Applying health impact assessment to watershed development projects in semi-arid areas in India: identifying prospects for health-sensitive food systems

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“Tell me,” went on Gafur, “how can I keep you alive in this dreadful year? If I let you loose, you will start eating other people’s paddy or munching their banana leaves. What can I do with you? You have no strength left in your body – nobody wants you.”

The Drought and Other Short Stories, by Sarat Chandra Chatterjee

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Summary

Background

Undernutrition and dietary risks are amongst the top risk factors for morbidity and mortality globally. Consequently, food systems can be considered a major determinant of population health. Action towards improving nutrition and inter-sectoral coordination for health have been strongly emphasised in contemporary developmental discourse. These approaches are especially relevant to India, where health is currently characterised by a “double burden of malnutrition”, with prevalent child undernutrition, maternal anaemia, obesity and cardiovascular diseases.

Majority of India’s population is dependent on agriculture for food and livelihood. A large proportion of these households sustain themselves on wage labour. In most regions, farmers are reliant on rainfall for cultivation, and some of them, based on their ability to afford it, have turned to exploiting groundwater. Climatic models have predicted poorer rainfall and reduced crop yields in India. In this context, watershed development (WSD) projects have been supported by the government and philanthropic institutions. These projects enhance soil and water conservation, enrich the local environment and foster livelihood activities, with the aim of improving agricultural productivity, food security, access to water and income. Livestock rearing has also been promoted through WSD projects for improving livelihood security among poor households. However, few studies have been conducted to understand the types and distribution of health impacts due to WSD projects. In addition, the potential of WSD projects to improve rural health, especially nutrition, was indicated by experts, but no efforts have been made to systematically incorporate health considerations as part of WSD project-planning.

Health impact assessment (HIA) has been used to incorporate health concerns in development planning in several countries. While impact assessments are conducted in India under the broader umbrella of environmental impact assessment (EIA), the practice of HIA is negligible due to the: (i) poor focus on health assessment as part of environmental impact assessment; (ii) narrow scope of projects covered under the EIA regulation, e.g., large mining projects, thermal power plants and chemical industries; and (iii) low accountability for the quality of impact assessments, and for implementing recommendations in assessment reports. The author did not find even one published case study of a comprehensive HIA from India, and none on WSD projects from anywhere worldwide. In addition, the national health policy has strongly encouraged a “Health in All” approach for addressing cross-sectoral concerns such as nutrition and sanitation. However, it is unclear to what extent this paradigm has been operationalised in policy documents addressing food systems in India.

Objectives

The overall aim was to deepen the understanding on how health has been considered as part of food systems decision-making, and develop a case study on how health can be systematically incorporated in the planning process of a food systems-related project. The specific objectives were to, at the policy-level, (i) examine how health has been addressed in food systems policy documents in India; and then, at project-level, (ii) study the perceived health impacts of WSD projects; (iii) conduct an HIA of a proposed WSD project; (iv) describe the baseline health conditions in the WSD project area; (v) study the association of livestock ownership with household dietary quality in a WSD project area.

Methods

A qualitative study design was used to examine food systems policy documents (n = 29) and relevant health policy documents (n = 6), and the data were analysed through thematic and content analysis to identify which health concerns have been addressed in policy, and mechanisms instituted in policies to incorporate health concerns.

The field-based studies were located in Kolar district, southern India. A qualitative study with data collection through semi-structured interviews (n = 40), focus group discussions (n = 2) and transect walks (n = 4) was undertaken to document perceptions of local people, project staff and key informants about the health impacts of completed WSD projects. The data were collected from across four WSD projects in various sub-districts of Kolar, and analysed thematically.

The HIA was conducted for a WSD project that was planned for a cluster of four neighbouring villages, using methods validated by Winkler and colleagues for projects in tropical settings, e.g., a biofuels plantation project. The health concerns included in the HIA were informed by our earlier qualitative study and the wider literature. Due to gaps in secondary data for relevant health concerns, primary data were also collected from these four villages through a household survey (n = 195 households) and an anthropometric survey (n = 83 children under the age of 5 years). All available households and children from these villages were included in the surveys. Comparison villages (n = 138 households from 2 villages for household survey; and n = 77 children from 4 villages for anthropometric survey) were also part of the baseline surveys to help with the eventual impact evaluation. The data collected from the project and comparison villages on key health concerns were described using proportions and means. The data were also used to study the association of dairy animal ownership on household dietary quality using a multivariable logistic regression model.

Results

At national policy level, undernutrition received relatively high attention, being explicitly mentioned in many food-related policies across sectors (agricultural, environmental, health, industrial and social). Non-communicable diseases were only addressed in health policies, and were largely missing in food policies. Agricultural injuries and mental health concerns of farmers received limited consideration. Several advisory and executive groups instituted for food systems governance by the analysed policies were found to include representation from the health ministry (nine of the 17 identified inter-ministerial groups), but the effect of this representation on health consideration in decision-making would require further research. Overall, the data revealed that health was not systematically considered in food policy-related decision-making.

At the local project level, the main health impacts of WSD projects were perceived to be on household nutrition (through food security, livestock ownership and income pathways; but also resulting in higher pesticide exposure due to expanded agriculture), potential for mosquito larval breeding (increase in surface water bodies such as farm ponds and troughs) and impacts resulting from opportunistic activities (e.g., improved water access leading to reduced mental stress). Perceived impacts varied between sub-groups of the local population (e.g., greater agricultural benefits for farmers with larger holdings; increased income through dairy for poor woman-headed households).

The HIA on the planned WSD project found several opportunities for risk mitigation (e.g., larval control in water bodies to reduce vector-borne diseases, and fencing of farm ponds to prevent drowning) and health promotion (e.g., improving nutrition through provision of fruit tree saplings and awareness). The baseline survey data revealed that the local health concerns included nutritional status among children under the age of 5 years (undernutrition prevalence of 23.8%), vector-borne disease (over one in ten households reported occurrence of malaria, chikungunya and dengue during the previous year), food insecurity (experienced by over one in five households during the past 2 years) and access to potable water (almost three in five households consumed unpurified groundwater which is high in fluoride content). It was also demonstrated that, at project baseline, household ownership of dairy animals (43.1% at project baseline) was associated with household milk consumption (adjusted odds ratio (OR) 2.1, 95% confidence interval (CI) 0.9, 5.5). Households owning dairy animals were found to be richer (land ownership, access to irrigation, ownership of motorised vehicle), larger, male-headed and belonging to dominant castes. This indicated the need for context-specific understanding and reflection on livelihood support initiatives, and their potential to improve income and health in the household.

Conclusions

Through the case study of WSD projects, we demonstrated approaches to further understand health impacts of food systems interventions, conduct comprehensive HIAs of food production projects in semi-arid rural areas, and utilise data from baseline surveys conducted for HIAs to answer empirical research questions on linkages between agriculture and nutrition. We also showed the cross-cutting concern regarding undernutrition from local project level to national policy level. Food systems projects and policies were demonstrated to be relevant to several health concerns. Gaps were identified in health considerations of food systems policies and projects, and the utility of HIA to identify potential health impacts and facilitate risk mitigation and health promotion was exhibited.

We discussed approaches to increase adoption of HIA in India by using non-controversial projects such as WSD projects to build local capacity, experience and interest. The important role of partnership with experienced non-governmental organisations, the key actors of WSD and other rural development projects, was highlighted. The potential role of academic institutions in evidence generation, capacity building and knowledge translation was also emphasised. This PhD thesis can be considered a contribution towards the operationalisation of the “Health in All” approach, mentioned in the National Health Policy of 2017, for developmental policies and projects in India.

List of abbreviations

10YFP:	10-Year Framework of Programmes
ADWDRS:	Agricultural Debt Waiver and Debt Relief Scheme
AF:	Andrea Farnham
AM:	Arima Mishra
ANH:	Agriculture, Nutrition and Health Academy
ANM:	auxiliary nurse midwife
AP:	Adithya Pradyumna
ARMPD:	Annual Report of Ministry of Public Distribution 2017
AYUSH:	Indian Systems of Medicine
BDA:	Biological Diversity Act 2002
BMI:	body mass index
CI:	confidence interval
COREQ:	consolidated criteria for reporting of qualitative research
CSR:	corporate social responsibility
CVD:	cardiovascular disease
EHA:	environmental health area
EIA:	environmental impact assessment
EKNZ:	Ethics Commission of Northwest and Central Switzerland
ESCB:	Economic Survey 2017-18
ESKAS:	Swiss Government Excellence Scholarships
FDIP:	Foreign Direct Investment Policy 2017
FGD:	focus group discussion
FP:	Fertilizer Policy 2015
FSSA:	Food Safety and Standards Act 2006
FTP:	Foreign Trade Policy 2015-2020
GC:	other caste
HIA:	health impact assessment

HiAP:	Health in All Policies
IAIA:	International Association for Impact Assessment
ICDS:	Integrated Child Development Services
IFC:	International Financial Corporation
INR:	Indian Rupees
JU:	Jürg Utzinger
LMICs:	low- and middle-income countries
MEFSB:	Macroeconomic Framework Statement for Budget 2018
MIDH:	Mission for Integrated Development of Horticulture
MNREGS:	Mahatma Gandhi National Rural Employment Guarantee Scheme
MoHFW:	Ministry of Health and Family Welfare
MS:	Microsoft
MSW:	Mirko S. Winkler
MUAC:	mid-upper arm circumference
NAPCCHH:	National Action Plan for Climate Change and Human Health
NCDs:	non-communicable diseases
NFHS:	National Family Health Survey
NFS:	Nutri-Farms Scheme
NFSA:	National Food Security Act 2013
NFSM:	National Food Security Mission
NGO:	non-governmental organisation
NHP:	National Health Policy 2017
NLM:	National Livestock Mission
NMAET:	National Mission on Agricultural Extension and Technology
NMFP:	National Mission on Food Processing
NMOOP:	National Mission on Oilseed and Oil Palm
NMSA:	National Mission on Sustainable Agriculture
NNM:	nearest neighbour matching
NNS:	National Nutrition Strategy 2017

NPC:	National Policy for Children 2013
NPCDCS:	National Programme for the Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke
NPF:	National Policy for Farmers 2007
NPMCR:	National Policy for Management of Crop Residues
ODK:	Open Data Kit
OR:	odds ratio
PDS:	Public Distribution System
PMB:	Draft Pesticide Management Bill 2017
PPVFRA:	Protection of Plant Varieties and Farmers Rights Act 2001
PSM:	propensity score matching
PSSG:	Price Support Scheme Guidelines
QQ:	quantile-quantile
RKVY:	*Rashtriya Krishi Vikas Yojna*
SC:	scheduled caste
SD:	standard deviation
SDG:	Sustainable Development Goal
SES:	socioeconomic status
SHG:	self-help group
ST:	scheduled tribe
SWM:	Solid Waste Management Rules 2016
UN:	United Nations
VBD:	vector-borne disease
VIUC:	Vegetable Initiative for Urban Clusters
WASH:	water, sanitation and hygiene
WHO:	World Health Organization
WSD:	watershed development

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1. Introduction

This chapter provides the foundation for and motivation behind this PhD thesis by describing the interlinkages between food systems, population health and health-related decision-making. First, health is located as an important outcome of food systems activities, and the global initiatives dealing with food systems-related health concerns are touched upon. Second, the contextual situation of health and food systems in India are covered, indicating the primary motivation for the thesis. A short description of watershed development (WSD) projects is also provided, which was the case study for most of the objectives of this thesis. Third, a review of health impact assessment (HIA) practice globally and in India is presented, especially in the context of food systems projects and policies. Drawing on these three sections, the research gaps were listed, which, in turn, inspired the research objectives of this thesis. The chapter concludes with a methodological overview of the five included research papers, and also a brief description of the study sites.

1.1. Health and food systems interlinkages

The preamble to the constitution of the World Health Organization defines health as "*a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*" (WHO, 1948). Health is determined by the conditions that a person is born into, lives in and works. These conditions, in turn, are related to a variety of forces in society that shape individual and population health (CSDH, 2008). While health indicators have improved on average across the world, the gains made are also dependent on the health of natural systems (Whitmee et al., 2015).

According to the High Level Panel of Experts on Food Security and Nutrition "*a food system gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes*" (HLPE, 2014). This definition of food system and its broad linkage to health outcomes has been illustrated in Figure 1.1.

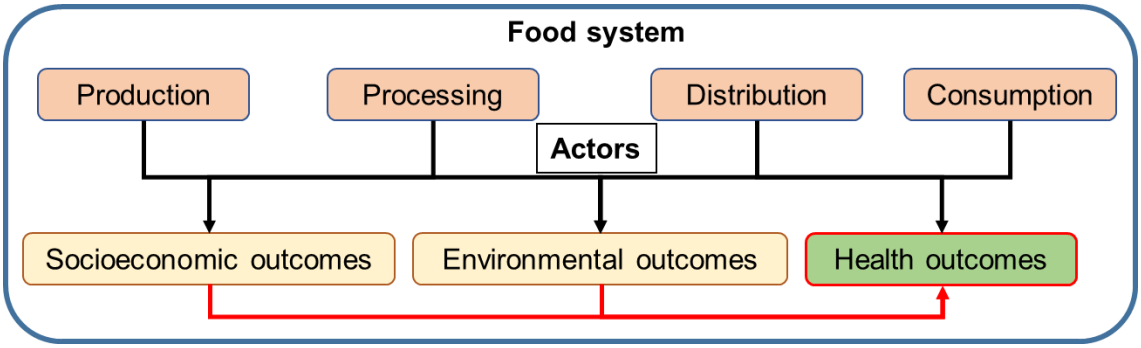

Figure 1.1: Pathways of health impacts of food systems

1.1.1. Potential mechanisms of impact of food systems on health

Undernutrition and dietary risks were the top two risk factors globally for morbidity and mortality, and particularly important in low- and middle-income (LMICs) countries (GBD 2016 Risk Factors Collaborators, 2017). This can be interpreted as a failure of food systems (IFPRI, 2015). Impact on health occurs through several direct and indirect mechanisms. These include access to food (e.g., low access causing undernutrition), food quality (e.g., processed foods causing chronic disease), land and water management (e.g., vector-borne diseases), exposure to chemicals (e.g., pesticides) and food waste (Neff et al., 2009; Pradyumna et al., 2019).

Food production is an important mechanism for household nutrition in agrarian nations such as India. There are several pathways linking agriculture and nutrition including agriculture as a source of food and income, impact of agricultural policy on food prices, women's time allocation to child-care and women's involvement in decision-making (Kadiyala et al., 2014). These factors operate at household level through complex mechanisms (Carletto et al., 2015).

1.1.2. Global prioritisation of health impacts of food systems

The Sustainable Development Goals (SDGs) provide a strong basis for the adoption of a health lens in development work (Becerra-Posada, 2015). The interdependence of various goals and targets (UN, 2015; Nilsson et al., 2016) and the dependence of health outcomes on the fulfilment of other goals have been discussed (Buse and Hawkes, 2015). Concomitantly, a report by the United Nations Development Programme described food systems as a key concern of the SDGs (Westhoek et al., 2016). An analysis of SDG indicators demonstrated strong associations between indicators of environment, health and food systems (Pradhan et al., 2017; Pradyumna, 2018). An effort was made to identify the potential direct linkages between SDG targets on food systems and health, which has been presented in Figure 1.2.

The global focus on nutrition and food systems has been further elaborated through specific programmes within the framework of the SDGs. Firstly, the period of 2016 to 2025 has been declared as the United Nations Decade of Action on Nutrition, with several agreed-upon targets (UN, 2017) encompassed within SDG 2.2 (UN, 2015). Secondly, the 10 Year Framework of Programmes on Sustainable Food Systems (10YFP, integrated into SDG 12.1) (FAO and UNEP, 2016) has a vision that "*all food systems are sustainable, delivering food security and nutrition for present and future generations*" (UNEP, 2017). These global targets demonstrate an understanding of the determinants of undernutrition, and the commitment to address them worldwide. Therefore, nutrition experts have called to make food systems "nutrition-sensitive", implying that any planned food systems policies and projects should explicitly consider potential impacts on nutrition and accordingly incorporate appropriate measures (Ruel et al., 2013; IFPRI, 2015).

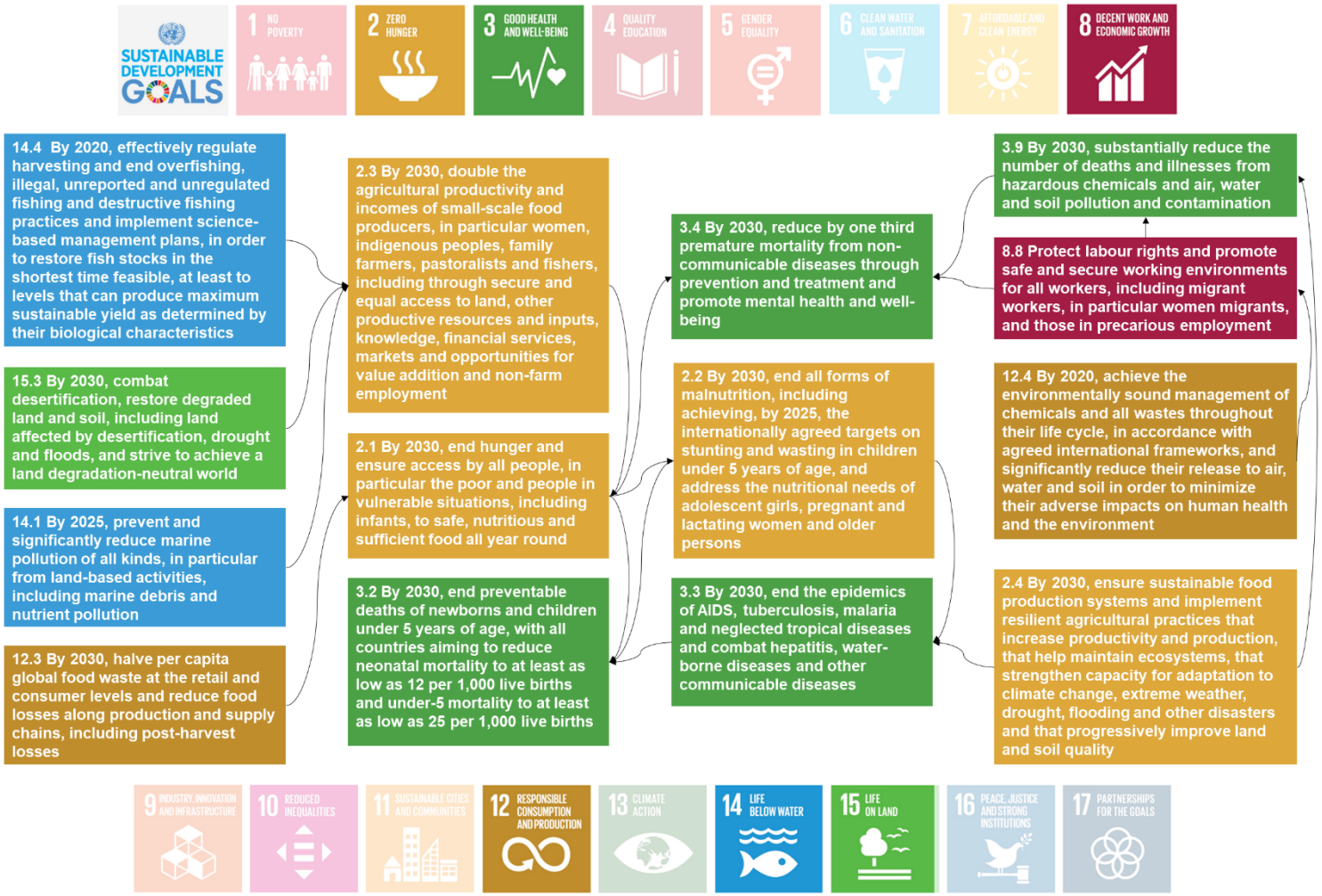

Figure 1.2: Direct linkages between SDG targets on public health and food systems (adapted from Pradyumna et al. (2019)); public health-relevant SDG targets included in figure: 2.2, 3.2. 3.3, 3.4, 3.9 and 8.8

1.2. India's health and food systems situation

Health in India is characterised by high prevalence of undernutrition, and increasing prevalence of obesity and chronic disease. The agriculture sector, which employs the majority of the working population, is underproductive, inadequately remunerative and vulnerable to climate change. Policy has tried to address these complex challenges through various schemes and programmes. These aspects have been elaborated in the following section.

