13.8
Peru	3.8	5.7	7.6	5.2	12.8
South Africa	7.7	1.7	15.2	1.9	17.1
Suriname	6.5	4.8	12.3	1.3	13.6
Thailand	5.1	7.7	7.7	1.9	9.6
Uzbekistan	9.9	0.1	1.8	0.3	2.1
Vietnam	12.2	8.8	4.9	2.3	7.2
Average	**6.363636**	**4.995455**	**9.145455**	**3.322727**	**12.46818**

Appendix 3d. Average Supply from Protein Sources (grams/capita) **Hunger Group 4**

Country	Red Meat	Seafood	Poultry	Pulses	F & V
Angola	4.6	3.8	4.9	5.1	10
Bangladesh	0.5	5.4	0.8	3.9	4.7
Benin	1.4	3.6	3.3	7.3	10.6
Bolivia	9.3	0.6	13.4	2.8	16.2
Botswana	3.1	1	2.4	2.9	5.3
Cambodia	4.5	11.5	1	2.8	3.8
Cameroon	2.6	4.6	1.2	12.7	13.9
Cote D'Ivoire	1.2	6.2	1	2.7	3.7
Djibouti	3.4	0.6	0.7	9.1	9.8
Gambia	1.2	8.6	1.5	0.6	2.1
Guatemala	3.8	0.4	8.9	9.2	18.1
Guinea	2.2	2.9	1	2.8	3.8
Guinea-Bissau	4.3	0.3	0.8	2.3	3.1
Indonesia	1.8	9	3.7	0.9	4.6
Kenya	4.6	1	0.7	7.9	8.6
Laos	5.3	5.1	1.8	1.7	3.5
Lesotho	2.9	0.2	1.8	6.6	8.4
Liberia	1.1	0.7	2.4	1.3	3.7
Malawi	1.5	1.5	0.8	9.5	10.3
Mali	4.4	2.2	1.2	6.9	8.1
Mauritania	2.9	3.1	1.4	8.3	9.7
Mongolia	6.4	0.2	1	0.8	1.8
Namibia	4.8	3.9	2.7	4.7	7.4
Nepal	2.8	0.6	0.5	5.2	5.7
Nigeria	1.3	3.9	1.6	7.7	9.3
North Korea	1.7	2.5	1.9	6.6	8.5
Pakistan	2.9	0.6	2.2	3.5	5.7
Paraguay	14.4	0.4	7	5.6	12.6
Philippines	7.2	10.4	5	1.1	6.1
Rwanda	1.5	0.6	0.2	18.5	18.7
Senegal	2.4	7.3	1.7	3.3	5
Sri Lanka	0.7	9.2	2.5	5.3	7.8
Swaziland	7.3	0.5	2.5	2.3	4.8
Tajikistan	1.9	0.1	1.6	0.8	2.4
Togo	1.1	2	2.3	6.9	9.2
Uganda	3.1	4	0.9	9.8	10.7
Zimbabwe	3.8	0.7	2.7	3.4	6.1
Average	**3.510811**	**3.221622**	**2.459459**	**5.210811**	**7.67027**

Appendix 3e. Average Supply from Protein Sources (grams/capita) **Hunger Group 5**

Country	**Red Meat**	**Seafood**	**Poultry**	**Pulses**	**F & V**
Burkina Faso	3.8	1.7	1.6	8.9	10.5
Central African Republic	9.2	2.8	0.7	5.1	5.8
Chad	3.4	1.7	0.3	4.5	4.8
Ethiopia	1.9	0.1	0.3	11.5	11.8
Haiti	3.1	1.1	2	9.9	11.9
India	0.6	1.7	1.3	7.7	9
Madagascar	3.9	1.7	1.4	2.5	3.9
Mozambique	1.6	2.1	0.9	7.2	8.1
Niger	3.4	0.6	0.5	21.6	22.1
Republic of Congo	1.3	6.1	4.2	1.8	6
Sierra Leone	0.8	10.1	1.6	6.8	8.4
Sudan	3.3	0.5	0.5	5.7	6.2
Tanzania	2.3	2.3	0.6	11.8	12.4
Timor-Leste	3.4	1.1	2.2	4.7	6.9
Yemen	1.9	0.9	4.5	4.1	8.6
Zambia	2.9	2	2	1	3
Average	**2.925**	**2.28125**	**1.5375**	**7.175**	**8.7125**

Appendix 4. Indian States and Their Food Potential (see Fig. 6.1)

Sources: Indiastat 2011a; Indiastat 2011b; Indiastat 2012a; Indiastat 2011c; Indiastat 2012b; Indiastat 2013a.