1.1.1. Health status and health policy overview

Health indicators have improved substantially in past two decades in India, for instance, a reduction in infant mortality rate from 57 per 1,000 live births (in 2006) to 41 (in 2016) (Dhirar et al., 2018). Though the situation of child undernutrition has also improved over the past two decades, data from 2016 suggested that the prevalence of stunting (38%), wasting (21%) and undernutrition (36%) among children under 5 years of age were still relatively high (IIPS and ICF, 2017). Years of life lost due to diarrhoeal disease, another determinant of child undernutrition, was higher than expected for the local socio-demographic index (GBD 2016 Causes of Death Collaborators, 2017). The prevalence of anaemia among women aged 15 to 49 years was also alarmingly high (53%) (IIPS, 2016a). Overall, undernutrition was identified as the top risk factor for mortality and morbidity in India, and dietary risks was ranked third (India State-Level Disease Burden Initiative Collaborators, 2017).

A large proportion of adults aged over 18 years demonstrated metabolic risk factors such as high blood pressure (24%) and elevated blood glucose levels (8%). Prevalence of obesity and hypertension have increased since 2000 (WHO, 2018). However, the proportion of families consuming an adequate diet has fallen from 30% to 22% between 2006 and 2016 (NITI Aayog, 2017). Since 2006, the regular consumption of green leafy vegetables has decreased, and daily consumption of milk or curd has increased in households (IIPS and ICF, 2017). Various factors have contributed to the state of double burden of malnutrition in India, with undernutrition a greater problem in rural areas and poorer states, and obesity an escalating concern in urban populations (Dutta et al., 2019). The status of nutritional indicators in India (and also Karnataka state and Kolar district) has been presented in Table 1.1.

Table 1.1: Status of nutritional indicators in India, Karnataka state and Kolar district (from NFHS-4*)

Indicators	India	Karnataka	Kolar		
	Total (%)	**Total (%)**	**Urban (%)**	**Rural (%)**	**Total (%)**
Child nutritional indicators					
Children under 5 years who are stunted (height-for-age)	38.4	36.2	28.3	34.3	32.0
Children under 5 years who are wasted (weight-for-height)	21.0	26.1	15.0	20.6	18.4
Children under 5 years who are underweight (weight-for-age)	35.7	35.2	26.5	28.5	27.7
Adult nutritional indicators					
Women (15-49 years) whose BMI < 18.5 kg/m^2	22.9	20.7	17.0	27.4	23.5
Women (15-49 years) who are overweight/obese (BMI ≥ 25.0 kg/m^2)	20.7	23.3	37.4	15.2	23.6
Men who are overweight or obese (BMI ≥ 25.0 kg/m^2)	18.6	22.1	29.2	12.9	21.3
All women aged 15-49 years who are anaemic	53.0	44.8	43.1	45.9	44.9

*NFHS, National Family Health Survey (collated from (IIPS, 2016a, 2016b, 2016c)); BMI, body mass index

There are several other relevant health concerns. For instance, the national health policy listed reducing agricultural injuries as a priority (Government of India, 2017a). A large number of farmer suicides have also been reported in India, with the official mortality figures in Karnataka state in India being 30,620 for 2000 to 2014. These were partly related to crop failure due to drought or other reasons (16.8%) (Manjunatha and Ramappa, 2017). Other specific examples of health impacts of food systems interventions in India include a malaria outbreak in the arid state of Rajasthan following an irrigation project (Anushrita et al., 2017; Tyagi, 2004), impacts of expanded use of hybrid seeds and chemicals across India (Dhanagare, 1988; Pingali, 2012) and congenital anomalies that occurred as a result of aerially-sprayed endosulfan pesticide in cashew plantations in Kerala state (Pradyumna and Chelaton, 2018).

To address undernutrition among women of reproductive age and children under the age of 5 years, the Integrated Child Development Services scheme provides supplementary nutrition at government-managed crèches (Rao, 2016). While this strategy has been considered important, impact was lesser than anticipated (Chudasama et al., 2014; Dixit et al., 2018). Regarding chronic diseases, the strategy has been to improve access to screening tests and

healthcare in governmental hospitals (Ministry of Health and Family Welfare, 2013). The National Nutrition Strategy has emphasised the need for inter-sectoral action to address underlying causes of malnutrition (NITI Aayog, 2017). This will be important, because India was found to be off-course for all 10 global nutrition targets for the year 2025 (Development Initiatives, 2020).

1.1.2. Food systems status and policy context in India

India has a “rural food system”, characterised largely by low urbanisation, low agricultural productivity and high food budget share (IFPRI, 2015). There has been steady decline in public investment in the agriculture sector (Gillespie et al., 2012). Land degradation and depletion of ground water are important concerns (Shah, 2010; FAO, 2015; ISRO, 2016). However, the vast majority of the population (263 million individuals, or 54.6% of the workforce) continue to depend on agriculture for livelihood, of which 54.9% are labourers (Government of India, 2019). The proportion of persons dependent on agricultural labour has been steadily increasing (Government of India, 2019). Climate change is also a major concern, for which impact pathways include extreme weather events, drought, higher temperatures, sea level rise and impact on glaciers (INCCA, 2010). The agricultural sector in India has been designated as highly vulnerable to climate change (O’Brien et al., 2004).

After India became independence in 1947, the major focus was on famine prevention, which also included food-for-work programmes (Dreze, 1995; Banik, 2016). In more recent decades, the focus has largely been on food security and welfare. Issues of dietary diversity, adaptive capacity and environmental sustainability have been inadequately addressed (Pingali et al., 2019). The National Food Security Act, 2013 reiterated equitable access to food in India. It lists provisions for “advancing food security” including the need for securing interests of small and marginal farmers, access to irrigation, appropriate procurement, insurance and compensations; safe and adequate drinking water, sanitation and healthcare (Government of India, 2013). The Public Distribution System is the main intervention for food welfare, but systemic inefficiencies have led to low impact despite rising food stocks (Gillespie et al., 2012).

Several policies have addressed challenges in agriculture. These include policies to improve production (Ministry of Agriculture and Farmers Welfare, 2017), increase access to technology (Ministry of Agriculture and Farmers Welfare, 2012), protect agro-biodiversity (Government of India, 2003), improve wage-labour opportunities (Ministry of Rural Development, 2008) and conserve natural resources (Ministry of Agriculture and Farmers Welfare, 2014a). Several policies are also in place to support other components of food systems, for instance, food processing (Ministry of Food Processing Industries, 2013) and food trade (Ministry of Commerce and Industry, 2015, 2017).

1.1.3. Watershed development projects in India

The challenges of land degradation (over 1.46 million km^2) and access to irrigation (0.85 million km^2 of rain-fed arable land) have been important in India (Government of India, 2011). Rain-fed agriculture has suffered neglect as compared to irrigated agriculture (Technical Committee on Watershed Programmes in India, 2006). This situation may only worsen due to climate change (INCCA, 2010). To address this, several programmes in soil and water conservation have been implemented in India since decades (Kerr, 2002). During the early 1990s, these programmes were brought together under the banner of WSD (Technical Committee on Watershed Programmes in India, 2006). As evidence of best practices improved, the programmes were expanded to include concerns of equity, participation, women's empowerment, livelihood and involvement of non-governmental organisations (NGOs) (Technical Committee on Watershed Programmes in India, 2006). For instance, earlier projects had inadvertently impacted the landless livestock rearers negatively due to restrictions on grazing in common lands treated by the projects (Technical Committee on Watershed Programmes in India, 2006). Guidelines were re-issued in 2008 which now form the basis for WSD projects in India (Government of India, 2011). The Government of India has defined WSD as

> *"the conservation, regeneration and the judicious use of all the resources – natural (land, water, plants and animals) and human – within the watershed area. Watershed management tries to bring about the best possible balance in the environment between natural resources on the one side and man and animals on the other"* (Government of India, 2018a).

WSD projects have been carried out all over India with the aim of soil and water conservation, maintaining ecological balance and providing livelihood support (Meenakshi and Ramanathan, 2010; Government of India, 2011; Smyle et al., 2014). While these programmes are mainly supported by the government, philanthropic institutions too have recognised the potential of these projects and funded them (Smyle et al., 2014). NGOs are important planning and implementing agencies for many of these projects (Government of India, 2011). Participation of local people has been an important aspect of these projects, which was shown to improve project quality, impact and sustainability (Technical Committee on Watershed Programmes in India, 2006). The broad list of actors involved at various levels of planning and implementation of WSD projects has been depicted in Figure 1.3.

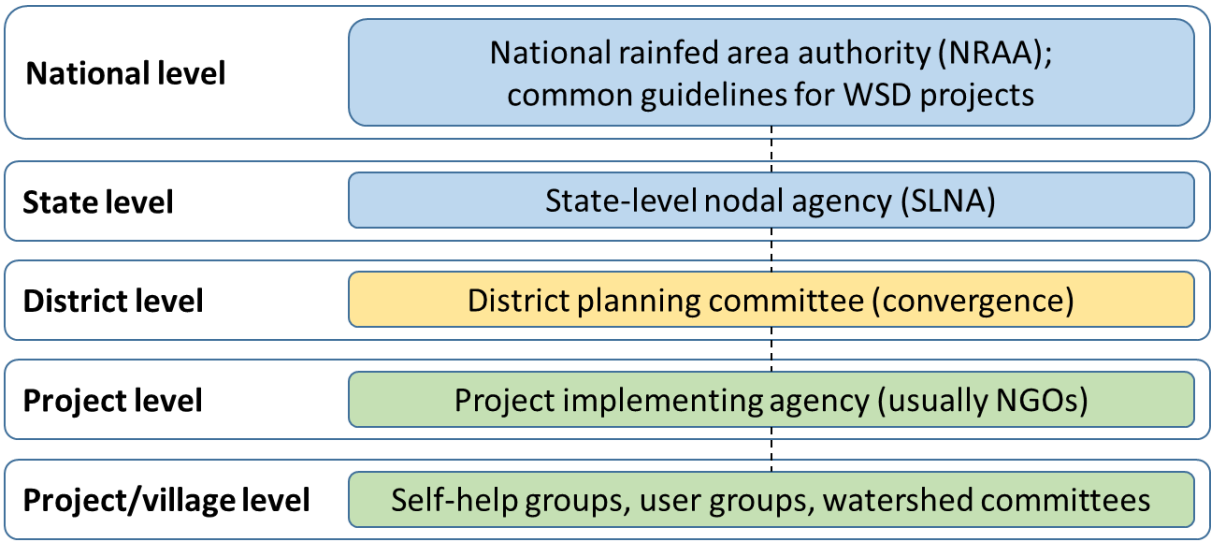

Figure 1.3: Governance of watershed development in India (based on Government of India (2011))

WSD projects are composed of several physical, ecological and social activities. The physical structures for soil and water conservation include contour bunds, gully plugs, plantation and vegetative checks, ponds and wells, trenches, check dams and land-levelling (Meenakshi and Ramanathan, 2010). Ecological improvement is achieved through horticulture, enhancing pastures and sustainable use of resources (Government of India, 2011). Social activities include formation and management of local institutions and provision of livelihood support, especially livestock management and dairy animals (Lele et al., 2007; Government of India, 2011). These components are illustrated together in Figure 1.4.

> *"The new approach would systematically…encourage dairying….When effectively integrated with the watershed development projects, a comprehensive animal husbandry component would contribute significantly to ensuring a better and sustainable livelihood for the people of the rain-fed areas"* (Government of India, 2011).

The unit of intervention is usually a micro-watershed, which is an area from which all rainfall runoff collects into a single drain at any particular point. This often comprises a few villages in semi-arid areas. Some projects have covered much larger areas, but activities are planned at smaller scales (Kerr, 2007). The project is carried out over 4 to 7 years (Government of India, 2011). WSD has also been suggested as an approach to improve adaptation to climate change in semi-arid areas (IISc, 2014). The guidelines indicate that the main nodal ministry is the Ministry for Rural Development, alongside the Ministry of Agriculture, and the Ministry for Environment, Forests and Climate Change (Government of India, 2011).

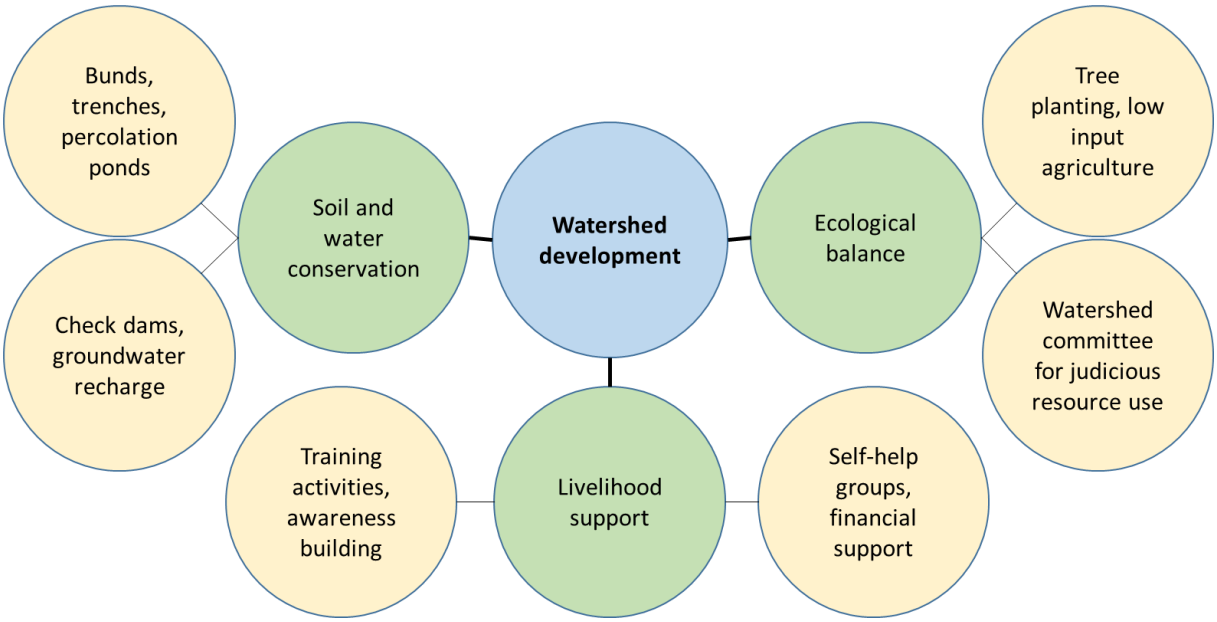

Figure 1.4: Typical components of WSD projects in semi-arid regions of India

A meta-analysis of over 600 WSD project evaluations showed positive impacts on income, improving local employment opportunities (151 person days per ha), higher crop yields, greater cropping intensity (35.5%), groundwater recharge, decrease in run-off (45%) and soil loss (1.1 tons per ha), contributing to social capital and reduction in poverty (Joshi et al., 2008). Other impacts reported in evaluations included a shift to commercial crops, reduction in migration and increased local vegetation. However, results are inconsistent due to variation in quality of projects (Technical Committee on Watershed Programmes in India, 2006; Lele et al., 2007; Meenakshi and Ramanathan, 2010). From a determinants of health perspective, there were reports of improved food security, reduced workload on women, improved sanitation and increased women's empowerment (Nerkar et al., 2013, 2015). Benefits were highest where people's participation was highest (Joshi et al., 2008).

WSD was deemed critical for food security, poverty reduction and "*freedom from drought…by 2020*", while also addressing the "*nutritional emergency*" of child undernutrition and anaemia among women, and farmer suicides (Technical Committee on Watershed Programmes in India, 2006). To improve women's participation, it was recommended that WSD projects address access to drinking water, sanitation, clean fuels, healthcare and social services. The potential risk of increased alcohol consumption among males due to better income was also perceived. Finally, convergence of WSD projects with health and social programmes was recommended at village level, with the Technical Committee on Watershed Programmes in India (2006) concluding that "*…there is a strong case for making watershed the framework and umbrella for uniting all development programmes that are implemented in the village".* However, literature on health impacts of WSD projects is inadequate, and incorporation of health considerations in planning WSD projects has not systematically taken place.

1.3. Health impact assessment: a focus on food systems and India

"*Health impact assessment is a combination of procedures, methods and tools by which a policy, programme or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population*" and suggest options to maximise positive health impacts and minimise negative health impacts (WHO and ECHP, 1999). It has also been identified as an important instrument to advance Health in All Policies or HiAP (Government of South Australia and WHO, 2017).

HiAP is defined as "*… an approach to public policies across sectors that systematically takes into account the health implications of decisions, seeks synergies, and avoids harmful health impacts in order to improve population health and health equity*" (WHO and Ministry of Social Affairs and Health, 2013). HIA has also been identified as an approach to address health inequities arising through policies and projects (CSDH, 2008).

1.1.4. Global status of HIA practice

HIA practice is prevalent across several countries, though in its infancy in LMICs (Winkler et al., 2020a). Many frameworks and guidelines exist for HIA practice, including those published by international agencies such as the International Finance Corporation (IFC) (IFC, 2009) and the International Association for Impact Assessment (IAIA) (Winkler et al., 2020b), practitioners (Birley, 2011) and research groups (Winkler et al., 2010, 2011, 2012). A survey among practitioners indicated that HIA was applied most often to projects, followed by policies (Winkler et al., 2020a). While the HIA approach may vary between guidelines, a set of core values are aspired to (WHO and ECHP, 1999). They have been listed in Table 1.2.

Table 1.2: Addressing the values of HIA

Values	Best case HIA scenario	Worst case HIA scenario
Democracy	Reaching out to and involving potentially affected communities	No community involvement, conducted as desk job
Equity	Sub-groups identified; differential exposure considered	No disaggregated analysis; vulnerable groups ignored
Ethical use of evidence	Best available evidence used, primary data collected if needed; monitoring and evaluation reported	Irrelevant health data used, disproportionate positive impact of project reported; no accountability
Sustainable development	Long term impacts also considered; monitored	Long term impacts not considered; no monitoring/follow-up
Comprehensive approach to health	Outcomes and determinants addressed; including health systems	Health areas not systematically approached; gaps in areas covered

Adapted from a table in a conference paper by Pradyumna et al. (2018)

There are a few case studies of HIA on food systems-related projects and policies. At project level, one example is the HIA of a biofuels project in Sierra Leone (Knoblauch et al., 2014; Winkler et al., 2014). At policy level, the health impact of Slovenia joining the European Union on its food policy was assessed and reported (Lock et al., 2003, 2004). A modified version of HIA has also been applied to assess fast-food businesses (Anaf et al., 2017). However, the paucity of literature on this subject indicates that the application of HIA to food systems-related projects and policies has been low.

1.1.5. India situation: policy provisions and HIA experience

In India, policy mandates environmental impact assessments (EIA) for specific projects of particular sizes. For instance, proposals of large mining projects, chemical industries and thermal power plants (Government of India, 2006a). The first EIA notification was instituted in 1994 and revised in 2006. A new draft notification has been shared for public feedback in April, 2020 by the Ministry of Environment Forests and Climate Change (2020). Health and social assessments form a part of the EIA. The notification itself is under the purview of the Ministry of Environment, Forests and Climate Change. The notification does not mandate the involvement of health professionals or HIA-trained individuals in the EIA. An analysis of few EIA reports indicated that the health assessment was inadequate, covered irrelevant information and was of poor quality (Pradyumna, 2015). In other settings too, it was reported that health assessments in EIA were inadequate as compared to stand-alone HIA (Diallo et al., 2017).

Many types of projects are outside the purview of the EIA regulation (Rajaram and Das, 2011). However, attempts have been made to apply EIA methods to various projects and contexts. For instance, urban housing projects in Lucknow city (Dutta and Tiwar, 2015), sea level rise in coastal Tamil Nadu (Dhanalakshmi et al., 2019) and waste management in Allahabad (Rawal, 2019) and Dhanbad cities (Yadav and Samadder, 2018). An integrated assessment was also done for impacts mediated through urban housing for future climate change scenarios in Hyderabad (but not by an Indian researcher) (Reckien, 2014). The impact of loss of plant biodiversity on food and medicine was noted in an EIA of a large hydroelectric power project (Dixit and Geevan, 2000). A meta-analysis of EIA reports indicated that while local people were worried about several factors related to the planned projects, health was not one of them (Sainath and Rajan, 2015).

Only one case study of an HIA from India was identified during a literature search. A quantitative risk assessment approach using secondary data for a scenario of bus rapid transport system for the city of Indore was done, estimating the potential reduction in mortality due to reduced air pollution, accidents and improved physical activity (Mahendra and

Rajagopalan, 2015). Frameworks for HIA of transportation projects in India were also developed (Conti and Mahendra, 2014; Verma et al., 2020). In addition, one case study of a community-driven HIA was reported, where community empowerment and highlighting community priorities related to the proposed intervention was the focus (Cameron et al., 2011). Some case studies on irrigation and industrial projects from India have been published as “health impact assessment” (Patil, 2011; Anushrita et al., 2017). However, based on the definition of HIA from the Gothenburg consensus paper (WHO and ECHP, 1999) and the IFC manual (IFC, 2009), these case studies are not HIAs, but rather impact evaluations.