Calculations: Author

State	Economic	Nature	Nutrition	Development	Governance	Total
Delhi	1	1	0.8092869	1	0.7702738	4.579561
Kerala	0.454545	0.999743	0.880597	0.254464	0.9553329	3.544682
Goa	0.5	1	0.8723051	0.138357	0.8863372	3.396999
Mizoram	0.337662	0.987133	1	0.017307	0.9183018	3.260405
Punjab	0.441948	0.948791	0.9104478	0.078026	0.7052275	3.084439
Karnataka	0.349351	0.999743	0.6766169	0.06783	0.9388425	3.032382
Manipur	0.009091	1	0.9635158	0.03702	1	3.009627
Jammu and Kashmir	0.194805	0.965517	0.8706468	0	0.9651898	2.996159
Maharashtra	0.25974	1	0.6998342	0.06103	0.9741975	2.994802
Rajasthan	0.357143	1	0.628524	0.029375	0.9754059	2.990448
Nagaland	0	1	0.8656716	0.097542	0.9987079	2.961922
Assam	0.12987	0.850232	0.6882255	0.149026	0.9793656	2.796719
Andhra Pradesh	0.207792	0.804941	0.7529022	0.037438	0.9631939	2.766267
Tamil Nadu	0.12987	0.868502	0.8076285	0.068318	0.8689534	2.743272
Meghalaya	0.12987	1	0.5903814	0.02078	0.9555018	2.696533
Gujarat	0.12987	0.986104	0.5721393	0.03399	0.9384853	2.660589
Madhya Pradesh	0.220779	1	0.358209	0.026104	0.9805589	2.585651
Chhattisgarh	0.12987	1	0.4941957	0.028872	0.8152789	2.468217
Haryana	0.566429	0.909676	0.6633499	0.041388	0.223797	2.404639
Odisha	0.064935	0.682964	0.628524	0.077548	0.8385179	2.292489
West Bengal	0.262987	0.265054	0.6368159	0.163555	0.8844824	2.212894
Uttar Pradesh	0.12987	0.890633	0.5737977	0.075409	0.4900257	2.159735
Tripura	0.12987	1	0.7114428	0.155976	0.154916	2.152205
Uttarakhand	0.218701	0.164951	0.7280265	0.040261	0.9324219	2.084362
Arunachal Pradesh	0.354675	0	0.7462687	0.006844	0.9312342	2.039023
Jharkhand	0.201299	0.555327	0.3764511	0.008983	0.8729364	2.014996
Himachal Pradesh	0.194805	0.918682	0.7578773	0.037246	1.73E-07	1.908611
Bihar	0.220779	0.247298	0.3897181	0.063713	0.7005179	1.622026

Appendix 5. Consumption Gap of Pulses to Cereals (see Table 6.1)

Sources: Indiastat 2012c; Indiastat 2012d.

Calculations: Author

State	Rural Cereals Kg	Rural Pulses Kg	Urban Cereals Kg	Urban Pulses Kg	Average Gap Kg
Delhi	7.8	0.79	7.97	0.68	7.15
Gujarat	8.72	0.66	7.89	0.71	7.62
Kerala	8.5	0.48	8.24	0.54	7.86
Tamil Nadu	9.51	0.83	8.48	0.89	8.135
Goa	8.81	0.45	8.55	0.56	8.175
Punjab	9.28	0.53	8.47	0.57	8.325
Maharashtra	9.88	0.79	8.38	0.81	8.33
Haryana	9.43	0.49	8.5	0.59	8.425
Karnataka	9.76	0.68	8.78	0.79	8.535
Meghalaya	10.29	0.28	9.97	0.47	9.755
Uttar Pradesh	11.45	0.75	9.76	0.72	9.87
Madhya Pradesh	11.51	0.72	10.19	0.78	10.1
Andhra Pradesh	11.77	0.79	10.29	0.85	10.21
Himachal Pradesh	11.89	0.7	10.11	0.8	10.25
West Bengal	11.97	0.39	9.44	0.5	10.26
Rajasthan	11.84	0.42	10.08	0.44	10.53
Jharkhand	11.92	0.44	10.66	0.64	10.75
Uttarakhand	12.19	0.65	10.85	0.66	10.865
Bihar	12.13	0.59	11.31	0.68	11.085
Chhattisgarh	12.35	0.5	11.2	0.76	11.145
Assam	12.7	0.58	10.92	0.71	11.165
Odisha	13.42	0.52	11.38	0.65	11.815
Jammu and Kashmir	12.71	0.38	11.74	0.38	11.845
Arunachal Pradesh	12.59	0.34	12.36	0.53	12.04
Mizoram	13.05	0.38	12.06	0.53	12.1
Tripura	13.65	0.35	12.55	0.52	12.665
Nagaland	13.34	0.22	12.89	0.28	12.865
Manipur	14.15	0.27	13.28	0.26	13.45

Appendix 6. Cost Estimates: Cultivation/Production and Yield of Masoor

English Name: Red Lentil. Latin: *Lens culinaris*
Source: Indiastat 2012e
Calculations: Author

APE: Absolute Production Efficiency
RPE: Relative Production Efficiency

State	Cost of Cultivation (Rs/Hectare)	Yield (Qtl/Hectare)	Result	Efficiency
Bihar	18467.14	8.15	0.000441	
Madhya Pradesh	19536.46	8.82	0.000451	APE; RPE
Uttar Pradesh	23152.94	8.99	0.000388	
West Bengal	23893.45	7.7	0.000322	RPE

Appendix 7. Cost Estimates: Cultivation/Production and Yield of Gram

English Name: Brown/White Chickpea. Latin: *Cicer arientinum*
Source: Indiastat 2012f
Calculations: Author

APE: Absolute Production Efficiency
RPE: Relative Production Efficiency

State	Cost of Cultivation (Rs/Hectare)	Yield (Qtl/Hectare)	Result	Efficiency
Andhra Pradesh	28608.56	7.44	0.00026	
Bihar	19622.81	8.72	0.000444	APE; RPE
Chhattisgarh	21487.06	9.23	0.00043	
Haryana	20674.15	5.65	0.000273	RPE
Karnataka	21794.57	7.95	0.000365	RPE
Madhya Pradesh	29948.11	11.83	0.000395	
Maharashtra	31554.14	10.7	0.000339	RPE
Rajasthan	22226.27	8	0.00036	RPE
Uttar Pradesh	30746.91	12.09	0.000393	

Appendix 8. Cost Estimates: Cultivation/Production and Yield of Moong

English Name: Green Chickpea. Latin: *Vigna vadiata*
Source: Indiastat 2012g
Calculations: Author

APE: Absolute Production Efficiency
RPE: Relative Production Efficiency

State	Cost of Cultivation (Rs/Hectare)	Yield (Qtl/Hectare)	Result	Efficiency
Andhra Pradesh	20669.97	7.22	0.000349	APE
Karnataka	14007.79	3.3	0.000236	
Maharashtra	26008.25	5.05	0.000194	
Odisha	13352.63	3.2	0.00024	
Rajasthan	17243.8	4.41	0.000256	
Tamil Nadu	16464.64	4.58	0.000278	RPE

Appendix 9. Cost Estimates: Cultivation/Production and Yield of Urad

English Name: Black Chickpea. Latin: *Vigna mungo*
Source: Indiastat 2012h
Calculations: Author

APE: Absolute Production Efficiency
RPE: Relative Production Efficiency

State	Cost of Cultivation (Rs/Hectare)	Yield (Qtl/Hectare)	Result	Efficiency
Andhra Pradesh	33307.67	12.03	0.000361	RPE
Chhattisgarh	15390.73	8.79	0.000571	APE; RPE
Madhya Pradesh	18349.33	7.78	0.000424	
Maharashtra	28116.51	4.55	0.000162	
Odisha	12802.24	3.35	0.000262	
Rajasthan	18608.08	4.84	0.00026	
Tamil Nadu	21682.35	5.85	0.00027	
Uttar Pradesh	15945.79	3.21	0.000201	