Despite advances having been made in improving access to healthcare services in rural areas (Government of India, 2017a), improving household food security (Government of India, 2013) and access to livelihood (Government of India, 2005), the status of wellbeing of a sizable proportion of the population in India is still poor, many falling back into poverty due to catastrophic healthcare expenditure (Garg and Karan, 2008; Thorat et al., 2017). The investment in public health system still falls far short of the recommended levels of 5% of the gross domestic product (Mudur, 2016). Nutritional challenges continue to be of concern, and are projected to worsen in the context of climate change (Government of India, 2016a). Due to these conditions, the role of risk mitigation and health promotion as part of developmental projects and policies become critical.

1.4. Research gaps

Literature suggests that food systems interventions, including policies, have considerable potential to impact population health (Neff et al., 2009; Kadiyala et al., 2014; IFPRI, 2015; Thow et al., 2016). The need for inter-sectoral action for health has also been clearly expressed by the recent National Health Policy from India, as follows:

> *"The policy articulates to institutionalise inter-sectoral coordination at national and sub-national levels to optimise health outcomes…This is in line with the emergent international 'Health in All' approach…"* (Government of India, 2017a).

This paradigm of action is also endorsed by the National Nutrition Strategy (NITI Aayog, 2017). While some studies have looked at the potential for policies to improve nutrition and related outcomes in India, no studies have elucidated how food systems-related policies have addressed relevant health concerns, especially those beyond nutrition. The coherence between policies has also not been assessed, and the existing governance mechanisms for incorporating health concerns in food policy-related decision-making have also not been adequately described. Such a study could illuminate the current status of operationalisation of "Health in All" at policy level in India.

While the common guidelines for WSD projects mentioned the importance of expertise from various disciplines towards assisting nodal agencies (Government of India, 2011), the need for involvement of health experts were not explicitly mentioned. To understand the utility of HIA towards incorporating health considerations in WSD projects, a decision was taken to conduct an HIA of a planned WSD project. In addition, there is a paucity of case studies on HIA from India, and few examples of HIA on food systems projects worldwide. However, it was first necessary to better understand the types and distribution of health impacts of completed WSD projects in the region. The sparse literature on health impacts of WSD project has only reported impacts such as reduction in diarrhoeal disease, improved sanitation, improved food diversity and reduced workload on women to collect water (Pandit, 2010; Nerkar et al., 2013, 2015). However, there are other potential positive and negative health impacts, for instance vector-borne diseases, that need to be further explored. This is also important because WSD projects are implemented across India (Technical Committee on Watershed Programmes in India, 2006), with scope for reaching a large population. In addition, research on health impacts of WSD has only been conducted in remote and tribal areas of Maharashtra (Pandit, 2010; Nerkar et al., 2013, 2015, 2016), and there is no literature from southern India. These studies have also not adequately explored the differential impacts between sub-groups of the population, for instance, by land ownership or gender. Further research is needed to understand the full

range of potential health impacts of WSD projects. This evidence could then feed into WSD project planning to improve health outcomes.

The need and potential of HIA was identified by Indian health researchers (Ahuja, 2007; Kumar et al., 2010; Cave et al., 2013; Pradyumna, 2015; Pradyumna and Chelaton, 2018). HIA is not mandated for WSD projects in India. However, the Technical Committee on Watershed Programmes in India (2006) had envisioned WSD projects as an important platform to improve key health determinants, such as drinking water and nutrition. More importantly, a recommendation on budget allocation for "*impact assessment, monitoring and research*" as part of WSD projects was made (Technical Committee on Watershed Programmes in India, 2006), though they may have meant impact evaluation. The relevance of a "*risk managing paradigm*" from an economic perspective was also emphasised (Government of India, 2011). Based on these points, a case for addressing health risks associated with WSD projects was made, and for this, the HIA approach was considered.

While livestock management and dairy animals have been strongly promoted as part of WSD projects to improve income and nutrition, there is insufficient literature from southern India on the role of ownership of dairy animals on household dietary quality. This would be important to understand better, as literature suggests that impacts vary widely with context (Bhagowalia et al., 2012). It would also be useful to study this in an area conducive for future WSD projects, where livestock rearing will be a focus. Such studies could also reveal the additional utility of baseline survey data from HIAs in rural areas to answer empirical research questions in the area of agriculture, nutrition and health.

1.5. Thesis objectives

The overarching aim of this PhD thesis was to deepen the understanding on health considerations in food systems policies in India, health impacts of food systems projects in India, and demonstrating approaches to improve health considerations in food systems decision-making.

The specific objectives were

- To elucidate how health has been addressed across food systems policy documents in India
    - types of health concerns mentioned;
    - mechanisms to address health concerns; and
    - measures to incorporate health considerations in decision-making.
- To understand the types and distribution of health impacts of completed WSD projects in a semi-arid area in southern India as perceived by various actors
    - local people: land-owning, landless, women and men who participated in these projects;
    - NGO officials and fieldworkers who implemented these projects; and
    - local health workers knowledgeable about the project areas.
- To conduct a health impact assessment of a planned WSD project in a semi-arid area in southern India
    - describe the baseline health conditions of the local population;
    - identify and prioritise the potential health impacts of the planned WSD project; and
    - make evidence-based recommendations towards mitigating potential negative health impacts and maximising health promotion.
- To describe the health status of the local population at the outset of a planned WSD project.
- To study the association of livestock ownership and household dietary quality in semi-arid villages of southern India
    - to assess the status of health determinants of households based on ownership of dairy animal(s);
    - to determine the correlation of household milk consumption with other foods; and
    - to examine the association between livestock ownership and household milk consumption.

1.6. Methodological overview

The thesis was initiated with a policy document analysis using qualitative methods, to address the first objective. Objectives 2, 3, 4 and 5, were centred around local WSD projects and the HIA approach. This included primary data collection through qualitative methods and a baseline health survey. Figure 1.5 provides an overview of the chapters of the thesis and the respective methods used in each of them.

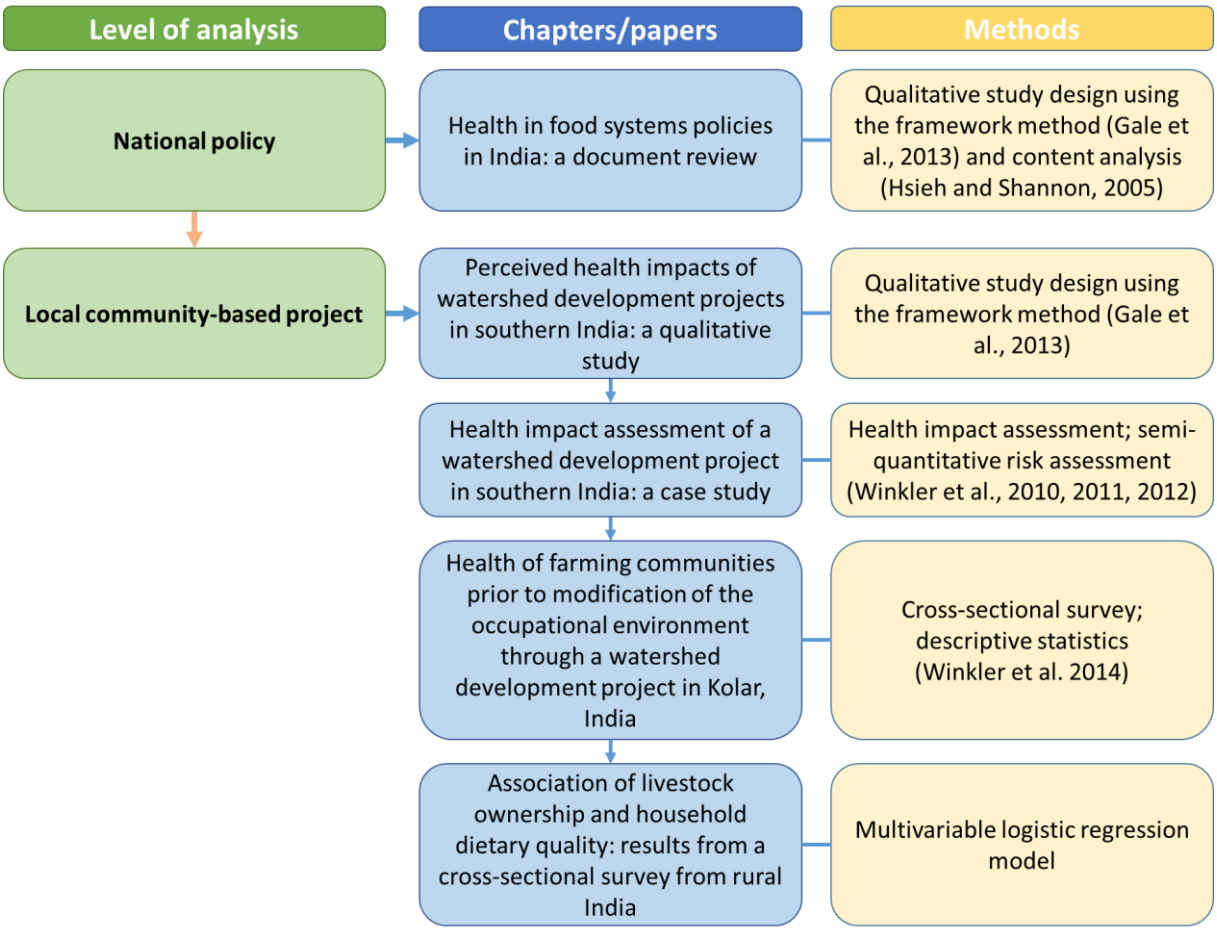

Figure 1.5: Overview of the PhD thesis components and outputs

Reflexivity

The author's background in medicine and public health may have contributed to the predominantly biomedical and public health lens employed, though efforts were made to include a social science orientation for this work. The author has some experience in semi-arid rural areas, but comes from an urban and a socio-economically secure background. The author believes that food systems should be a critical focus of the development sector to ensure health of the population and environmental sustainability. In addition, the author would join as a faculty member at a university in India to work on environment and health. All these factors have impacted the nature of the research outputs and the discussion chapter.

1.7. Study settings

For the field-based studies, the site was Kolar district in Karnataka state, southern India (an overview of health indicators of Kolar district was provided in Table 1.1). Several villages from across Kolar district were visited between 2018 and 2020, of which 13 were included as part of various studies in this thesis. WSD projects had been completed in some of these villages, and planned for others.

Kolar district (geographic coordinates: 13.13°N latitude; 78.13°E longitude) is located around 70 km from Bengaluru City (indicated in Figure 1.6). It has six sub-districts which are connected by road and rail. However, several villages located near the border of other states have poorer connectivity to district headquarters. While agriculture is the main economic activity, it was previously also known for its gold mines, with the district popularly referred to as the "land of silk, milk and gold" (Government of Karnataka, 2020). Many study villages were located near border areas, and one was also located near the erstwhile mines.

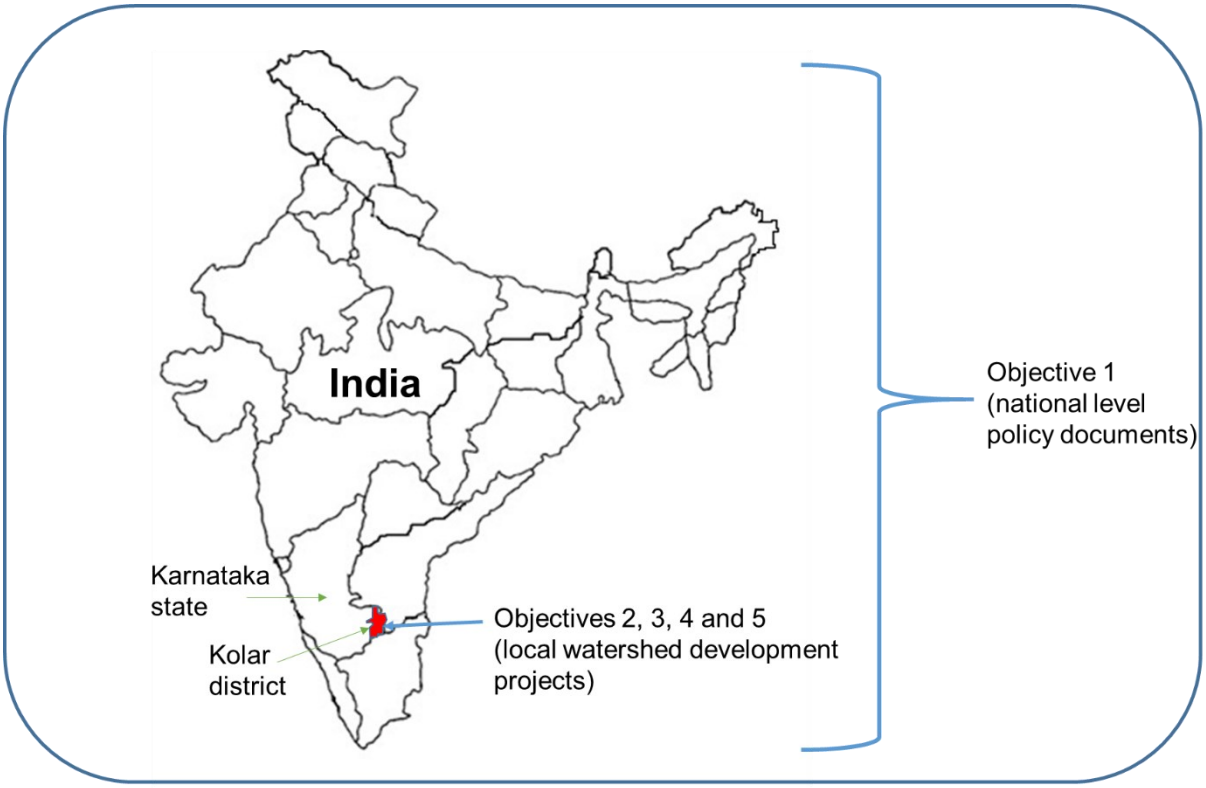

Figure 1.6: Study sites (modified from images by 3xK and PlaneMad respectively, distributed under a CC-BY 2.0 license); detailed maps of study sites available in the individual papers

Kolar is a drought-prone rural district classified under the "South Eastern Dry Zone" in Karnataka state (University of Agricultural Sciences - Bangalore, 2011). The main agricultural produce is finger millet (Office of the Registrar General & Census Commissioner, 2011), which is primarily for household consumption. The main commercial crop is tomato, for which there is a large market with national and international trade, but farmers also cultivate vegetables

(several varieties), flowers (both for domestic and international markets) and fruit (mainly mango) (Government of Karnataka, 2011; Singh et al., 2016).

There is heavy dependence on ground water for agriculture, and the district is vulnerable to climate change (BCCI-K, 2011). The projected impacts of climate change are: very high vulnerability for surface and ground water, increase in rice and finger millet yields, decrease in red gram and sorghum yields. Some climate change models predict increase in drought in these areas during *rabi* (winter planting) season, but also some increase in overall rainfall during the year (University of Agricultural Sciences - Bangalore, 2011).

MYRADA Kolar Project is a local NGO that has implemented several WSD projects and other development projects in Kolar. They have provided the field support for this thesis. Insights on the work done by this NGO can be found in literature (Technical Committee on Watershed Programmes in India, 2006; Meenakshi and Ramanathan, 2010; Smyle et al., 2014) and they have also been recognised for their work on WSD projects by the Government of India (2011).

2. Health in food systems policies in India: a document review

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2.1. Abstract

Background: Food systems affect nutritional and other health outcomes. Recent literature from India has described policy aspects addressing nutritional implications of specific foods (e.g., fruits, vegetables, and trans-fats), and identified opportunities to tackle the double burden of malnutrition. This paper attempts to deepen the understanding on how health concerns and the role of the health sector are addressed across food systems policies in India.

Methods: This qualitative study used two approaches; namely (i) the framework method and (ii) manifest content analysis, to investigate national-level policy documents from relevant sectors (i.e., food security, agriculture, biodiversity, food processing, trade, and waste management, besides health and nutrition). The documents were selected purposively. The textual data were coded and compared, from which themes were identified, described, and interpreted. Additionally, mentions of various health concerns and of the health ministry in the included documents were recorded and collated.

Results: A total of 35 policy documents were included in the analysis. A variety of health concerns spanning nutritional, communicable and non-communicable diseases (NCDs) were mentioned. Undernutrition received specific attention even beyond nutrition policies. Only few policies mentioned NCDs, infectious diseases, and injuries. Governing and advisory bodies were instituted by 17 of the analysed policies (e.g., food safety, agriculture, and food processing), and often included representation from the health ministry (9 of the 17 identified inter-ministerial bodies).

Conclusions: We found some evidence of concern for health, and inclusion of health ministry in food policy documents in India. The ongoing and planned intersectoral coordination to tackle undernutrition could inform actions to address other relevant but currently underappreciated concerns such as NCDs. Our study demonstrated a method for analysis of health consideration and intersectoral coordination in food policy documents, which could be applied to studies in other settings and policy domains.

Keywords: Agriculture, Food Systems, India, Intersectoral Coordination, Nutrition, Policy Analysis

<u>Key Messages:</u>

Implications for Policy Makers

- While the disproportionate policy focus on undernutrition is justified, there is a need to also emphasise other health implications of food systems, such as obesity, non-communicable diseases, and agrarian distress

- Dietary guidelines have been created for the Indian population by government-affiliated nutrition research institutions, but these have not been adequately used to guide food policy
- Representation from the Ministry of Health and Family Welfare was listed in inter-ministerial regulatory, advisory and executive groups of other food-related ministries. While this is good, there is a need for further clarity on whether such representation is influencing food systems to become more health-sensitive
- The intersectoral approaches being used and planned for undernutrition can provide a template for addressing other food systems-related health concerns. This would also be relevant towards fulfilling the National Health Policy goal of the “Health in All” approach

Implications for Public

Our research identified that undernutrition is a priority concern for various ministries in India. Several measures have been implemented to address vulnerability to undernutrition among marginalised communities, women, and children. Detailed insights are also available for measures towards food safety. However, several other relevant health concerns, such as obesity, cardiovascular disease, agricultural injuries, agrarian distress, and hazards of food wastes were not adequately addressed, despite being critical population health concerns. In our view, though the health ministry is often represented in inter-ministerial groups to govern food systems, measures to systematically include health considerations in food policy should be explicitly described and further enhanced.

2.2. Background

A United Nations (UN) report highlighted that "Food systems are at the heart of the 2030 Agenda for Sustainable Development" (Westhoek et al., 2016). Food systems include "*all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes*" (HLPE, 2014). These elements of food systems involve various actors, each of whom pursues different goals and priorities (IFPRI, 2015; Thow et al., 2016). For instance, farmers are concerned about sustained income, and the public health sector aims to address malnutrition (IFPRI, 2015). One important outcome of food systems is people's health and wellbeing (IFPRI, 2015), and thus it warrants specific attention. The challenge, however, is that the linkages between food systems and health are manifold and complex (Neff et al., 2009; Pradyumna et al., 2019).

Food systems-related health concerns include malnutrition (undernutrition and obesity) (Global Panel on Agriculture and Food Systems for Nutrition, 2016), non-communicable diseases (NCDs; e.g. diabetes, cardiovascular disease (CVD), and cancer) (GBD 2016 Risk Factors Collaborators, 2017), antibiotic resistance (due to indiscriminate use particularly in the livestock sector) (IFT Expert Report Panelists, 2006), vector-borne diseases (VBDs; due to increased risk of malaria from water resources and deforestation) (Keiser et al., 2005; Whitmee et al., 2015), parasitic infections (Steinmann et al., 2006), exposure to pesticides (Mew et al., 2017) and farmers' suicides (Mohanty, 2005). In addition, due to greenhouse gas emissions from food systems, climate change-related health risks such as extreme weather events, malnutrition, and VBDs are enhanced (Whitmee et al., 2015; Myers et al., 2017). Globally, undernutrition and dietary risks are currently the top risk factors for mortality (GBD 2016 Risk Factors Collaborators, 2017). There is a growing recognition that addressing challenges related to nutrition and NCDs need strong intersectoral coordination (Global Panel on Agriculture and Food Systems for Nutrition, 2014; Development Initiatives, 2017).

In that context, impacts of food systems policies on public health are being examined internationally (Shannon et al., 2015; Development Initiatives, 2017). The role of governments towards healthy food environments for NCD prevention was seen as regulatory (i.e., legal frameworks, economic instruments, and guidelines) and catalyst (i.e., awareness creation, building multi-stakeholder partnerships, and making funding available for coordinated action) (Lencucha et al., 2018a). Financial and technical assistance towards production of healthier food was reported to have strong potential from a health perspective (Lencucha et al., 2020). However, the general challenge towards intersectoral coordination for better health has persisted over decades, which may be driven by the complexity of setting up and managing

such a system, its potential to compromise the existing political economy, and importantly, the neglect of preventive measures even within the health sector (de Leeuw, 2017). In situations where systems for intersectoral coordination have been instituted, the impact on health equity was reported to be lower for upstream interventions as compared to downstream interventions (Ndumbe-Eyoh and Moffatt, 2013).