Appendix 10. Cost Estimates: Cultivation/Production and Yield of Tur

English Name: Pigeon Pea. Latin: *Cajanus cajan*
Source: Indiastat 2012i
Calculations: Author

APE: Absolute Production Efficiency
RPE: Relative Production Efficiency

State	Cost of Cultivation (Rs/Hectare)	Yield (Qtl/Hectare)	Result	Efficiency
Andhra Pradesh	30976.04	8.85	0.000286	
Bihar	15898.85	-	-	
Gujarat	22927.11	8.69	0.000379	RPE
Madhya Pradesh	20133.3	7.25	0.00036	
Karnataka	19420	7.07	0.000364	
Maharashtra	40308.28	10.05	0.000249	
Odisha	12717.51	4.59	0.000361	RPE
Tamil Nadu	17586.49	-	-	
Uttar Pradesh	23644.63	10.09	0.000427	APE; RPE

Appendix 11. State-wide Cold Storage Capacity per 000 mega tons

Source: Indiastat 2012j
Calculations: Author

State	Requirement	Capacity	Gap	%
Punjab	1318	1345	-27	1.020486
Uttar Pradesh and Uttarakhand	12228	10187	2041	0.833088
Rajasthan	391	324	67	0.828645
Madhya Pradesh	1213	808	405	0.666117
Chhattisgarh	543	342	201	0.629834
West Bengal	10566	5682	4884	0.537763
Haryana	804	393	411	0.488806
Gujarat	2748	1267	1481	0.461063
Andhra Pradesh	2324	901	1423	0.387694
Bihar	4241	1147	3094	0.270455
Jharkhand	796	170	626	0.213568
Tripura	163	30	133	0.184049
Karnataka	2404	407	1997	0.169301
Odisha	1835	291	1544	0.158583
Assam	919	88	831	0.095756
Maharashtra	6273	547	5726	0.087199
Nagaland	70	6	64	0.085714
Jammu and Kashmir	737	43	694	0.058345
Himachal Pradesh	487	20	467	0.041068
Tamil Nadu	7906	239	7667	0.03023
Kerala	2771	58	2713	0.020931
Meghalaya	239	3	236	0.012552
Mizoram	74	0	74	0
Manipur	80	0	80	0

Appendix 12. Number of Cellular Phones by State/Per Capita

Sources: Indiastat 2014; Indiastat 2011d
Calculations: Author

State	Total March 2014	2011 Census	Per Capita
Delhi	31044206	16753235	1.853028
Kerala	26276204	33387677	0.787003
Maharashtra + Mumbai+ Goa	80889667	112372972	0.719832
Tamil Nadu + Chennai	62514727	72138958	0.866588
Karnataka	40375079	61130704	0.660471
Gujarat	45148392	60383628	0.747693
Himachal Pradesh	5876710	6856509	0.857099
Andhra Pradesh + Telangana	54369126	84665533	0.642164
Punjab	23546311	27704236	0.849917
North East	8623095	13811022	0.624363
Jammu + Kashmir	6968481	12548926	0.555305
Haryana	16222670	25353081	0.63987
W Bengal + Sikkim, Kolkata + Isle	49093633	91347736	0.537437
Rajasthan	42352059	68621012	0.617188
Odisha	20452619	41947358	0.487578
M Pradesh + Chhattisgarh	39547870	98137761	0.402983
Assam	12868055	31169272	0.412844
U Pradesh + Uttarakhand	103431729	209698229	0.493241
Bihar + Jharkhand	52328622	136770875	0.382601