Historically, since independence in 1947, the focus of food systems-related policy in India has mainly been on food security. The early focus was on famine prevention, which also included food-for-work programmes (Dreze, 1995). Subsequently, safety nets for food security and welfare were enhanced (Banik, 2016), and greater thrust was provided for maternal and child nutrition (Rao, 2016). However, India is not on track to meet the Global Targets 2025 on stunting, exclusive breast feeding, and anaemia (Development Initiatives, 2020). In addition, risk factors for NCDs are of increasing concern, with one in five adults aged above 30 years having high systolic blood pressure, and 7.7% of adults aged above 20 years showing elevated fasting sugar levels (India State-Level Disease Burden Initiative CVD Collaborators, 2018). The proportion of individuals who are overweight has increased rapidly between 2006 and 2016 (NITI Aayog, 2017). Overall, undernutrition and dietary risks were the first and third highest ranked risk factors for mortality in India (India State-Level Disease Burden Initiative Collaborators, 2017). Meanwhile, agrarian distress, driven by low productivity, poor remuneration, and indebtedness, is also of concern, overtly manifesting through farmers' suicides (Manjunatha and Ramappa, 2017). Hence, there is a considerable burden of health impacts directly associated with food systems in India, warranting a closer look at how policies are addressing them. It has been suggested that the entire range of food systems policies should be considered to improve health outcomes (Muller et al., 2009). The policy space in India has been analysed for opportunities to address malnutrition, NCDs (Thow et al., 2016), and the consumption of fats (Downs et al., 2015a), trans-fats (Downs et al., 2015b) and fruits and vegetables (Thow et al., 2018). Nutrition, despite being the most obvious health outcome of food systems, was perceived as a minor consideration by food supply policy actors in India (Thow et al., 2016), which is a matter of concern.

Nutrition is but one of many health outcomes of food systems policies, as discussed earlier. The review of literature did not reveal any studies that have addressed whether and how various relevant health concerns have been considered in food policies in India. Moreover, besides health aspects of food consumption policies and pathways, those related to food production are important in India as the majority of the population is dependent on agriculture for livelihood (Government of India, 2019). Finally, the recent National Health Policy indicated the need for a "Health in All" approach (Government of India, 2017a), but the inclusion in health policies of intersectoral coordination with food systems actors, and the role of the health

ministry in food systems governance in India have not been adequately described in the literature.

This paper attempts to deepen the understanding on how health, including nutrition and several other related health concerns, and the role of the health sector, specifically the Ministry of Health and Family Welfare (MoHFW) and other central health institutions, are included and addressed across food systems-related policy documents in India. The following research questions governed the current analysis: First, what were the health concerns addressed in food systems policies in India? Second, whether and how these concerns were addressed in health policies themselves? Third, what were the roles identified for the health ministry in food systems governance in India? While the first two questions helped us to better understand the consideration for health outcomes, the last question looked at governance avenues for these considerations.

2.3. Methods

Study design

A qualitative study design was employed, using two approaches to content analysis; namely (i) the framework method, as described by Gale and colleagues (2013), and (ii) manifest content analysis, as described by Hsieh and Shannon (2005) The framework method is a type of thematic analysis that facilitates the identification of relevant themes to describe the findings (Gale et al., 2013). This method was used because the breadth of study topics was large, stemming from diverse sectors. This approach also helped contextualise data from individual policies within the pool of analysed policies (Gale et al., 2013). Manifest content analysis was used to document mentions of specific diseases or risks, and health-related and other institutions (Hsieh and Shannon, 2005).

Data sources

National-level policy documents, including statutory, technical, or official documents, relevant to broad food systems activities and outcomes (Westhoek et al., 2016), such as agriculture, food security, food processing, trade, agro-biodiversity, health, nutrition, and NCDs were employed. The analysis was initiated with 14 purposively selected documents, which were identified by the first author based on prior knowledge and relevant literature (Thow et al., 2016). The documents were downloaded in English language from governmental portals to ensure authenticity (Bowen, 2009). This sample was enhanced, first with other policy documents that were cited in the initially analysed set, second by referring back to the food systems definition for aspects that were not adequately covered by the current sample and, third data gaps in the analytical framework (e.g., documents on vegetable production and food

waste management). Table 2.1 provides the list of policy documents analysed in the current paper. Of the 35 analysed policies, 17 were 'agricultural', seven were 'social', two were 'environmental', two were 'trade', and one was 'industrial'. Six 'health' policies were also included to better understand the health ministry perspective on food systems governance and relevant health concerns.

Table 2.1: Food systems policies from India (from 2001 to 2018) included in the current analysis

Name of policy (abbreviation)	**Year**	**Type of document**	**Sector**
Protection of Plant Varieties and Farmers Rights Act 2001 (PPVFRA) (Government of India, 2001)	2001	Statutory	Agriculture
Biological Diversity Act 2002 (BDA)(Government of India, 2003)	2002	Statutory	Environment
Public Distribution System (part of the Xth Plan document) (PDS) (Planning Commission, 2002)	2002	Technical report	Social; intersectoral
Food Safety and Standards Act 2006 (FSSA) (Government of India, 2006b)	2006	Statutory	Health; intersectoral
Agricultural Debt Waiver and Debt Relief Scheme 2008 (ADWDRS) (Government of India, 2008)	2008	Official (scheme)	Agriculture
National Policy for Farmers 2007 (NPF) (Ministry of Agriculture, 2007)	2008	Official (policy)	Agriculture; intersectoral
National Programme for the Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS) 2008 (Ministry of Health and Family Welfare, 2008) and 2013 (Ministry of Health and Family Welfare, 2013)	2008	Official (programme)	Health
Mahatma Gandhi National Rural Employment Guarantee Scheme (2008 guidelines) (MNREGS) (Ministry of Rural Development, 2008)	2008	Official (based on statute)	Social; intersectoral
Common Guidelines for Watershed Development Projects 2008 (WSD) (revised 2011) (Government of India, 2011)	2011	Official (policy)	Agriculture; intersectoral
Vegetable Initiative for Urban Clusters 2011 guidelines (VIUC) (Ministry of Agriculture, 2011)	2011	Official (scheme)	Agriculture
National Mission on Agricultural Extension and Technology (XIIth plan, 2012) (NMAET) (Ministry of Agriculture and Farmers Welfare, 2012)	2012	Official (scheme)	Agriculture
National Food Security Mission (part of the XIIth plan document) (NFSM) (Ministry of Agriculture, 2012)	2012	Official (scheme)	Agriculture; intersectoral

Nutri-farms Scheme (2013 guidelines) (NFS) (Ministry of Agriculture, 2013)	2013	Official (scheme)	Agriculture; intersectoral
National Mission on Food Processing (2013 guidelines) (NMFP) (Ministry of Food Processing Industries, 2013)	2013	Official (scheme)	Industry; intersectoral
National Food Security Act 2013 (NFSA) (Government of India, 2013)	2013	Statutory	Social; intersectoral
The National Policy for Children 2013 (NPC) (Ministry of Women and Child Development, 2013)	2013	Official (policy)	Social; intersectoral
Mission for Integrated Development of Horticulture 2014 (MIDH) (Ministry of Agriculture and Farmers Welfare, 2014b)	2014	Official (scheme)	Agriculture
National Mission on Oilseed and Oil Palm 2014 (NMOOP) (Ministry of Agriculture and Farmers Welfare, 2014c)	2014	Official (scheme)	Agriculture
National Mission on Sustainable Agriculture 2014 (NMSA) (Ministry of Agriculture and Farmers Welfare, 2014a)	2014	Official (scheme)	Agriculture
National Policy for Management of Crop Residues 2014 (NPMCR) (Ministry of Agriculture, 2014)	2014	Official (policy)	Agriculture
Fertilizer Policy 2015 (FP) (Ministry of Chemicals and Fertilizers, 2015)	2015	Official (policy)	Agriculture
Foreign Trade Policy 2015-2020 (FTP) (Ministry of Commerce and Industry, 2015)	2015	Official (policy)	Trade
National Livestock Mission (2016 guidelines) (NLM) (Government of India, 2016b)	2016	Official (scheme)	Agriculture
Solid Waste Management Rules 2016 (SWMR) (Government of India, 2016c)	2016	Statutory	Environment; intersectoral
National Action Plan for Climate Change and Human Health 2016 (NAPCCHH) (Government of India, 2016a)	2016	Official (policy)	Health; intersectoral
Rashtriya Krishi Vikas Yojna (14th Financial Commission 2017) (RKVY) (Ministry of Agriculture and Farmers Welfare, 2017)	2017	Official (scheme)	Agriculture
Draft Pesticide Management Bill 2017 (PMB) (Department of Agriculture Cooperation and Farmers Welfare, 2018)	2017	Statute (draft)	Agriculture; intersectoral
National Health Policy 2017 (NHP) (Government of India, 2017a)	2017	Official (policy)	Health
Integrated Child Development Services (2017 guidelines) (ICDS) (Ministry of Personnel Public Grievances and Pensions, 2017)	2017	Official (scheme)	Health; intersectoral

National Nutrition Strategy 2017 (NNS) (NITI Aayog, 2017)	2017	Official (policy)	Health; intersectoral
Annual Report of Ministry of Public Distribution 2017 (ARMPD) (Ministry of Consumer Affairs Food & Public Distribution, 2017)	2017	Technical report	Social; intersectoral
Foreign Direct Investment Policy 2017 (FDIP) (Ministry of Commerce and Industry, 2017)	2017	Official (policy)	Trade
Economic Survey Chapter 1 2017-18 (Part of Budget 2017-18) (ESCB) (Ministry of Finance, 2018)	2018	Technical report	Social; intersectoral
Macroeconomic framework statement for Budget 2018 (MEFSB) (Government of India, 2018b)	2018	Technical report	Social; intersectoral
Price Support Scheme guidelines (PSSG) (Ministry of Agriculture, 2018)	-	Official (scheme)	Agriculture

Analysis

For the thematic analysis by the framework method, aspects that were of interest based on the study objectives and relevant literature were: (i) health and nutrition outcomes addressed; (ii) healthy diets and dietary diversity; (iii) social protection and equitable access for nutritional security; (iv) trade and investment for healthy food systems; (v) environmental sustainability of food systems; (vi) health system role in food systems-related health action; and (vii) intersectoral coordination. The coding scheme was guided by these interests (deductive) and also the data themselves (inductive) (the scheme is presented in Additional file 2). The working analytical framework was developed and applied to all the policy documents using the OpenCode 4.03 software (ICT Services and System Development and Division of Epidemiology and Global Health, 2013).

Summarised data (with meaning of the original data, and references to relevant quotations) from each data item were charted into a spread-sheet containing the analytical framework (Microsoft Corporation, 2010). Interpretation was done by understanding the content and source of data within each category of the analytical framework, and identifying potential synergies and differences between data from various sectoral and policy documents. Analytical memos were prepared for themes that addressed the main research questions (Braun and Clarke, 2006; Gale et al., 2013).

The manifest content analysis was conducted to document (i) the various diseases and health risks, and (ii) the various ministries and health institutions mentioned in each document. For this, during the reading and re-reading of the documents, notes were made about the specific diseases, risks and ministries that were mentioned in the document. In addition, as a second

check, the following generic terms were searched for using the search function of the PDF reader: ‘health’, ‘risk, ‘wellbeing’, ‘disease’, ‘nutrition’, and ‘ministry’. These frequencies were tabulated and presented as figures using Microsoft Excel 2016 (Microsoft Corporation, 2010) and R statistical software version 3.5.1. (R Core Team, 2018). Further details are available under each figure.

2.4. Results

The findings have been presented under the five themes that helped describe the data: (i) ‘Undernutrition recognised and addressed as a cross-sectoral concern’; (ii) ‘The focus on NCDs’; (iii) ‘Supporting healthy and balanced diets’; (iv) ‘Addressing health concerns beyond nutrition and NCDs’; and (v) ‘Involvement of health ministries in food systems governance’. The relevant policies contributing to each specific finding is cited in the text using their respective abbreviations from Table 2.1. Findings from the manifest content analysis have been reported using figures, interspersed within the appropriate themes. The first paragraph under each theme summarises the findings from the theme.

2.4.1. Undernutrition recognised and addressed as a cross-sectoral concern

Nutrition was identified as an important policy concern, with aspects related to nutrition mentioned or discussed in several policies (FSSA, ICDS, NAPCCHH, NHP, NNS, NPCDCS, MIDH, NFS, NFSA, NFSM, NLM, NPF, and RKVY). The focus was primarily on undernutrition (ICDS, NFS, NFSA, and NNS). Three policies were dedicated almost exclusively to undernutrition (ICDS, NFS, and NNS). Moreover, undernutrition was the only health concern to have an agricultural scheme dedicated to it (NFS). Several groups were deemed vulnerable to undernutrition from a social security perspective (i.e., challenges in accessing food; ARMPD, NFSA, NPF, and PDS) and a public health perspective (i.e., high prevalence of undernutrition; ICDS, NAPCCHH, and NNS). The factors articulated as contributing to vulnerability were poverty (ARMPD, NFSA, and NLM), age (ICDS, NAPCCHH, NFSA, NNS, and NPC), gender (ICDS, NAPCCHH, NFSA, NHP, and NNS), infirmity (ARMPD, ICDS, NFSA, and NPF), caste (NNS), disasters or shocks (NAPCCHH, NNS, and PDS), and remoteness of residence (NFSA and PDS). Towards addressing undernutrition and the associated vulnerability, the approaches mentioned included provision of food grains (NFSA), food supplementation for target groups (ARMPD, ICDS, NFSA, NPC, and PDS), healthcare support (ICDS, NHP, and NNS), and broader societal interventions related to empowering and enabling vulnerable communities (NAPCCHH, NLM, NNS, and NPF).

> *“Malnutrition in India, especially among children and women, is widespread, acute and even alarming.”* (NFS)

Micronutrient deficiencies and its consequences such as restriction of growth and development were other aspects of undernutrition that received attention (NHP). This included deficiencies of iron, vitamin A, zinc, iodine (NNS), calcium, selenium, and magnesium (NFS). Serious consequences of undernutrition were recognised in health policies (NNS and NHP) and also one agricultural policy (NFS).

> *"The consequences, in terms of malnutrition and health, are devastating and can result in blindness, stunting, disease and even death."* (NFS)

Figure 2.1 depicts the prominence of nutritional concerns among all relevant health concerns in the analysed policies. Only one agricultural policy (NFS, which was just a pilot scheme of limited geographic and temporal scope) was designed primarily to address undernutrition (other agricultural policies were oriented towards productivity and remuneration). Some policies mentioned "nutritional security" (rather than nutrition) as a concern, relating to the availability of adequate nutritious food at country or household level (MIDH, NFS, NFSA, NFSM, NLM, NPF, and RKVY).

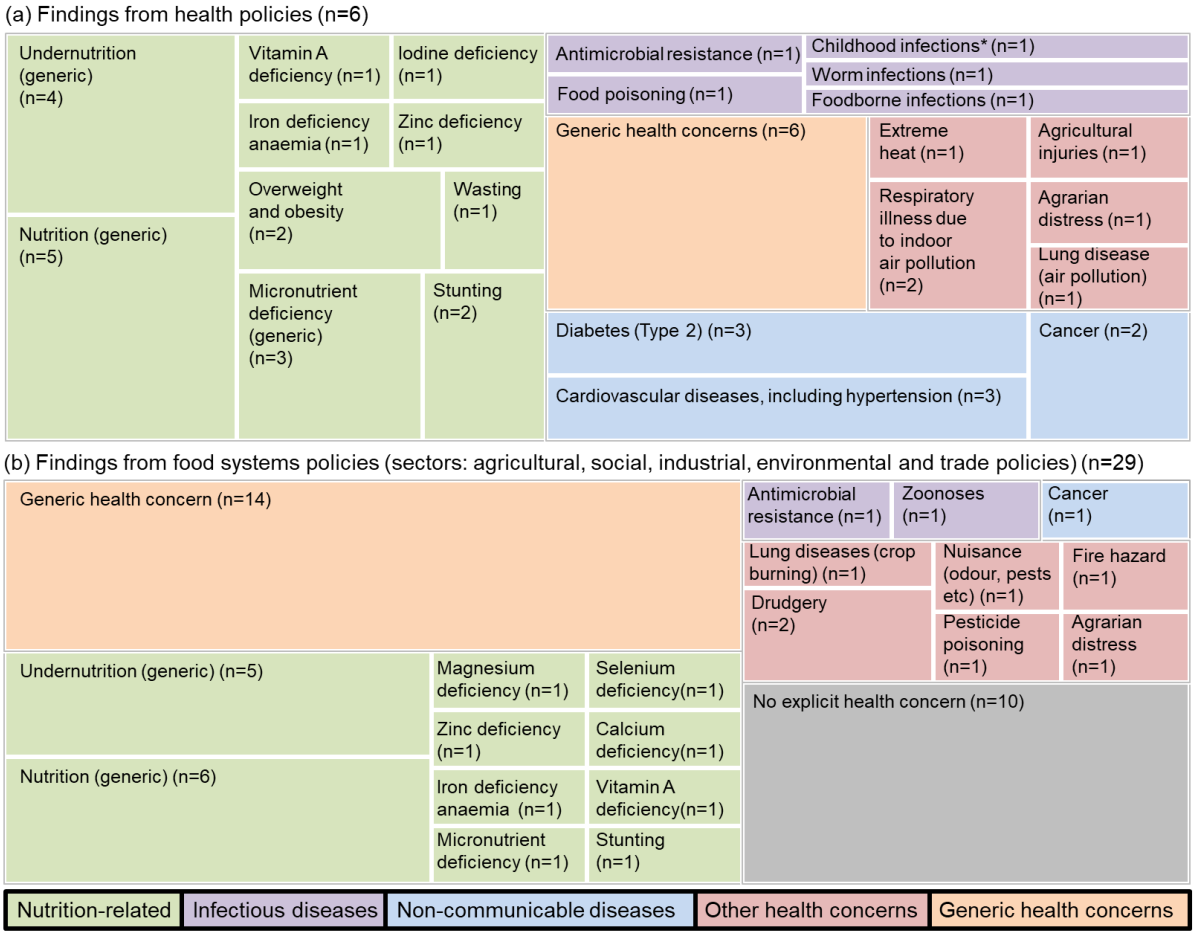

Figure 2.1: Food systems-related health concerns mentioned in (a) health policies (n=6); and (b) food systems policies/policies of other sectors (n=29); box size proportional to number of policies mentioning the respective health concern; "generic health concerns" indicates that 'health' or 'well-being' was explicitly mentioned; *includes diarrhoeal diseases. (Figure prepared using the portfolio package in R statistical software version 3.5.1 and edited in MS PowerPoint 2010).

> *"Main objectives of scheme are…. enhancing production and productivity, improve nutritional security and income support to farmers."* (RKVY)

From a social security perspective, several population groups were indicated as vulnerable: (i) the landless and marginal farmers (i.e., those owning under two acres of land); (ii) artisans; (iii) slum dwellers; (iv) informal sector workers; (v) the destitute; (vi) households headed by widows, the terminally ill, disabled, or elderly (ARMPD); (vii) HIV positive individuals (ARMPD and NPF); (viii) pregnant and lactating women; (ix) adolescent girls; (x) children (NFSA); (xi) those living in beggar homes; (xii) hostels with students from marginalised communities (ARMPD); (xiii) living in remote settings, including hilly and tribal areas (NFSA); and (xiv) communities facing shocks such as agrarian distress, seasonal migration, disruptions in access to services, disease outbreaks, endemic disease areas, and natural disasters (NNS and PDS). The only mention of "caste" was in the context of ensuring representation of scheduled castes in vigilance committees of the NFSA. In effect, various criteria such as socioeconomic, demographic, gender, shocks, caste, and health were used to identify beneficiaries or vulnerable groups, covering large section of the total population.

While health policies have acknowledged these multiple vulnerabilities to undernutrition (ICDS, NHP, and NNS), their focus was on vulnerability of women, adolescent girls, and children to undernutrition and micronutrient deficiency (ICDS and NNS), and the strong gender and inter-generational dimension to the problem (NNS).

> *"The girl child goes on to become an undernourished and anaemic adolescent girl, often deprived of …nutritional support, educational opportunities, …married too early, with early child bearing and inadequate inter-pregnancy recoupment. This perpetuates a vicious cycle of undernutrition and morbidity…"* (NNS)

Women and children from scheduled castes, scheduled tribes, and particularly vulnerable tribal groups (these categories have been officially defined) were indicated as especially vulnerable (NNS), additionally in the context of climate change (NAPCCHH). Therefore, considerations for gender, demography, caste, and remoteness of communities were acknowledged. In effect, the population addressed by nutritional and health policies and programmes is a sub-set of the population recognised as food insecure. Agricultural, industrial, or trade policies did not include any explicit considerations on nutritional vulnerability.

Subsidised foodgrains and pulses has been the main approach towards ensuring household food security, covering priority households and those under the *Antyodaya Anna Yojana* (a scheme for the poorest sections). Support is based on the number of members in the eligible household (NFSA). The food supplementation approach for women and children used by the health sector is a more targeted version of the broader food welfare approach. Nutritional

supplementation is provided to pregnant and lactating women through the local *anganwadi* (crèche; ICDS and NFSA). Schemes for improving nutrition of adolescent girls through additional foodgrains were also introduced (ARMPD). For children, meals are provided at *anganwadis* or government schools free-of-charge. In addition, state governments have been directed to identify and provide meals to malnourished children based on prescribed standards (ICDS and NFSA).

> *"Every child has a right to adequate nutrition and to be safeguarded against hunger, deprivation and malnutrition."* (NPC)

In remote tribal areas, grants for setting up village grain banks were provided in some areas to store one quintal of grain per family to protect children in times of scarcity.

> *"As a part of the Government's efforts to prevent deaths of children in remote and backward tribal areas due to malnutrition, a Village Grain Banks scheme was launched in 1996-97."* (PDS)

In addition to food supplementation, the health sector also screens and treats severe nutritional deficiencies within the target groups. Pregnant women are monitored for weight gain (ICDS), screened for anaemia and managed accordingly (NHP). Screening for other micronutrient deficiencies was recommended (NHP). Support was also encouraged for enhanced care during and after illness for severely and acutely undernourished children (ICDS and NNS). Proposed steps towards this also include a second *anganwadi* worker for childcare and nutrition counselling through home visits (ICDS).

Additionally, broader interventions such as female literacy, women's empowerment and autonomy in decision-making and use of resources have been listed as critical towards improved maternal and child nutrition (NNS). Engaging vulnerable communities in decision-making, seasonal nutritional screening, and scaling-up nutrition action were recommended (NAPCCHH). Only one agricultural policy mentioned nutritional support, through the development of backyard poultry among "below poverty line" families, for whom livestock rearing was identified as an important intervention for livelihood (NLM)

2.4.2. The focus on NCDs

NCDs, while recognised as a major problem, were only mentioned in few health policies (NHP, NNS, and NPCDCS) and none of the food systems policies. The interventions to tackle these challenges were largely biomedical.

NCDs were addressed in some health policies, with particular emphasis on obesity, CVD, diabetes, hypertension, stroke, and cancer (NHP and NPCDCS). Two health policies

mentioned overweight and obesity (NNS and NPCDCS), with one policy identifying obesity as being especially prevalent among urban, wealthier, and older adults, and also discussed childhood obesity as a concern indicating a double burden of malnutrition in the country (NNS). Reduction of premature mortality due to CVDs, cancer, and diabetes by 25% by 2025 was listed as a priority (NHP). However, they were not listed as cross-sectoral goals, unlike stunting (NHP), despite unhealthy diet being a major risk factor for NCDs. Though the risk of NCDs is largely determined by circumstances created by non-health sectors, the analysed policies of those sectors conspicuously make no mention of NCDs.

> "*Non-communicable diseases are expensive to treat. National strategies have to focus on prevention and health promotion as key to reduce disease burden. Health education programme that promote exercise, weight reduction, early diagnosis, screening are some of the key interventions that need to be promoted at various levels of health facilities.*" (NPCDCS)

Interventions for those vulnerable to, or affected by, hypertension and diabetes, were primarily biomedical and operationalised through the healthcare sector under the aegis of the National Health Mission in urban and rural areas (NHP). Early detection has been emphasised (NHP), and screening of blood pressure and sugar has been supported from the primary care level (i.e., sub-health centres) through auxiliary nurse midwives (ANMs), along with a referral system. "NCD clinics" were planned at sub-district and district hospitals (NPCDCS). Health promotion and counselling for behaviour change has been encouraged at all levels from sub-centre to district hospital, about diet and lifestyle management (NPCDCS). No specific interventions to prevent or control NCDs were found in agricultural, social, industrial, trade, or environmental policies.

2.4.3. Supporting healthy and balanced diets

Various policies have mentioned healthy and balanced diets in the context of (i) health implications of various food groups (ARMPD, NNS, NPCDCS 2013, PDS, and VIUC); (ii) dietary diversity (NHP, NFS, NNS, and NPF); and (iii) food safety (FSSA, NAPCCHH, and NMFP). Several interventions for supporting healthier diets were discussed: (i) food supplementation (ARMPD, ICDS, NHP, and NNS); (ii) fortification (ARMPD, NFS, NHP, and NNS); (iii) health promotion (ICDS, NAPCCHH, NNS, and NPCDCS); and (iv) regulatory and fiscal instruments (FSSA, FDIP, MEFS, MIDH, NFSA, NFSM, NHP, NNS, and NPF).

Amongst various food groups, vegetables (VIUC), edible oils and fats (ARMPD) have been explicitly mentioned as important towards a balanced diet. Other food groups listed as (or implied to be) contributing towards nutrition included fruits, milk, eggs (NNS), coarse grains (NPF), and meat (PDS). However, there was inadequate coherent and nuanced articulation

on healthy diets. Only the nutrition policy explicitly referred to a dietary guideline (i.e., Nutrient Requirements and Recommended Dietary Allowances for Indians, 2010) for informing food supplementation programmes (NNS). The health policy identified healthy diets as a priority area, but offered no further details.

> "*The policy identifies coordinated action on …priority areas for improving …health:…balanced, healthy diets…*" (NHP)

Diet has been recognised as a main risk factor for both micronutrient deficiency (NFS) and NCDs (NPCDCS). Relatively high intake of staples, such as wheat and rice, and low intake of fruits, vegetables, and animal products were associated concerns (NFS). Food groups of concern towards NCDs were:

> "*Unhealthy diet including high intake of salt, sugar and trans-fats and low intake of fruits and vegetables.*" (NPCDCS 2013)

Improving dietary diversity was identified as contributing to a healthy diet (NHP, NFS, and NNS) and as an avenue for "coordinated action" (NHP). However, it was seen as not feasible from a short-term perspective.

> "*While dietary diversification remains the most desirable way forward, supplementation and fortification require to be considered as short- and medium-term solutions to fill nutrient gaps.*" (NHP)

Standards for fortification of wheat flour and oil have been prepared (ARMPD). The use of iron and iodine-fortified salt has been recommended (NNS). The nutrition policy has encouraged other ministries to promote local processing of nutritious foods through training women's groups, strengthening supply systems (for vegetables and animal products), and improve quality of mid-day meals for children (NNS).

> "*Use SSA (universal education programme) flexi funds for kitchen gardens in/around school premises contributing to addition of local/seasonal vegetables and fruits…*" (Recommendation to Ministry of Human Resource Development in NNS)

The health sector has also used health promotion through awareness for addressing undernutrition (ICDS) and NCDs (NPCDCS). The engagement of local mothers of well-nourished children through positive-deviance-hearth approach was suggested to help mothers optimally utilise local resources for higher quality diets (NNS). State NCD cells were tasked with the responsibility to make the public aware about dietary risk factors and healthy foods. Folk media has been suggested to reach rural and urban poor communities (NPCDCS). ANMs were also expected to create awareness about healthy foods (NPCDCS). Climate change,

nutrition, and health was also planned to be incorporated into school and college curricula (NAPCCHH).

A role for Indian Systems of Medicine (AYUSH) in health promotion for lifestyle modification was also recognised (NHP). Some of these systems have a substantial focus on dietary interventions. However, this was not described in further detail.

> "*Promotion of healthy living and prevention strategies from AYUSH systems… has a special appeal and acceptability in the Indian context.*" (NHP)

A regulatory approach has been in place to ensure that food products produced by manufacturers, and claims made about food products by manufacturers or advertisers are in accordance with standards that safeguard health (FSSA).

> "*…endeavour to achieve an appropriate level of protection of human life and health and the protection of consumer's interests…with reference to food safety standards and practices.*" (FSSA)

Several regulatory and fiscal instruments have also been used to control prices of staple, nutritionally important foods such as pulses (MEFS), with recommendation to also cover milk, eggs, fruits, and vegetables (NNS). Regulations have also been made in the context of foreign direct investment in food retail, agriculture, livestock, and aquaculture (FDIP) but there was no explicit health consideration. It was also suggested that fiscal instruments could be considered to modify behaviour, but no further details were provided on commodities to be targeted.

> "*The Government could consider imposing taxes on specific commodities- such as …foods having negative impact on health...*" (NHP)

The inclusion of "nutritious millets" in the food security programme was recommended (NPF). Bio-fortified food crops were identified and promoted in a pilot scheme (NFS). Agricultural policies also supported horticulture (fruits, vegetables, nuts, and mushrooms) (MIDH), and encouraged backyard poultry among poor families (NLM). To promote access of vegetables in urban areas, production through cluster approach was also supported (VIUC). Year-round availability of certain fresh produce is an emerging demand (RKVY), with potential negative implications for seasonal foods. The promotion of several micronutrient-rich varieties of staples, sweet potato, and drumstick (*Moringa oleifera*) and effective supply to target communities was also tried in a pilot scheme (NFS).

2.4.4. Addressing health concerns beyond nutrition and NCDs

Nutrition-related concerns were not the only food systems-related health concerns in the reviewed policies (Figure 2.1). However, only few policies explicitly named specific concerns:

(i) food production-related health concerns included antibiotic resistance (NHP), agricultural injuries (MIDH, NHP, NMAET, and NPF), agrarian distress (NPF, NNS and implied in ADWDRS, ESC, MNREGS, NAPCCHH, and RKVY), and pesticide poisoning (PMB); (ii) consumption-related health concerns (besides undernutrition and NCDs) include food poisoning (FSSA) and food-borne infections (NAPCCHH); and (iii) waste management-related health concerns included various hazards associated with crop waste (NPMCR) and food waste (NMFP, NMSA, RKVY, and SWMR). Concerns related to new technologies were also discussed (BDA, FSSA, FTP, NLM, NPF, PMB, and PPVFRA). Few documents only mentioned a generic concern for health (ARMPD, BDA, FDIP, FTP, MNREGS, and PPVFRA), for instance:

> "*Safety and health norms applicable to domestically produced goods shall apply, mutatis mutandis, to imports, unless specifically exempted.*" (FTP)

To address antimicrobial resistance, strengthening pharmacovigilance against the use of antimicrobial agents as growth promoters in livestock was recommended (NHP). However, this was not discussed in the livestock policy, where the focus was more on vaccinations, animal health, and other biosecurity threats (NLM).

A common concern across health and agricultural policies was to reduce agricultural occupational injuries (to half by 2020 (NHP)), and this was identified as a cross-sectoral goal (NHP). Towards this, agricultural policies have supported mechanisation and better-adapted instruments as key interventions, especially to reduce drudgery among women (MIDH, NMAET, and NPF).

> "*Horticulture mechanization is aimed to improve farm efficiency and reduce drudgery of farm work force.*" (MIDH)

Further mitigation of agrarian distress was recommended (NPF). The categories of farmers identified as vulnerable included tribal farmers, pastoralists (issues of access to common lands, grazing, camping rights, and migration paths), plantation farmers (market fluctuations in price), and island farmers (transportation costs and natural disasters) (NPF). There was cognisance about the potential impact of climate change, which was expected to "reduce farm incomes by up to 20-25 percent in the medium term" (ESCB and NAPCCHH). Awareness campaigns about debt waiver schemes (ADWDR), farming insurance schemes (NPF and MIDH), and general extension services towards various schemes (RKVY) are planned or recommended. Assistance has been provided for promoting farmer-interest groups and farmer-producer organisations, which may strengthen their bargaining position, make production more efficient, and also reduce risk (MIDH).

Heat stress was also mentioned as a concern for farmers (NAPCCHH), and the employment scheme recommended that shade, drinking water, and childcare facilities be provided at the worksite (MNREGS). Occupational health of workers of pesticide manufacturing plants and of farmers using pesticides was of concern. Regular medical examination of pesticide industry workers was recommended (PMB). Management of misbranded or damaged pesticides were also discussed, alongside the mandated notification of cases of pesticide poisoning (PMB).

Various agricultural policies supported or encouraged progressively shifting to eco-friendly technologies, conservation of natural resources, location-specific agronomic practices, judicious use of chemicals, crop diversification, and adoption of crop-livestock farming systems (MIDH, NMAET, NMOOP, NMSA, NFSM, NPF, and WSD). While these may have an important bearing on health, it was not explicitly discussed in these policies.

Food-borne infections were mentioned in the context of climate change, with recommendations for additional capacity in food safety and nutrition monitoring (NAPCCHH). Food poisoning cases are notifiable, to enhance food safety (FSSA).

Another important concern is indoor air pollution from unclean fuels in kitchens (NAPCCHH and NHP), but this topic is beyond the scope of this paper. To alleviate health concerns raised by air pollution and carcinogens due to the prevalent crop residue-burning practices, various approaches were suggested, such as through mulching or use in industry (NPMCR). The waste management rules aimed to minimise fire hazard and nuisance of rodents, flies, birds and animals at landfills (SWM), all of which are related to food waste. Moreover, equipment, including gloves, coats, masks, and footwear were required be provided to handlers of solid waste (SWM).

> "*...minimise impact of solid waste on human health and environment.*" (SWM)

Agricultural policies have discussed biosecurity threats through import of pigs (NLM) and birds (NPF), which may carry disease-causing agents. The approaches adopted to address this include regulation of import and facilities for quarantine. Policies also mentioned human health-related concerns or discussed approaches to regulate new food products (FSSA), new pesticides (PMB), living modified organisms (BDA), plant varieties with restriction use and "terminator technology" (PPVFR), and imported products (FTP). It was stated that genetic technology also needs to be assessed for risks and benefits (BDA and NPF).

"*…to regulate, manage or control the risks associated with…living modified organisms…likely to have adverse impact on the conservation and sustainable use of biological diversity and human health.*" (BDA)

2.4.5. Involvement of health ministries in food systems governance

Intersectoral coordination for health in food systems governance was found to have occurred in two ways: (i) health policies encouraging other ministries towards nutrition-sensitive planning; and (ii) inclusion of health ministry representatives in inter-ministerial bodies.

> "*The policy articulates to institutionalise inter-sectoral coordination at national and sub-national levels to optimise health outcomes, through constitution of bodies that have representation from relevant non-health ministries… in line with the emergent international "Health in All" approach as complement to Health for All.*" (NHP)

Such articulation for inter-sectoral coordination was stronger and more specific for undernutrition, where the role of the MoHFW has been proposed as convenor of inter-sectoral action (NHP and NNS). Addressing stunting has been mentioned as a "cross-sectoral goal". Health policies mentioned other ministries more often as compared to food systems policies (Figure 2.2).

> "*A wide spectrum of national programmes contribute to improved nutrition outcomes…These include the Integrated Child Development Services…Targeted Public Distribution System, National Food Security Mission, Mahatma Gandhi National Rural Employment Guarantee Scheme…among others.*" (NNS)

> "*Policy envisages that the MoHFW would take on the role of convener to monitor and ensure effective integration of both nutrition-sensitive and nutrition-specific interventions for coordinated optimal results.*" (NHP)

Broad category of policies	Health related ministries (n=2)	Health related institutions (n=5)	Agriculture related ministries (n=4)	Other food related ministries (n=2)	Other social sector ministries (n=10)	Other ministries (n=13)
Health oriented (n=6)	0.50	0.17	0.21	0.50	0.32	0.09
Agriculture oriented (n=17)	0.15	0.04	0.28	0.27	0.12	0.10
Social oriented (n=7)	0.00	0.00	0.00	0.07	0.04	0.00
Environment oriented (n=2)	0.25	0.00	0.25	0.00	0.10	0.16
Industry and trade oriented (n=3)	0.17	0.07	0.08	0.33	0.00	0.15

Figure 2.2: Mentions of various ministries and health institutions within each policy-category; green indicates relatively higher proportion of policies mentioning the respective category of ministries; red indicates no mentions; formula: (number of policies mentioning respective ministries) / (total number of respective policies * total number of respective ministries); prepared in MS Excel 2010

While "convergence with other related departments" was also mentioned in the NCDs policy document (NPCDCS), it is unclear whether it meant convergence of departments within the health ministry or outside it, and what the objective of this convergence was. The nutrition policy has provided specific suggestions for agricultural and other sectors to focus on food and nutritional security of vulnerable groups (NNS).

> "*Promote processing of locally available nutritious foods through training of women's (groups)… and use this for nutrition communication*" (suggestion to the Ministry of Food Processing Industries in NNS)

For the priority concern of maternal and child undernutrition, leadership was under Ministry of Women and Child Development, with the MoHFW as a key partner in all the envisaged programmes (ICDS and NNS). The interventions go beyond biomedical approaches, through convergence with other ministries, such as public distribution and agriculture at the level of the *anganwadi* (ICDS).

Food systems policies either engaged MoHFW representatives in their respective inter-ministerial advisory or steering groups, or involved health institutions such as the Food Safety and Standards Authority of India (FSSAI) and the Indian Council of Medical Research (ICMR) (Figure 2.3). For example, as part of the 'General Council' instituted by the horticulture mission, representation from the MoHFW and the Ministry of AYUSH (Indian systems of medicine) were included (MIDH) (Figure 2.3).

> "*General Council will be the formulation body giving overall direction and guidance to Mission, monitor and review its progress and performance.*" (MIDH)

Of the 35 analysed policy documents, 17 had instituted inter-ministerial steering or executive groups. Of these, nine had involvement of a health-related ministry (Figure 2.3). Of these nine groups, two were regulatory (FSSA and PMB, which are related to food and worker safety) enforcing rules to safeguard health, five were advisory and oversight-related (BDA, MIDH, NFS, NLM, and NMFP, which are mainly related to food production and processing) towards policy advice and review, and two were action-oriented (ICDS and NNS, related to addressing undernutrition), which were aimed at coordinating the implementation of programmes. In food systems policies, the MoHFW found itself mainly in advisory groups. No further specifications on the role of the involved ministries were provided in these documents. Representatives of health ministries in most of these groups were those with political or bureaucratic background rather than health expertise. Some groups also involved the Indian Council of Medical Research (NAPCCHH and PMB) and the National Institute of Nutrition (PMB) in a governance role.

Among the analysed policies, the nutrition policy cross-referenced policies from agricultural and social sectors (NNS), whereas policy documents on agricultural programmes and missions only cross-referenced other agricultural policies (Additional file 1). Barring some minor additional sources, most of the agricultural (MIDH, NFS, NLM, NMOOP, NMFP, NMSA, RKVY, and WSD), social (MNREGS and NFSA), environmental (NPMCR), and health (ICDS, NAPCCHH, and NPCDCS) schemes are funded by the central and state governments (with the centre providing the majority share).

Policies	Name of inter-ministerial body	MoHFW (n=1)*	Min AYUSH (n=1)*	FSSAI (n=1)*	Other ministries (n=29)
MIDH	General Council	1	1	0	0.31
PMB	Central Pesticide Board	1	0	1	0.28
ICDS*	National mission steering group	1	0	0	0.28
NNS*	National Nutrition Mission Steering Group	1	0	0	0.24
NMSA	National Advisory Committee	0	0	0	0.24
NFSM	General Council	0	0	0	0.24
NLM	General Council	1	0	0	0.21
FSSA*	Food Safety and Standards Authority of India	1	0	1	0.21
NFS	Inter-ministerial group	1	0	0	0.17
SWMR	Central monitoring committee	0	0	0	0.17
NMOOP	High level executive committee	0	0	0	0.14
PPVFRA	PPVFR Authority	0	0	0	0.10
BDA	National Biodiversity Authority	0	1	0	0.10
NMFP	National Food Processing Development Council	1	0	1	0.07
FP	Inter-ministerial committee	0	0	0	0.07
MNREGS	Central employment guarantee council	0	0	0	0.04
NPC	National coordination action group	0	0	0	0.04

Figure 2.3: Index portraying inter-ministerial bodies instituted by the analysed policies to govern food systems in India; *health-oriented policy or ministry/institution; green indicates inclusion; yellow indicates not included; MoHFW, Ministry of Health and Family Welfare; Min AYUSH, Ministry of Indian Systems of Medicine; calculated as follows: (total number of ministries mentioned) / (total number of ministries in the category); prepared in MS Excel 2010

2.5. Discussion

The findings have been discussed in three sections, namely (i) nutrition (covering themes 1, 2, and 3 pertaining to undernutrition, NCDs, and healthy diets); (ii) other health concerns (covering theme 4); and (iii) intersectoral coordination (covering theme 5). Some of our inferences used the Health in All Policies (HiAP) paradigm, to consolidate our arguments on health considerations in food systems policies.