Appendix 13. Number of Internet Subscribers

Sources: Indiastat 2015; Indiastat 2011d
Calculations: Author

State	Total March 2014	2011 Census	Per Capita
Delhi	6432349	16753235	0.383947
Kerala	3548961	33387677	0.106296
Maharashtra + Mumbai+ Goa	10462914	112372972	0.093109
Tamil Nadu + Chennai	6507367	72138958	0.090206
Karnataka	4878419	61130704	0.079803
Gujarat	4133311	60383628	0.068451
Himachal Pradesh	421241	6856509	0.061437
Andhra Pradesh + Telangana	4807959	84665533	0.056788
Punjab	1546153	27704236	0.055809
North East	659805	13811022	0.047774
Jammu + Kashmir	530713	12548926	0.042292
Haryana	1047774	25353081	0.041327
W Bengal + Sikkim, Kolkata + Isle	3383868	91347736	0.037044
Rajasthan	2275035	68621012	0.033154
Odisha	1208316	41947358	0.028806
M Pradesh + Chhattisgarh	2662430	98137761	0.02713
Assam	620318	31169272	0.019902
U Pradesh + Uttarakhand	3652710	209698229	0.017419
Bihar + Jharkhand	2094791	136770875	0.015316

Appendix 14: India State Connectivity

Calculations: Author

State	Total
Delhi	2.236974
Tamil Nadu+ Chennai	0.956794
Himachal Pradesh	0.918536
Punjab	0.905727
Kerala	0.893299
Gujarat	0.816143
Maharashtra + Mumbai+ Goa	0.802530
Karnataka	0.740274
Andhra Pradesh + Telangana	0.698951
Haryana	0.681197
North East	0.672137
Rajasthan	0.650342
Jammu + Kashmir	0.597596
W Bengal + Sikkim, Kolkata + Isle	0.574481
Odisha	0.516384
U Pradesh + Uttarakhand	0.51066
Assam	0.432746
M Pradesh + Chhattisgarh	0.430113
Bihar + Jharkhand	0.397917

Appendix 15. Nutritional HDI Score for 27 Districts in Karnataka

District	Income	Health	Education	Income Formula	Health Formula	Education Formula	Total	Cubed Root
Belgaum	1571.65	53.6	69.28	0.243603	0.540782	0.620741	0.081774	0.434049
Bagalkot	1564.003	30.5	64.2	0.242386	0.282682	0.558025	0.038235	0.336889
Bijapur	1844.72	36.3	62.81	0.287066	0.347486	0.540864	0.053952	0.377864
Gulbarga	1360.147	45.1	58.09	0.20994	0.44581	0.482593	0.045167	0.35613
Bidar	1554.031	31.7	66.73	0.240799	0.296089	0.589259	0.042013	0.347639
Raichur	1638.774	38.5	54.11	0.254287	0.372067	0.433457	0.04101	0.34485
Koppal	1494.75	46.8	66.05	0.231364	0.464804	0.580864	0.062465	0.396777
Gadag	1832.974	48.9	71.86	0.285196	0.488268	0.652593	0.090875	0.449588
Dharwad	1445.047	26.4	70.09	0.223453	0.236872	0.630741	0.033385	0.321996
Uttara Kannada	2364.727	50	81.31	0.369832	0.500559	0.769259	0.142407	0.522208
Haveri	2000.371	32.1	75.69	0.31184	0.300559	0.699877	0.065597	0.403299
Bellary	2097.018	32.1	61.81	0.327222	0.300559	0.528519	0.05198	0.373202
Chitradurga	1719.733	47	70.68	0.267173	0.467039	0.638025	0.079613	0.430191
Davanagere	1561.481	34.4	71.77	0.241985	0.326257	0.651481	0.051434	0.371892
Shimoga	1799.116	36.8	76.37	0.279807	0.353073	0.708272	0.069972	0.412073
Udupi	2574.22	15	83.91	0.403175	0.109497	0.801358	0.035377	0.328277
Chikmagalur	2106.556	23.7	76.95	0.32874	0.206704	0.715432	0.048615	0.36497
Tumkur	1724.779	26.6	71.66	0.267976	0.239106	0.650123	0.041656	0.346652
Kolar	2278.92	18.9	69.08	0.356174	0.153073	0.618272	0.033708	0.323033
Bangalore Urban	2936.96	5.3	78.21	0.46091	0.001117	0.730988	0.000376	0.072205
Bangalore Rural	2201.429	11.1	75.16	0.343841	0.065922	0.693333	0.015715	0.250482
Mandya	1916.85	14.3	67.78	0.298546	0.101676	0.602222	0.01828	0.263428
Hassan	1803.412	24.1	72.79	0.280491	0.211173	0.664074	0.039335	0.340088
Dakshina Kannada	2491.408	17	85.33	0.389994	0.131844	0.818889	0.042106	0.347894
Kodagu	2521.797	37.5	81.09	0.394831	0.360894	0.766543	0.109226	0.478016
Mysore	1519.779	36.2	63.29	0.235347	0.346369	0.54679	0.044573	0.35456
Chamarajnagar	1680.594	26.7	57.95	0.260943	0.240223	0.480864	0.030143	0.311215