Nutrition

Undernutrition received relatively high policy attention. Literature affirms that there has been a strong degree of political will for addressing undernutrition in India for several decades (Rao, 2016), and this continues to exist (Thow et al., 2016; NITI Aayog, 2017). However, the NNS is

by no means a comprehensive “nutrition” strategy because NCDs and their risk factors (e.g., ultra-processed foods) have not been included. The disproportionate policy attention to undernutrition may be because it is an older problem, has relatively higher burden, and hunger is deemed unacceptable (Mail Today Bureau, 2012).

In contrast, NCDs were addressed only by health policies, for which only biomedical solutions have been instituted. This neglect of NCDs in food policy is important due to the burden of NCDs on families and the health system, and also the potential for prevention. This may be explained by the larger neglect of social and commercial determinants of health, which include, among others, the strong influence of corporations on food environments and consequently on NCDs (Lencucha and Thow, 2019; Dodd et al., 2020; Maani et al., 2020a, 2020b). The gap in health consideration in trade policies is also related to similar factors, such as the primary objective of trade policies being economic development, neoliberal ideology, and power disparities between actors (Schram, 2018), and shifting the health responsibility to the consumer (Labonté et al., 2011). These aspects have also been reflected in multi-country trade deals involving high-income countries (Friel et al., 2013). The challenge is further explainable from the continuing difficulties of health consideration even in tobacco trade policies (Drope and Lencucha, 2014; Lencucha et al., 2018b). On a similar line, “counterproductive policies”, such as those increasing access to highly processed foods, were also of concern (Thow et al., 2016). Empirical insights on mechanisms through which food trade may impact health are available (Thow, 2009; Friel et al., 2015), and there are also calls for specifically improving coherence between trade policies and nutrition goals (UNSCN, 2016). We found some coherence in identification and targeting of vulnerable groups for undernutrition, but not for other challenges. Recent literature has described policy opportunities from the perspective of policy actors to tackle the double burden of malnutrition in India (Thow et al., 2016).

Our research also showed that dietary guidelines were ignored by food systems policies. There are at least two guidelines developed in India on healthy diets. The NNS was the only policy document that mentioned one of them (NITI Aayog, 2017), and the other guideline was *Dietary guidelines for Indians*, put forth by the National Institute of Nutrition (NIN, 2011). The latter claims that it could be considered towards reaching “the goals specified in the National Nutrition Policy” (NIN, 2011).

The nutri-farm scheme was the only agricultural policy explicitly addressing undernutrition (NFS). However, while the objective of the NFS was to improve dietary diversity, it surprisingly focused predominantly on cereals. This may reflect the perception of fortified cereals as a ‘silver-bullet’ for undernutrition, and also the preoccupation with production and food security. A few other policies, such as the livestock and horticulture missions, have potential for stronger nutritional thrust, as was recognised for the latter in an earlier study (Thow et al., 2016).

Other health concerns

Concerns related to agricultural injuries, antibiotic resistance, food safety, crop-residue burning, and food waste disposal were identified. With the majority of India's working population dependent on agriculture (Chowdhury, 2011), designating agricultural injuries as a priority concern was understandable. However, aspects related to mental (Das, 2011) and social wellbeing of agrarian households (Rao et al., 2017) was not adequately addressed. For instance, there was no mention of farmer suicides. As these challenges are driven by agricultural and economic policies, they may be most efficiently dealt with at that level.

Health impacts due to crop-residue burning (Vasudeva, 2018) has recently started receiving attention from the public health sector (Ravindra et al., 2019). Avian flu and other zoonoses were inadequately discussed in the included policy documents, but health system measures to address these for humans (Government of India, 2020a) and animals (Government of India, 2020b) were in place. While antibiotic resistance due to use in livestock production was mentioned as a concern in the health policy, it was missing from the livestock mission, demonstrating another gap in coherence. Overall, the impacts of food system policies on various health risks and outcomes (whether positive or negative) are potentially incidental rather than planned.

Inter-sectoral coordination

The NNS and the NHP emphasised intersectoral coordination to address undernutrition, possibly also because they were released in 2017 after the launch of the 2030 Agenda for Sustainable Development. A cautionary note is that similar calls for intersectoral coordination were made in the 1993 National Nutrition Policy, but those aspirations were not adequately realised (Rao, 2016). From the NHP, it appeared that the health ministry felt it within their power to employ nutrition-specific interventions such as food supplementation, but beyond their immediate power to address dietary diversity.

The NHP recognised the potential of inter-ministerial bodies "to optimise health outcomes", bearing relevance for operationalising "Health in All". Literature suggested that there were limitations to positing health as the main argument for developmental planning and interventions (de Leeuw, 2017), and hence, involvement of the health ministry in "advisory" roles in many of these groups may be an adequate starting point. The impact of this involvement would have to be studied through different data.

Health considerations in food policy may also be more challenging due to the complex nature of causal linkages, as compared to, for example, asbestos regulation, for which the health basis for policy intervention is straightforward (Kanchanachitra et al., 2018). To foster healthier

food systems, there were suggestions to improve the understanding about nutrition among agricultural policymakers (Gillespie et al., 2015), linking policy agendas across sectors (Thow et al., 2018), advocacy (Thow et al., 2016), and also build relationship between food systems actors (James et al., 2017), which the nutrition policy (NNS) has shown some intention of doing. Another recommendation was for improved data from the health and agricultural sector to provide feedback on the impact of policy interventions (Thow et al., 2018), but approaches to strengthen data systems were only discussed in passing in the health policies (NNS and NHP). The ICDS scheme is an example of a programme incorporating nutritional and other goals at upstream planning level with downstream coordinated implementation at creches.

General contributions

To our knowledge, this is the first paper that considered a broad range of health outcomes while studying food systems policies, in contrast to the usual focus on undernutrition and NCDs. Our method helped navigate and weave together diverse findings from a range of sectors. The empirical findings on the policy focus on undernutrition may resonate with other low- and middle-income countries, but those on the involvement of the health ministry in food systems governance may be more widely relevant. Various typologies were offered through the study: (i) factors contributing towards vulnerability to undernutrition; (ii) responses towards undernutrition; (iii) topics pertaining to healthy and balanced diets; (iv) non-nutritional health concerns of food systems policies; (v) broad approaches to intersectoral coordination for health; and (vi) specific types of involvement of the health ministry in food systems governance. Each of these may be of value for research in other settings and/or for policy analyses of other sectors.

Limitations

The focus of the analysis was limited to national level policy. The Constitution of India has divided responsibilities related to food systems between national and state governments. For example, international trade and establishment of food standards are on the national list; agriculture, animal husbandry, irrigation, land, and markets are on the state list; and social security and trade in food stuff are on the concurrent list (Government of India, 1950). Hence, a better view of the policy landscape could be achieved by analysing policy content from one or more states in India in addition to what has been done here. For example, irrigation, a state subject, has several associated health risks, such as VBDs (Keiser et al., 2005). However, national-level policy has considerable influence on local action (Government of South Australia and WHO, 2017), and most of the funding for food systems-related programmes stems from the national government, and so it was worthwhile focusing on national policies to start with.

A richer picture on operationalisation and practice of policies would emerge through key informant interviews in addition to document analysis. Furthermore, some food-group specific policies, which may have had important implications for health have not been included, for example the so-called “beef ban” policy. There was no clear policy document, and there were state-level variations on how these have been implemented. However, such policies have important repercussions on health, especially for marginalised groups (Sathyamala, 2018).

2.6. Conclusions

In food systems policy in India, undernutrition was considered to some extent, NCDs were completely ignored, and details on other health concerns were often superficial. Some evidence of intersectoral coordination and policy coherence were found for the management of undernutrition, but not for any other health outcomes. Policies spearheaded by the health ministry for nutrition-specific interventions, such as the ICDS, best exemplified ideas and actions for intersectoral coordination for better health outcomes. The participation of health ministry representatives in few advisory groups of food production and processing policies theoretically provided an avenue for fostering health considerations in those areas, but such groups were not found for the included social and trade policies. Policies were understandably focused on sectoral objectives, including productivity, economic development, technology or environmental protection. Gaps from the health perspective warrant further policy attention to help address the double burden of malnutrition, and also the several other relevant health concerns.

The COVID-19 pandemic further highlighted the vulnerabilities of food systems and their health ramifications in India and elsewhere (Galanakis, 2020; Nestle, 2020), emphasising the need for broad analyses, as was presented here. Our study contributed potential methods and typologies for such analyses. Our findings also set the stage for further studies on specific health concerns, specific inter-ministerial and policy interlinkages, and also similar research in other development sectors.

Additional file 1

Policies	RKVY	MNREGS 2008	MIDH 2014	NFSM	FSSA 2006*	NMSA 2014	VIUC 2011	CPDS 10FYP	FTP 2015	NLM 2016	NMOOP 2014	NNS 2017*	BDA 2002	FP 2015	ICDS *	NFSA 2013	NHP 2017*	NMAET 2012	NMFP 2013	NPC 2013	NPF 2007	PMB 2017	PPVFRA 2001
NNS 2017*	1	1	1	1				1				1			1	1	1			1			
NMSA 2014	1	1	1	1			1			1	1							1	1				
NPF 2007	1	1	1	1							1		1	1									1
MIDH 2014	1	1				1	1																
RKVY		1	1	1			1																
NLM 2016	1	1								1													
FSSA 2006*									1													1	
NFS 2013	1											1											
VIUC 2011	1		1																				
FP 2015																					1		
FTP 2015									1														
NAPCCHH 2016*						1																	
NFSA 2013								1															
NHP 2017*					1																		
NMFP 2013					1																		
NMOOP 2014						1																	
NPMCR 2014	1																						
PMB 2017					1																		
Total policies citing this policy	**8**	**6**	**5**	**4**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Figure 2.4: Cross-references by policies to other policies in the sample; Green indicates reference to current policy or scheme; red indicates reference to the service rather than the policy; and yellow indicates reference to an older policy in the same domain;*health-related policy document; Policies which were not cross-referenced by any other policies: FDIP, NAPCCHH, NFS, NPCDCS, NPMCR, SWMR; policies not cross-referencing any other policies from the sample: BDA, CPDS, FDIP, ICDS, MNREGS, NFSM, NMAET, NPC, NPCDCS, PPVFRA, SWMR; WSD cross-referenced MNREGS and MIDH, but was not included here due to lack of space

Additional file 2 – coding scheme

Table 2.2: Coding scheme

Themes	**Categories**
Undernutrition recognised and addressed as cross-sectoral concern	Under-nutrition related, nutrition security, obesity related; vulnerable groups, household food security, food security, food affordability, health systems responses to undernutrition
The focus on NCDs	Chronic-disease related, health systems responses to NCDs
Supporting healthy and balanced diets	Food groups, food diversity, food safety, food supplementation, food fortification, health promotion, regulatory instruments, fiscal instruments
Addressing health concerns beyond nutrition and NCDs	Other health problems, generic health concerns, environmental sustainability, animal health, trade and business, other health determinants
Involvement of health ministries and institutions in food systems governance	Health sector as lead agency, inter-ministerial groups involving health sector, inter-ministerial groups without involving health sector, health being encouraged in other sector action, health through intersectoral action, resources for action

3. Perceived health impacts of watershed development projects in southern India: a qualitative study

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3.1. Abstract

Watershed development (WSD) projects—planned for over 100 million ha in semi-arid areas of India—should enhance soil and water conservation, agricultural productivity and local livelihood, and contribute to better nutrition and health. Yet, little is known about the health impacts of WSD projects, especially on nutrition, vector breeding, water quality and the distribution of impacts. We conducted a qualitative study to deepen the understanding on perceived health impacts of completed WSD projects in four villages of Kolar district, India. Field data collection comprised: (i) focus group discussions with local women (n = 2); (ii) interviews (n = 40; purposive sampling) with farmers and labourers, project employees and health workers; and (iii) transect walks. Our main findings were impacts perceived on nutrition (e.g., food security through better crop survival, higher milk consumption from livestock, alongside increased pesticide exposure with expanded agriculture), potential for mosquito larval breeding (e.g., more breeding sites) and through opportunistic activities (e.g., reduced mental stress due to improved water access). Impacts perceived varied between participant categories (e.g., better nutrition in woman-headed households from livelihood support). Some of these findings, e.g., potential negative health implications, have previously not been reported. Our observations informed a health impact assessment of a planned WSD project, and may encourage implementing agencies to incorporate health considerations to enhance positive and mitigate negative health impacts in future WSD projects.

Keywords: agriculture; India; livestock; nutrition; vector-borne diseases; watershed development project

3.2. Introduction

India is an agrarian nation. Indeed, data for the year 2011 revealed that among the total working adult population of 482 million, 263 million (54.6%) were dependent on agriculture for their livelihood, including 144 million (30.0%) as wage labourers (Government of India, 2019). Of the net-cultivated area, around 56% is rain-fed (Government of India, 2017b). Agriculture in India faces several challenges, such as land degradation (Reddy, 2003; Ajai et al., 2009) and depletion of groundwater (Shiferaw et al., 2008). India is also vulnerable to climate change (O'Brien et al., 2004; Hijioka et al., 2014), which is projected to affect agriculture through increased mean temperature, increased mean precipitation and a decrease in rainy days (INCCA, 2010). These challenges are of particular concern to marginalised and small farmers (Panda, 2017) (those owning less than one and two ha of land, respectively (Government of India, 2019)). In order to address these challenges in semi-arid areas, several pathways have been suggested, including watershed development (WSD) (IISc, 2014).

The Government of India has defined WSD as "*the conservation, regeneration and the judicious use of all the resources—natural (land, water, plants and animals) and human—within the watershed area. Watershed management tries to bring about the best possible balance in the environment between natural resources on the one side and man and animals on the other*" (Government of India, 2018a). WSD projects involve several physical, ecological and social interventions. Physical interventions support soil and water conservation through structures such as contour bunds, gully plugs, plantation and vegetative checks, ponds and wells, trenches, check dams and land-levelling (Meenakshi and Ramanathan, 2010). Ecological interventions include support to horticulture and pastures (Government of India, 2011). Social interventions include the creation of local management institutions and livelihood opportunities (Lele et al., 2007; Government of India, 2011). These interventions, which are made at the level of a cluster of villages in semi-arid areas over a period of 4 to 7 years, are expected to enhance and sustain agriculture and livelihoods (Government of India, 2011). While soil and water conservation projects have been implemented by the Government of India and non-governmental organisations (NGOs) through various schemes over decades, WSD projects are in operation since the early 1990s, and common guidelines were reissued in 2008 (and revised in 2011), which have since formed the basis for WSD projects (Government of India, 2011).

Literature from high-income countries have addressed "watersheds" as a geographical unit that needs to be managed appropriately to have optimum impacts on ecology, human development and public health (Kolok et al., 2009; Bunch et al., 2014; Jordan and Benson, 2015). Water quality in rivers and surface water bodies was the main health issue addressed (Davies and Mazumder, 2003; Schmidt et al., 2013; Herrera et al., 2017). A review on

watershed management and public health highlighted specific concerns such as microbiological contaminants, and indicated that health and social concerns have, thus far, not been reported adequately (Bunch et al., 2014). Prior research from Ethiopia on the impact of soil and water conservation in semi-arid areas revealed that most farmers perceived positive impact of water-holding structures on agricultural productivity (Wolka et al., 2013).

A meta-analysis of over 600 WSD project evaluations in India showed positive impacts on increasing income, improving local employment opportunities (151 person-days per ha), higher crop yields, greater cropping intensity (35.5%), groundwater recharge, decrease in run-off (45%) and soil loss (1.1 ton per ha), contributing to social capital and reduction in poverty (Joshi et al., 2008). Positive impacts on livelihoods and milk production were also reported by an NGO in the state of Maharashtra in western India (Pandit, 2010; Pandit and Zade, 2012), where growth monitoring and child nutrition were incorporated as part of WSD project activities. A participatory evaluation from northern India also revealed perceived positive impacts on income, awareness and women's empowerment (James et al., 2002). These studies illustrate the impact of WSD projects on well-being and the local environment.

In addition to potential socioeconomic impacts, WSD projects have considerable potential for community health impact through influencing agriculture, water and livelihoods. From the Indian context, only three peer-reviewed journal articles describing the linkages between WSD and health were found, all conducted by Nerkar and colleagues. From a cross-sectional study, they found lower diarrhoea prevalence in watershed villages as compared to comparison villages (Nerkar et al., 2015). This quantitative paper was complemented by two qualitative studies. The first reported local people having perceived reduced water-borne diseases, reduction on workload on women due to water access, reduction in alcohol consumption, improved socioeconomic status (SES), support to education and women's empowerment (Nerkar et al., 2013). The second qualitative study with local health and development workforce reported perceived reduction in water scarcity, better access to sanitation and improved local agriculture, resulting in positive impacts on SES, educational and health status in communities affected by the WSD project (Nerkar et al., 2016). A limitation of the studies by Nerkar and colleagues is that they were conducted in a hilly tribal area in Maharashtra, thus representing one specific geographical and socio-cultural context. WSD projects in other regions may include additional locally-relevant activities potentially leading to different types of impacts (Mishra and Saxena, 2009). In addition, other health impact pathways, for instance, on nutrition, vector breeding, water quality and also the distribution of impacts within the population were not adequately explored. In summary, considerable knowledge gaps exist on the interlinkages between WSD projects and associated health impacts in India.

The objective of this paper was to describe and better understand the types of WSD project-related health impacts (positive and negative) as perceived among community members and

local organisations from a semi-arid agricultural area in Kolar district, southern India. The main value of this pursuit is due to WSD projects being planned for degraded and rain-fed regions in India covering an area of 146 million ha and 85 million ha, respectively, poised to benefit millions of households (Government of India, 2011). A high-level committee also envisioned WSD projects as an "*umbrella to unite all development programmes*" in rural areas, including those instituted by the Ministry for Health and Family Welfare on issues such as undernutrition (Technical Committee on Watershed Programmes in India, 2006). Therefore, this study contributes to the literature on how completed WSD projects have impacted health, by addressing some of the identified gaps. The research was conceptualised as an exploratory study to be followed by a health impact assessment (HIA) (Winkler et al., 2010) of a newly planned WSD project in the same region.

3.3. Materials and methods

3.3.1. Design and study setting

We designed a qualitative study, incorporating various methods, including semi-structured interviews, focus group discussions (FGDs) and transect walks. Interviews and FGDs were conducted with local people, NGO officials, field workers (project employees), local health workers, an environmental health academician and a WSD expert. The theoretical underpinning of our study was that WSD projects affect local well-being, the environment and livelihood – which are all determinants of health – and therefore also have potential to impact health, which can be appreciated and reported by people who participated. In addition, though our approach was largely interpretative (through asking open-ended questions on perceived health impacts), we also incorporated positivist elements (specifically prompting participants to consider plausibly relevant diseases informed by existing literature, as discussed later), to address our study objectives. These theoretical aspects informing the research design were described based on the qualitative research manual by Green & Thorogood (2004).

Our study was carried out in Kolar district in Karnataka state (Figure 3.1), classified under the "South Eastern Dry Zone", where a high vulnerability has been projected for surface and groundwater, with increased winter-time drought occurrence (University of Agricultural Sciences - Bangalore, 2011). Purposive sampling was applied for the selection of study villages. In a first step, NGO officials were invited to list and describe all recently completed WSD projects (four projects in total, completed 2–10 years prior to our study, as illustrated in Figure 3.1). Subsequently, one village from each WSD project was selected (Table 3.1).

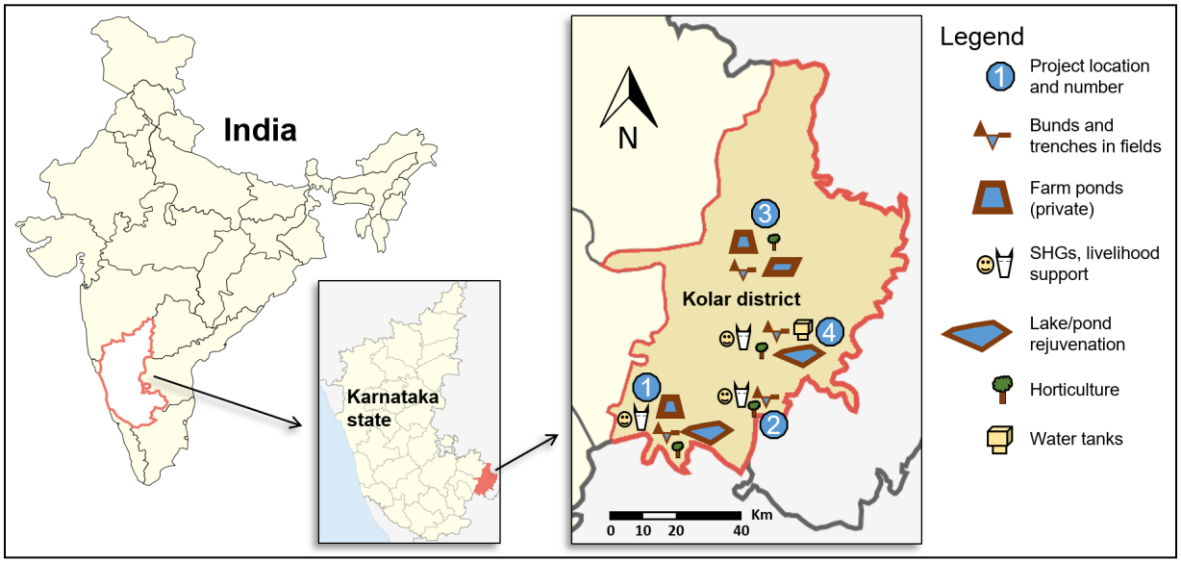

Figure 3.1: Map showing approximate locations of completed WSD projects included in this study and components of each project (modified from images by 3xK and PlaneMad, respectively, distributed under a CC-BY 2.0 license); SHG, self-help group

Table 3.1: Characteristics of the four study villages in Kolar district, southern India where watershed development projects were implemented (taken from Census, 2011).

Village Characteristics	Village 1	Village 2	Village 3	Village 4
Sub-district	Malur	Bangarpet	Kolar	Bangarpet
Distance to sub-district headquarters (km)	26	44	10	20
Total households	181	187	92	46
Total population	879	676	454	211
Scheduled caste population (%)	15.6	47.0	15.4	0.0
Scheduled tribe population (%)	24.6	6.5	0.0	100.0
Geographical area of village (ha)	440.6	777.6	87.2	151.8
Distance to primary health centre (km)	5-10	5-10	5-10	5-10
Water supply	Available	Available	Available	Available
Governmental crèche (*anganwadi*)	Available	Available	Available	At nearby village

3.3.2. Data collection

Initially, two FGDs adhering to methods described by van Eeuwijk and Angehrm (2015) were conducted with women of working age in the first study village. Following this, a total of 40 semi-structured interviews employing methods described by Britten (1995) were conducted with the following types of participants: (i) local people (both land-owning and landless) (n = 26); (ii) local health workers (n = 5); (iii) field project staff (n = 4); (iv) project managerial staff with experience in WSD (n = 3); (v) one senior environmental health academician; and (vi) one senior WSD project manager from another region and organisation. The sampling strategy was "purposive" (Marshall, 1996; Green and Thorogood, 2004) to ensure representation based on land ownership, access to irrigation, gender and caste. Participation in WSD project activities was a pre-requisite for those selected for interviews as we were interested in understanding perceived impacts, which would be better articulated by those who participated

(Green and Thorogood, 2004). As specific activities of the WSD project were targeted to sub-groups of the population, we interviewed land-owning persons (for insights on impacts of agriculture-related activities), landless persons (for insights on impacts of livelihood activities), men (for insights on activities performed by men) and women (for insights on impacts on activities performed by women) accordingly. The number of participants for interviews was not pre-decided. Interviews were continued until no additional insights on health impacts of WSD projects were obtained from further interviews, and we were able to validate findings across study sites and participant categories (Green and Thorogood, 2004). Most of the interviews were conducted in July and August 2018. A few additional and follow-up interviews were carried out in December 2018 and November 2019. The time interval between phases of interviews were used to analyse the data which helped frame new issues to explore in future interviews. These intervals did not affect the nature of the responses, as all the projects had already been completed 2–10 years prior to our data collection.

Participants were introduced to the interviewer by a local liaison. The interviews were conducted by the first author in Kannada language (except those with managers, experts and academicians were conducted in English). Potential participants were first informed about the research. After obtained informed consent, the interviews were conducted and audio-recorded. Most interviews with land-owning farmers were done on the spot in the agricultural fields. Interviews with the landless were conducted at their homes or in a community hall. FGDs were conducted at a vacant house. Occasionally, children and other family members were present during an interview. A field research journal was maintained to make notes of observations and interactions based on the method described by Phillippi and Lauderdale (2018).

Following initial interviews in each village, a transect walk, as described by Loewenson and colleagues (2014), was conducted with the local liaison to see the WSD-related structures mentioned in the interviews and to observe other factors that might influence health. Interview guides were used for the interviews and FGDs. The topics included in these guides were based on impact pathways described in relevant literature (Pandit, 2010; Pandit and Zade, 2012; Nerkar et al., 2013, 2015, 2016; IOM (Institute of Medicine) and NRC (National Research Council), 2015), brainstorming on potential health impacts and impact pathways (Figure 3.2) and insights gained from initial interviews (Green and Thorogood, 2004). Broadly, the topics covered in the interviews were: status of agriculture (i.e., productivity, crop choice and irrigation), wage labour, access to food, water, sanitation and health (i.e., infectious diseases, non-communicable diseases, injuries and access to healthcare), participation in WSD projects and perceived impacts of WSD projects on agriculture (i.e., productivity, output, irrigation and crop choices), water (i.e., conservation and access), livelihood, food (i.e., food security and dietary diversity) and health (e.g., nutrition, vector-borne diseases (VBDs), pesticide use, injuries and access to healthcare).

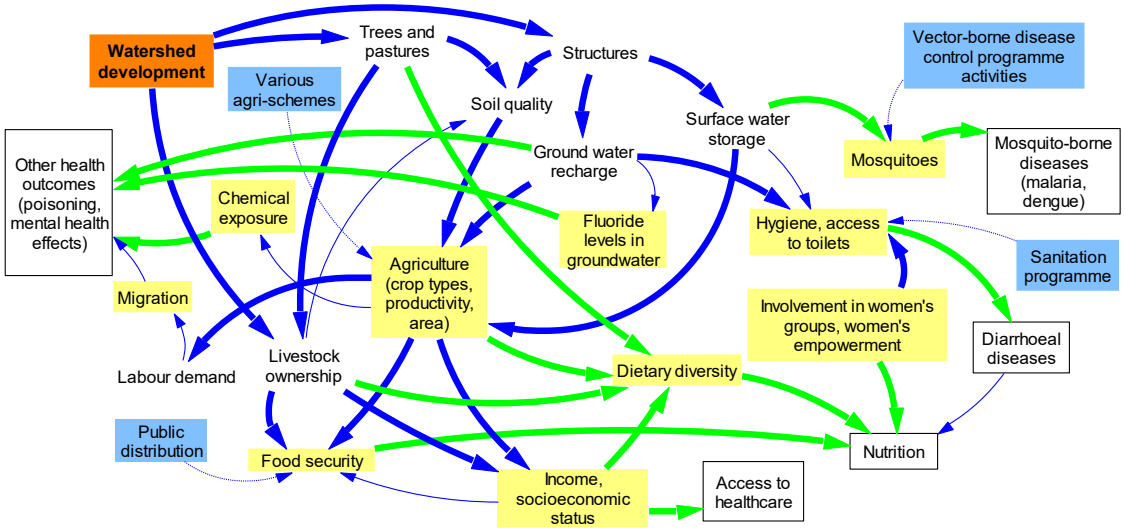

Figure 3.2: Potential pathways to health impacts of WSD projects; thick blue arrows indicate project activities and expected outcomes; blue boxes and dotted arrows indicate governmental programmes; yellow boxes indicate health-determining impacts; thick green arrows indicate potential health impact pathways; white boxes indicate potential health impacts of WSD projects

3.3.3. Data management and analysis

The recorded interviews were transcribed directly into English by the first author (AP). Some initial transcripts were reviewed by the second author (AM). The analysis used the framework method described by Gale and colleagues (Gale et al., 2013), with additional inputs on thematic analysis from Braun and Clarke (2006). The transcripts were read and re-read, and a coding scheme was developed through deductive and inductive approaches. The transcripts were loaded onto OpenCode 4.03 software created at Umeå University (Umeå, Sweden) (ICT Services and System Development and Division of Epidemiology and Global Health, 2013). After coding a few transcripts, a working analytical framework was developed, and the codes and categories were defined. The framework was applied to the entire dataset and updated when necessary. Coding was done by the first author. The codes are listed in Table 3.2. After coding, the data were summarised and charted into the framework matrix. Interpretation of the data was done by characterising the data and identifying agreement between data especially within groups in a village, between projects and between local people and key informants. Attempts were made to understand the reasons for the emergence of the identified phenomena (Gale et al., 2013). To describe and explain perceived health impacts of WSD projects, themes were identified through further interrogation within and between categories (Braun and Clarke, 2006; Gale et al., 2013). The consolidated criteria for reporting qualitative research (COREQ) were used to adhere to reporting standards (Tong et al., 2007).

The first author (AP, male) is a medical and public health graduate, currently pursuing a PhD in epidemiology. He has worked on climate change vulnerability in WSD project areas for five years. He is trained in qualitative research. AM (female) is a medical anthropologist (with a

PhD), currently a university professor in India. She is familiar with local nutritional and development challenges. JU (male) is a university professor (with a PhD) with vast experience in epidemiology, environmental sciences and public health, and has supervised PhD students from several countries. MSW (male) is an environmental epidemiologist (with a PhD), head of the HIA research group at the Swiss Tropical and Public Health Institute, and has worked in several countries on health impacts of developmental projects.

Table 3.2: List of codes and themes used during the analysis.

Themes	Sub-themes	Codes
Pathways towards nutritional impacts	Direct impacts on food security and nutrition; income-mediated impacts on food security and nutrition	Crop choices, irrigated agriculture, rain-fed agriculture, financing agriculture, agri-inputs, wildlife and pests, surface water irrigation, food security, diet, wage labour, livestock, self-help groups, common lands, migration, nutrition, chemical toxicity, participation in WSD project, tree-planting, livelihood activities, impact on water and soil conservation, impact on food production, impact on wage labour, impact on livelihood and impact on nutrition
Impacts on disease vector ecology		Mosquitoes, vector-borne diseases, watershed structures, impact on local environment, impact on mosquitoes and vector control activities
Health impacts of opportunistic activities		Hygiene, drinking water quality, diarrhoeal diseases, other work-related health problems, access to healthcare, creating local institutions, other structures created, health activities, water for domestic use, impact on awareness, impact on sanitation and other health impacts

3.3.4. Ethical considerations

This study obtained ethical approval from the Padmashree Institute of Clinical Research in Bengaluru, India (reference no. IEC-BIO-004; approval date: 10 August 2018) and the Ethics Commission of Northwestern and Central Switzerland (EKNZ, reference no. BASEC Nr Req-2018-00839, approval date: 19 October 2018). The purpose and procedures of the study were explained to the participants and informed consent (in the local language) was obtained prior to the interviews. An information sheet prepared in local language about the project and the contact details of the main investigator was handed over to participants and local liaisons. The data have been stored on a server at the Swiss Tropical and Public Health Institute (Basel, Switzerland), in an anonymised manner. At the time of writing this manuscript (April 2020), dissemination of findings to the NGO has already been initiated.

3.4. Results

The themes ‘Pathways towards nutritional impacts’, ‘Impacts on disease vector ecology’ and ‘Health impacts of opportunistic activities’ addressed the emergent health-related impacts of WSD projects in the study area. Details of the participants are provided in Table 3.3.

Table 3.3: Details of interviewed persons.

Participants	Number (%)	Average duration - minutes (SD)
Local people (*n* = 26)		
Men [average age (SD): 40.5 years (11.4 years)]	13 (50)	23.4 (10.1)
Women [average age (SD): 46.2 years (12.7 years)]	13 (50)	19.6 (7.9)
Scheduled caste	4 (15)	15.5 (2.4)
Scheduled tribe	9 (35)	16.8 (6.4)
Other caste	13 (50)	26.6 (9.4)
Land-owning, with irrigation	12 (46)	25.4 (7.9)
Land-owning, without irrigation	5 (19)	21.5 (15.7)
Landless	9 (35)	19 (2.5)
Key informants (*n* = 14)		
Field health-worker	5 (35.7)	16.8 (4.6)
Field project staff (liaison)	4 (28.6)	29 (6.2)
Project managerial officials	3 (21.4)	37.3 (18.5)
WSD expert (other region)	1 (7.1)	92
Environmental health academician	1 (7.1)	81
FGD participants (*n* = 2; with 12 participants)		
Female [average age (SD): 42.5 years (14.5 years)]	12 (100)	27 (5.7)

FGD, focus group discussion; SD, standard deviation; WSD, watershed development.

Quotes by local people have been labelled with gender, land ownership, caste (scheduled caste as SC; scheduled tribe as ST; other castes as GC) and age. Quotes by key informants are labelled with type of informant and a serial number.

3.4.1. Pathways towards nutritional impacts

Direct impacts on food security and nutrition

Pathways for direct impact on food security and nutrition included better survival of staple crops, fruit trees, vegetable production and milk from livestock. It was perceived that rain-fed staple crops such as finger millet were "*better-off*" (land-owning female, GC, 38 years) as WSD structures helped them survive "*even when there is no rain for some days*" (land-owning female, GC, 60 years), leading to "*increased*" production (land-owning male, GC, 38 years). Additionally, through improved soil and moisture, "*land for agriculture has increased*" (land-owning male, GC, 63 years) as fallow lands have been "*brought under production*" (NGO manager 2). Both these aspects were especially important for small farmers without irrigation access.

Simultaneously, during recently implemented WSD projects, farmers were encouraged to adopt water-conserving technologies such as drip-irrigation using available subsidies. Mulching paper was also privately adopted by vegetable farmers. These technologies helped increase yields as they doubled the irrigated area "*with the same volume of water*" (land-owning male, GC, 36 years). While these technologies and other interventions such as farm ponds led to more farmers taking up vegetable cultivation, they did not neglect the cultivation of staple crops for their household needs:

> "*For home use, we grow finger millet surely, and pigeon peas and flat beans. If we ignore that, and plant other crops in those lands and do not get returns…it will be difficult.*" (land-owning male, GC, 35 years).

However, many small farmers removed the WSD structures from their fields to reclaim land that was "*lost to the bunds and trenches*" (land-owning male, GC, 63 years). In two areas, enrolment itself was low due to the feeling that land "*will get wasted*" (land-owning male, GC, 38 years). This may have affected food security of their households. Unrelated to WSD, in some areas the recent "*nuisance*" of deer, pigs, elephants and peacocks had affected production of staple and commercial crops (land-owning male, GC, 35 years).

WSD may have marginally improved vegetable production in two ways: increased land productivity, and supporting drip irrigation and farm ponds. These impacts were evident in one remote village where vegetable production reportedly increased considerably after the project. Farmers also mentioned that cultivated vegetables were consumed regularly in their households, and wage labourers received "*beans, tomato, radish, carrot, beetroot, whatever was being grown*" (landless female, ST, 45 years), especially "*smaller and broken*" vegetables, to take back home (landless female, ST, 55 years). Vegetables also reportedly became more easily available at the villages.

Saplings of guava, pomegranate, custard apple, mango and plum were provided for planting on private and common lands through the projects, but "*few of them survived*" due to poor rains (landless female, ST, 45 years). Better survival and growth was noticed for "*trees near the farm ponds and check dams*" (NGO fieldworker 4), the former often adopted by those with larger holdings. In more recently completed WSD projects, the trees were still young, and people mentioned that they would "*eat the fruit*" when they were borne (local health-worker 3). Landless families that invested the financial aid in livestock were now able to "*consume milk regularly*" (landless female, ST, 37 years). This was perceived to have contributed to children becoming "*healthy*" (NGO manager 3).

On the other hand, it was felt that people were "*using lots of pesticide*" in vegetable farms (NGO manager 3), contributing to increased exposure to pesticides. However, improved soil quality has reportedly allowed farmers to manage "*with less fertiliser*" (land-owning male, GC, 63 years). Another impact was "*increased workload*" on women in households cultivating vegetables through irrigation (NGO fieldworker 1). Women were involved in "*sowing seeds and removing weeds*" (NGO fieldworker 1), which need to be done manually, unlike men's work that "*can be done by machines*" (land-owning female, GC, 35 years).

Income-mediated impacts on food security and nutrition

Several landless households in remote villages did "*not have enough to eat*" but the situation became "*much better*" following the WSD project (landless female, ST, 45 years). These households were also often woman-headed and from SC or ST. While the governmental "*ration shop*" contributed to food security (FGD, landless women), livelihood support through WSD projects considerably enhanced food security and nutrition through the income route. NGO officials perceived that "*more varieties*" of food products were consumed following the projects due to better income and awareness (NGO manager 2). This was reciprocated, especially by beneficiaries of livelihood support who felt "*everything has changed*" (landless male, ST, 28 years), including increased consumption of milk and meat.

Support for livelihood was directed to landless households and were carried out through creation of new and strengthening of existing self-help groups (SHGs, savings groups composed of around 10 members). The mechanism was through provision of small grants and loans, for example in one project it amounted to "*Rs. 10,000 as grant and Rs. 15,000 as loan*" (NGO manager 3). Women also were trained on "*taking loans, how it could be used for livelihoods and investment*" (landless female, ST, 45 years). The "*focus on animal husbandry has been high*", which provided "*good returns*" (NGO fieldworker 4). "*People who were unable to go for daily wage*" (land-owning female, GC, 60 years), were now able to earn a reasonable livelihood by "*taking care of cows and sheep*" (landless female, ST, 37 years).

> *"I had bought one (cow), and eventually bought four. Now I have two, but have kept 20 sheep too. I did not have cows or sheep earlier. I only worked for daily wage."* (landless female, ST, 37 years).

Similarly, some poor households that invested in livelihoods were able to build on it to improve their quality of life considerably. One beneficiary who earlier was a wage carpentry labourer "*bought tools and started own business*" using grants and loans provided (landless male, ST, 28 years). Eventually he "*hired people to work*" for him and also "*bought two bikes*" (landless male, ST, 28 years).

One participant "*had planted 400 trees of many varieties*" through the project and felt he "*would have been rich*" had it rained at the right time (land-owning male, GC, 50 years). A prolonged drought shortly after the completion of the WSD project which further contributed to agricultural debt and unpredictability of labour opportunities, may have impacted on potential benefits of the WSD project. Indeed, several households started travelling regularly for work due to prospects of "*better income in Bengaluru*" and elsewhere (land-owning male, GC, 50 years). Members of some households reportedly travelled during the dry season, while some have migrated permanently. For some of these households, it may have been because of inability to invest the livelihood grant.

> *"They gave us Rs. 7,000…told us to buy a goat and grow the money...but we did not …we just used it for our regular expenses."* (landless female, SC, 68 years).

In another village, one woman cared for 20 custard-apple trees planted on common lands during a WSD project. She "*sold the fruit*" regularly for side-income (landless female, ST, 55 years). Large farmers of perennial rain-fed crops such as mango were highly benefited by WSD projects, but these farmers were already earning well, and less concerned about food security.

> *"We put bunds in 10 acres of mango plantation. I was not getting good yield earlier. Once it rained next year, the water was held in the soil in my field and the plants developed well. We got 5 tonnes earlier, then we got 10–15 tonnes and now we get even up to 25 tonnes."* (land-owning male, GC, 63 years).

3.4.2. Impacts on disease vector ecology

As part of the WSD projects, water-holding structures such as check dams, farm ponds and drinking-water troughs for cattle were constructed and open wells were encouraged (Figure 3.3). In addition, lakes and ponds were revitalised. These structures could potentially breed mosquitoes if they hold water for sufficient time. However, local people and NGO officials did not notice any increased mosquito nuisance or larval breeding in these structures and did not perceive any risk.

WSD projects "*encouraged conserving water using open farm ponds*" of which several were created (NGO manager 3). These could hold water "*between rainy season and summer for 6 months*" (local health-worker 2), but those ponds with loose soil did not hold water "*for even 8 days*" after rainfall (NGO fieldworker 4). Those with large fields empty the farm pond each day for irrigation, and then refill it with groundwater.

Some "*mini-check dams were constructed*" (NGO manager 3), which held water "*for 2–3 months*" following rains (NGO manager 3), and one was noted to "*always have at least some water*" (land-owning male, ST, 32 years). In one project area, public "*water troughs for cows*" were made that reportedly were always full (land-owning male, GC, 36 years). "*Open wells were promoted*" too (NGO manager 2); however, most "*wells do not hold rainwater*" for long (land-owning male, GC, 63 years). One well near a mini-check dam held "*water for 6 months*" following adequate rains (land-owning male, GC, 38 years). One lake re-vitalised by creating a mini-check dam through the project "*gets filled*" after rains (NGO fieldworker 4).

Figure 3.3: Water-holding structures created and encouraged as part of WSD projects: (a) check dam (without water); (b) farm pond (with tarpaulin lining); (c) open well; and (d) water trough for cattle (source: first author; images captured during transect walks)

It was perceived by local people and NGO workers that these water-holding structures had not contributed to any increase of mosquito nuisance. One official felt that "*mosquitoes usually go where there is pollution, like in the drains*" and had "*never seen mosquitoes*" in water-holding structures (NGO manager 2). One fieldworker opined that "*only if there is less water some mosquitoes may grow*" (NGO fieldworker 3). Local people mentioned that check-dams and farm ponds "*have been made outside the village. So, there is no problem about mosquitoes*" because of the distance (land-owning female, GC, 35 years). Most local people also perceived mosquitoes to be mainly associated with stagnant water in "*ditches which were made next to our houses*" (FGD, women of SHG) and forested areas with "*lots of plants*" (land-owning male, GC, 38 years).