Appendix 16. Pulse and Cereal Consumption for 27 Districts in Karnataka

Pulse Consumption					Cereal Consumption			
District	**Rs**	**Formula**	**Deficit**	**Proportional Deficit**	**Rs**	**Formula**	**Deficit**	**Proportional Deficit**
Belgaum	33.72	19.25412	-15.7459	-0.3582	102.7	254.4906	-145.509	-0.36377
Bagalkot	29.35	16.75885	-18.2412	-0.44137	97.95	242.7201	-157.28	-0.3932
Bijapur	37.86	21.61806	-13.3819	-0.2794	119.88	297.0626	-102.937	-0.25734
Gulbarga	36.06	20.59026	-14.4097	-0.31366	104.02	257.7616	-142.238	-0.3556
Bidar	48.27	27.56217	-7.43783	-0.08126	98.85	244.9503	-155.05	-0.38762
Raichur	32.99	18.83729	-16.1627	-0.37209	133.14	329.9209	-70.0791	-0.1752
Koppal	35.95	20.52745	-14.4726	-0.31575	110.48	273.7694	-126.231	-0.31558
Gadag	51.95	29.66345	-5.33655	-0.01122	138.05	342.0879	-57.9121	-0.14478
Dharwad	35.06	20.01926	-14.9807	-0.33269	110.7	274.3146	-125.685	-0.31421
Uttara Kannada	62.19	35.51049	0.51049	0.183683	147.22	364.8112	-35.1888	-0.08797
Haveri	51.6	29.4636	-5.5364	-0.01788	161.27	399.6271	-0.37294	-0.00093
Bellary	40.42	23.07982	-11.9202	-0.23067	225.7	559.2846	159.2846	0.398212
Chitradurga	34.12	19.48252	-15.5175	-0.35058	138.92	344.2438	-55.7562	-0.13939
Davanagere	39.71	22.67441	-12.3256	-0.24419	126.38	313.1696	-86.8304	-0.21708
Shimoga	43.36	24.75856	-10.2414	-0.17471	127.43	315.7715	-84.2285	-0.21057
Udupi	29.27	16.71317	-18.2868	-0.44289	161.27	399.6271	-0.37294	-0.00093
Chikmagalur	43.18	24.65578	-10.3442	-0.17814	134.88	334.2326	-65.7674	-0.16442
Tumkur	45.22	25.82062	-9.17938	-0.13931	112.65	279.1467	-120.853	-0.30213
Kolar	49.09	28.03039	-6.96961	-0.06565	158.26	392.1683	-7.83172	-0.01958
Bangalore Urban	55.03	31.42213	-3.57787	0.047404	170.49	422.4742	22.47422	0.056186
Bangalore Rural	48.73	27.82483	-7.17517	-0.07251	143.92	356.6338	-43.3662	-0.10842
Mandya	46.92	26.79132	-8.20868	-0.10696	123.68	306.479	-93.521	-0.2338
Hassan	40.19	22.94849	-12.0515	-0.23505	97.5	241.605	-158.395	-0.39599
Dakshina Kannada	26.21	14.96591	-20.0341	-0.50114	188.77	467.7721	67.77206	0.16943
Kodagu	36.33	20.74443	-14.2556	-0.30852	145.84	361.3915	-38.6085	-0.09652
Mysore	33.21	18.96291	-16.0371	-0.3679	100.2	248.2956	-151.704	-0.37926
Chamarajnagar	43.34	24.74714	-10.2529	-0.1751	156.58	388.0052	-11.9948	-0.02999