One environmental health academician commented that "*check dams can breed Anopheles*", wells are "*a major source of Anopheles*" and troughs holding some water "*will support breeding of Aedes*" (health academician 1). Structures such as compost pits, which were created in some projects "*can be huge Culex-breeding sites*" (health academician 1). It was also discussed that *Anopheles* species could travel "*up to 2 km*" (health academician 1). Hence,

structures located just outside the village were not far enough to be protective. The academician also confirmed that people get bitten in forested areas because *Culex* mosquitoes reside there, as they favour stagnant water in open drains for breeding. Bio-environmental control using *Poecilia* (guppy) and *Gambusia* fish species, already being practiced for hot-spots by local health services, was recommended for check-dams, wells and ponds, alongside other fish for nutrition:

> *"They can use carpio, which is edible and can grow to 600–700 grams and is a protein source, and use gambusia along with that."* (health academician 1).

However, fish rearing was not practiced because reportedly "*people keep taking the fish*" (land-owning male, ST, 32 years) and also because it was felt that fish "*do not survive well in tarpaulin-lined ponds*" (land-owning male, GC, 63 years). Local health workers mentioned visiting households regularly to inspect water containers and "*inform people to clean them*" (local health-worker 2). Fish release had reportedly been done once in some project villages a few years ago by the health department, but local people had "*never heard about this*" (NGO fieldworker 1). This is likely because fish inoculation was only done in public water bodies, and there have not recently been cases of malaria reported locally.

3.4.3. Health impacts of opportunistic activities during WSD projects

Various additional health-specific or health-determining activities were conducted. These were either entry-point activities, awareness sessions or support to leverage welfare schemes. Some health-related activities were conducted to build trust with the local community, such as "*cancer detection, eye and dental camps*" (NGO manager 3). "*Veterinary camps*" were also conducted to support livestock health (land-owning male, GC, 36 years). Local people were also encouraged and supported to enrol for "*health insurance schemes such as Rashtriya Swasthya Bima Yojana*" (NGO manager 3), but most respondents "*did not follow up*" to enrol (landless female, SC, 40 years). Assistance to sign up for health and life insurance were, like SHGs, also supported outside of WSD projects. Some poor and woman-headed households were "*managing mainly because of the self-help group*" (landless female, SC, 40 years), including high expenditures accessing healthcare.

One training on "*menstrual hygiene*" was conducted for SHG members and adolescent girls (NGO manager 3). "*Awareness about hygiene and toilets was also given as there are grants from panchayat*" (NGO manager 2). One older WSD project had also provided financial "*support for building toilets*" (land-owning male, GC, 50 years). In addition, voluntary service was organised for "*cleaning up the crèche and school*" (NGO fieldworker 4), "*local water bodies and planting trees near borewells*" (NGO manager 3). Women from remote villages especially appreciated the field trip outside the district where they learned about "*agriculture, plants,*

fodder and about the villages" (landless female, ST, 55 years). Farmers remembered training sessions about "*conserving water, about ground water conservation, the need for check dams and avoiding use of groundwater to conserve for our children*" (land-owning male, GC, 63 years).

Respondents in a remote tribal hamlet appreciated the entry-point activities, as their pressing needs for a water tank and community hall were addressed. Earlier they had to "*go down the hill to collect water*" (land-owning female, ST, 65 years), and now they were "*sure to get water after work in the evening*" (landless male, ST, 38 years), which contributed to physical and "*mental relief*" (NGO manager 2). Villages in other project areas already had water supply through governmental initiatives. Diarrhoeal diseases were "*not seen*" commonly in these villages (local health-worker 2).

Project field workers also helped local people access welfare schemes provided by NGOs such as subsidised cooking-gas connection. This was opined to have prevented the forests from "*getting damaged*" (NGO fieldworker 4) and would have also reduced exposure to indoor air pollution. This NGO-based subsidy preceded the governmental scheme by a few years.

> *"We bought it (gas connection) through the SHG itself. Earlier we used firewood. When it rained, we could not cook. The kerosene stove was also difficult to use. Now it is much better."* (landless female, ST, 37 years).

On prompting whether fluoride levels in groundwater may have reduced because of groundwater recharge, a manager felt it may have happened "*to a small extent*", mentioning "*this had been tested*" in another project site (NGO manager 2). Fluorosis was of concern locally, and participants were aware that "*fluoride has increased in groundwater*" (land-owning male, GC, 42 years). It was suggested that local people should consider "*surface water harvesting*" and increase "*groundwater recharge*" to address these challenges (senior WSD practitioner 1). A sample rainwater harvesting system including a "*sand filter was also installed*" at one farmer's home, which he was still using (land-owning male, GC, 63 years). Finally, on enquiry about farm ponds as potential hazards for drowning (based on information from an informal conversation with a health worker), local people mentioned that this had not occurred in their villages, but that they were "*now required to fence the ponds*" (land-owning male, GC, 63 years).

3.5. Discussion

Size and distribution of impacts of WSD projects

The impact of WSD projects perceived on agriculture, water availability and livelihood reported from remote parts of Maharashtra (Pandit, 2010; Pandit and Zade, 2012; Nerkar et al., 2013, 2015, 2016) were not uniformly seen in our study areas in Kolar district. This might, at least

partly, be explained by established groundwater exploitation, piped water supply and small land-holdings prior to the development and operation of the WSD projects, coupled with close proximity to a large city (Bengaluru). However, sizable impacts were experienced by some large dry-land horticultural farmers and poor landless labourers. An earlier evaluation from Karnataka also showed that only few households benefitted substantially from WSD projects (Lele et al., 2007). Literature also corroborated that farmers with large holdings showed stronger impact and were in a position to disproportionately exploit groundwater (Kerr, 2002; Shiferaw et al., 2008). Moreover, use of water-conserving technologies such as drip irrigation is encouraged by WSD policy (Meenakshi and Ramanathan, 2010) for synergistic impacts with WSD structures, especially benefiting larger farms. However, recent WSD projects have been more equitable in design due to the inclusion of livelihood support for landless households (Government of India, 2011). Several small-holder farmers either did not sustain the structures or did not even participate in the projects due to perceived wastage of land, as was also found elsewhere (Lele et al., 2007). It may be useful to study motivation behind participation in WSD projects. A relatively small proportion of SC and ST families owned land, which were reportedly of smaller size and lower quality compared to general category households, as corroborated by literature (Borooah et al., 2014). However, these households participated and benefitted similarly to what was experienced by families of other castes with comparable land-holdings. Impacts of WSD projects on water conservation and agricultural productivity have been well established in the literature (Joshi et al., 2008; Singh et al., 2010).

Women provided greater detail on health impacts, as most of the relevant project activities leading to these impacts (e.g., livestock management, livelihood training and awareness sessions) were coordinated through SHGs, and also the related household chores (e.g., cooking, water collection and livestock rearing) were primarily managed by women. While SHGs have also been created and supported outside of WSD projects, and the benefits of SHGs have been established (Meenakshi and Ramanathan, 2010), WSD projects provided scope for identifying and engaging all households that would benefit from small grants, and hence, provide systematic ground-level support over a few years. WSD projects without a strong livelihood component may miss an opportunity to benefit the poorest households, especially those unable to travel for work.

Interpreting nutritional impacts

Experience from India suggests that access to irrigation, ownership of livestock and elevated income had positive impacts on household nutrition (Kadiyala et al., 2014). In our study, poor landless households that took up livestock management and vocational support reported improved access to nutritious food. The few small farmers who maintained WSD structures also reported enhanced food security through higher survival and production of staple crops

during poor monsoons, as reported in an previous study from the region (Meenakshi and Ramanathan, 2010). Earlier studies found a shift to commercial crops and reduction in cultivation of staples (Meenakshi and Ramanathan, 2010; Pandit, 2010). Reduction of staples was not seen in our study area. Indeed, food security remained uncompromised, and nutritional quality was enhanced, pointing to impacts that depend on the specific contexts. A study reported that WSD projects led to increased irrigation and consequently increased workload on women (Pandit, 2010). Women in our study area perceived increased workload after installing borewells or farm ponds, potentially resulting in a negative impact on nutritional status (Kadiyala et al., 2014; Padmaja et al., 2019). However, while increase in the number of borewells has been noted in WSD project areas, it is not clear whether this is actually due to WSD development or other factors (Meenakshi and Ramanathan, 2010), as borewells are not promoted in WSD. Additionally, while fish rearing has been encouraged in surface water bodies by WSD policy (Government of India, 2011), local people faced challenges with the implementation.

Interpreting other health impacts

Although local people and NGO officials did not report any increase in mosquito nuisance, the potential for mosquito-breeding in farm ponds, check dams and water troughs has been documented in earlier studies in the same region (Balakrishnan et al., 2015; Ghosh et al., 2005). At present, malaria is not a concern locally, and Japanese encephalitis has not occurred in Kolar district for few decades. However, malaria cases have been reported from neighbouring districts (Shoba et al., 2019).

Allied activities that were conducted as part of WSD projects such as medical camps and health insurance enrolment were utilised only by a few households. Hence, the strategy for and utility of such activities should be reviewed.

High fluoride levels in groundwater—a concern in Kolar district—can lead to dental and skeletal problems (Shruthi et al., 2016, 2018), and potentially affect neuro-development in children (Saeed et al., 2019). Rainwater harvesting and groundwater recharge were encouraged as part of WSD projects in the study area, with evidence suggesting reduced exposure to high fluoride levels (Bhagavan and Raghu, 2005; Jacks et al., 2005). There were also consistent efforts to help local people leverage governmental welfare schemes, which was possible because of the NGO's commitment. This resulted in improving access to clean fuels, drip irrigation and sanitation, which contributed to improving people's health and well-being. Entry-point activities, such as through constructing a water tank, created impact only in villages without basic services. These activities also contributed to stress reduction, alongside better livelihood management. These kinds of activities and impacts cannot be expected consistently across WSD projects in India as they are context dependent.

Diarrhoeal diseases were not a concern in the study area, in contrast to findings from remote villages in Maharashtra, where WSD projects contributed significantly to sanitation practices and outcomes (Nerkar et al., 2013, 2015, 2016). Most study villages had improved access to water and toilets prior to WSD projects. Similarly, while other studies indicated reduced migration following the implementation of WSD projects (Meenakshi and Ramanathan, 2010; Nerkar et al., 2013), in our study only a few of the households that adopted livelihood opportunities showed reduced needs to travel for livelihood. This finding too was related to contextual factors. Drowning in farm ponds were reported from other parts of the district (Kanathanda, 2017), and people in the study area were aware of this risk and the need to install fences.

Challenges in eliciting health impacts

Health impacts of WSD projects, whether positive or negative, were largely incidental. Perceived health impacts were often elicited on probing, as was also noted by Pandit (2010). NGO officials were able to articulate more about health and other impacts possibly because they: (i) were more familiar with the theoretical basis for project activities and their anticipated impacts; (ii) were better aware about conducted activities; and (iii) knew about benefits experienced across villages and projects. Their accounts provided insights into both the efficacy (i.e., outcome expected in ideal circumstances) and effectiveness (i.e., outcome observed in real world situation) of interventions. Local people were limited to the experience of their own households and local area, besides complexity in interpreting the contribution of factors such as weather fluctuation and other governmental programmes. The size and distribution of impacts on agriculture and livelihood had implications for health impacts, which in turn are dependent on project quality and context.

Strengths of the study

The NGO that planned and implemented these WSD projects was experienced, which is an important factor explaining the overall high quality of the projects. The WSD projects examined in this study had been completed between 2 and 10 years prior to the interviews, which helped understand how activities and impacts were appreciated and sustained. A range of participants were interviewed to better understand how and why insights may wary between actors. Interviews were preferred to FGDs because of the need to probe individual and household-level experiences and impacts. Pictures taken of WSD structures were used in interviews with the academician to help contextualise the discussion. These features provided a strong and rounded impression of perceptions of impacts, opportunities and risks of WSD projects on health. Literature on adaptation strategies in semi-arid regions that are vulnerable to climate change is emerging (Rao et al., 2020). Our study contributes to this through a health lens, which has often been lacking.

Limitations, and scope for further research

As the study attempted to deepen the understanding of the full range of health and health-determining impacts of WSD projects, some aspects may not have received the required depth of attention as may have been possible if the scope was narrower. Additionally, interviews and coding were done by one person. There is scope for mixed method studies (i.e., combining quantitative and qualitative approaches), especially on nutritional impact, vector-breeding in water-holding structures, zoonotic diseases through livestock management and water quality. Other aspects that should be explored further are migration and mental health impacts, which are relevant to drought-prone agricultural communities (Berry et al., 2010). Using a resilience framework (Cairns et al., 2017) or a health access livelihood framework (Obrist et al., 2007) may help plan and study projects such as WSD. Quantitative studies through the use of appropriate methods such as structural equation models would further contribute to the understanding of the size of impacts of WSD projects, due to the presence of multiple impact pathways and multifactorial outcomes.

Future action

We planned this study to inform an HIA of a newly planned WSD project in Kolar district. HIA are applied prospectively to identify and judge potential health impacts of planned projects, programmes or policies and recommend measures to minimise negative and maximise positive impacts (WHO and ECHP, 1999). Through the current study, we identified a range of positive and potentially negative health impacts of WSD projects. This list of health impacts was used to identify gaps in health data for the project villages of the planned WSD project at baseline. The data gaps were then addressed through a baseline survey conducted in the project villages and comparison villages, which can then be monitored and later compared with baseline health status after project completion. This would give quantitative insights on the size of impacts of WSD projects and the utility of the HIA. These actions would demonstrate approaches to address critical cross-sectoral health policy concerns identified by the Government of India such as undernutrition and sanitation (Government of India, 2017a), and help realise the vision of WSD projects.

3.6. Conclusions

Our study revealed that WSD projects in semi-arid settings of southern India were perceived to impact various health outcomes and determinants. The identified pathways to health impacts were often secondary to the primary impacts on agriculture, livelihood and local ecology. We also found that WSD projects offered a platform for linking local people more effectively to existing health-related and health-determining schemes, especially because of involvement of all households through the SHGs. Health-wise, those benefitting most may be

the poor landless households that were able to effectively utilise and build upon the livelihood support. These families experienced better nutrition through mechanisms such as increased milk production in the household and higher income. However, potential for vector-breeding increased because of increase in water-holding structures, though local people and NGO workers did not perceive this as a risk. In addition, through comparison of findings with existing literature, it was demonstrated that impacts for such WSD projects are context-dependent – related to local geography, socioeconomic factors and developmental status. There is scope for integrating health activities and monitoring more systematically into these projects, especially for nutrition and VBDs. This would be useful as they are key health policy concerns for rural India, and also in semi-arid areas in other low- and middle-income countries. We have attempted this integration through an HIA of a proposed WSD project locally, which will be published as a case study separately.

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4. Health impact assessment of a watershed development project in southern India: a case study

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4.1. Abstract

A “Health in All” approach has been encouraged by India’s National Health Policy to address cross-sectoral health concerns. To illustrate how health concerns can be systematised in food system planning, we pursued a health impact assessment (HIA) of a watershed development (WSD) project in semi-arid Kolar district, in the southern part of India. The main features of the planned WSD project included measures for soil and water conservation, improving agricultural productivity, and enhancing livelihoods of landless and poor households in a cluster of villages. An HIA approach previously employed for an agricultural project in a tropical setting was adapted for the current HIA, to accommodate for (i) the project implementing agency being a non-profit, (ii) the HIA being conducted in-parallel with the baseline socioeconomic assessment. The HIA revealed that the WSD project might result in a range of positive (e.g., nutrition, sanitation and water quality) and negative health impacts (e.g., vector-borne diseases, pesticide exposure, drowning and zoonosis). HIA of these projects holds promise to influence health in remote drought-prone areas and build-up HIA capacity through application in non-controversial project environments. The current case study can serve as an example for HIA of agricultural projects in topical settings.

Keywords: agriculture; health impact assessment; India; nutrition; semi-arid; watershed development project

4.2. Introduction

Most of India's population relies on agriculture for livelihood (Government of India, 2019) and nutrition (Headey et al., 2012; Kadiyala et al., 2014). Farmers in semi-arid areas depend on rainfall and groundwater for cultivation. In these areas, watershed development (WSD) projects have been implemented to support local livelihood , enhance ecology (Kerr, 2002) and adapt to climate change (IISc, 2014). Official guidelines for WSD projects were re-issued in 2008 by the Government of India (2011), focussing on soil and water conservation, ecological balance, local participatory planning and management, equity and livelihood. Non-governmental organisations (NGOs) are often the primary implementors of these projects, in partnership with the local government and communities.

Few retrospective studies from India indicated positive impacts of completed WSD projects on water, sanitation and hygiene (WASH), access to healthcare (Nerkar et al., 2013, 2015, 2016), food security and nutrition (Pandit, 2010; Pradyumna et al., 2020). On the other hand, potential negative impacts on vector-borne diseases (VBDs) and pesticide exposure due to increase in surface waterbodies and agriculture, respectively, were also recently reported (Pradyumna et al., 2020). Such concerns and opportunities should be addressed early on in the project planning.

Health impact assessment (HIA) is an interdisciplinary approach that applies different tools and methods to systematically judge the potential, and sometimes unintended, effects of a project, programme, policy or strategy on the health of a population and the distribution of those effects within the population (Quigley et al., 2006). HIA has been used in the context of agricultural projects (Knoblauch et al., 2014) and policies (Lock et al., 2003). In India, health assessments are included under the umbrella of environmental impact assessment (EIA). However, EIA is mandated only for some types of projects, such as large mining projects (Government of India, 2006a), and not for agricultural policies, programmes or projects. In addition, it was recognised that attention to health assessment was grossly inadequate in EIA in India (Cave et al., 2013; Pradyumna, 2015). Also, while the need for nutrition-sensitive agriculture has received some attention in national policies (Ministry of Agriculture, 2013; NITI Aayog, 2017) and in international reports (IFPRI, 2015), several potential negative health impacts of food systems interventions have received less attention (Pradyumna et al., 2019). Hence, the need for health assessments has been recognised in India (Ahuja, 2007; Cave et al., 2013; Dua and Acharya, 2014), specifically also for agricultural projects (Pradyumna and Chelaton, 2018). HIA would also align well with the "Health in All" approach that has been encouraged in the National Health Policy (Government of India, 2017a).

WSD projects are a potential candidate for operationalising the “Health in All” vision for rural areas in India. With well over 2 million km^2 of land eligible for WSD projects (Government of India, 2011), they touch millions of households across India. Importantly, due to the integral participatory approach and of diverse social and environmental activities in WSD projects, their potential to be an “umbrella for uniting developmental programmes”, including health, for villages in India was recognised (Technical Committee on Watershed Programmes in India, 2006).

We present a case study of an HIA of a proposed WSD project in the semi-arid Kolar district in the southern part of India. We show the value of HIA in systematically and prospectively identifying potential impacts (negative and positive) for the planning of risk mitigation and health promotion measures, and discuss opportunities presented due to NGOs being the usual implementors of these projects. We hope that our case study will inspire future WSD projects to apply HIA at the planning stage and to provide opportunities for HIA capacity building in India.

4.3. Context for the HIA

MYRADA Kolar Project is a local non-governmental organisation (NGO) that has worked through partnerships with governmental departments, private philanthropies and local communities on agricultural and developmental projects. Their expertise, innovation and contribution to WSD practice has been recognised in the official guidelines by the Government of India (2011).

A preceding study by the authors identified perceived health impacts of recently completed WSD projects implemented by the aforementioned NGO in various parts of Kolar district (Pradyumna et al., 2020). Based on the findings, especially the few potential negative health impacts, the idea for conducting an HIA was proposed by the first author to the NGO management team for their next WSD project proposal. The NGO agreed to incorporate an HIA component in the feasibility studies of the WSD project as they appreciated the opportunity it would provide to identify and mitigate potential negative health impacts and further enhance positive health impacts of their project, through the proposed objectives of the HIA, which were:

- to describe the baseline health conditions of the local population;
- to identify potential health impacts of the proposed WSD project, including considerations of magnitude and significance; and
- to make evidence-based recommendations towards mitigation of potential negative health impacts and promotion of health opportunities.

The proposed WSD project covers a cluster of four villages in Kolar district (henceforth called project villages) (see Figure 4.1). Agriculture is the main livelihood in the area and the district is classified as highly vulnerable to climate change (University of Agricultural Sciences - Bangalore, 2011). The components of the proposed WSD project are summarised in Box 1. The HIA was initiated in March 2019 and the report was submitted in September 2019. A dissemination meeting with the project team was conducted in January 2020.

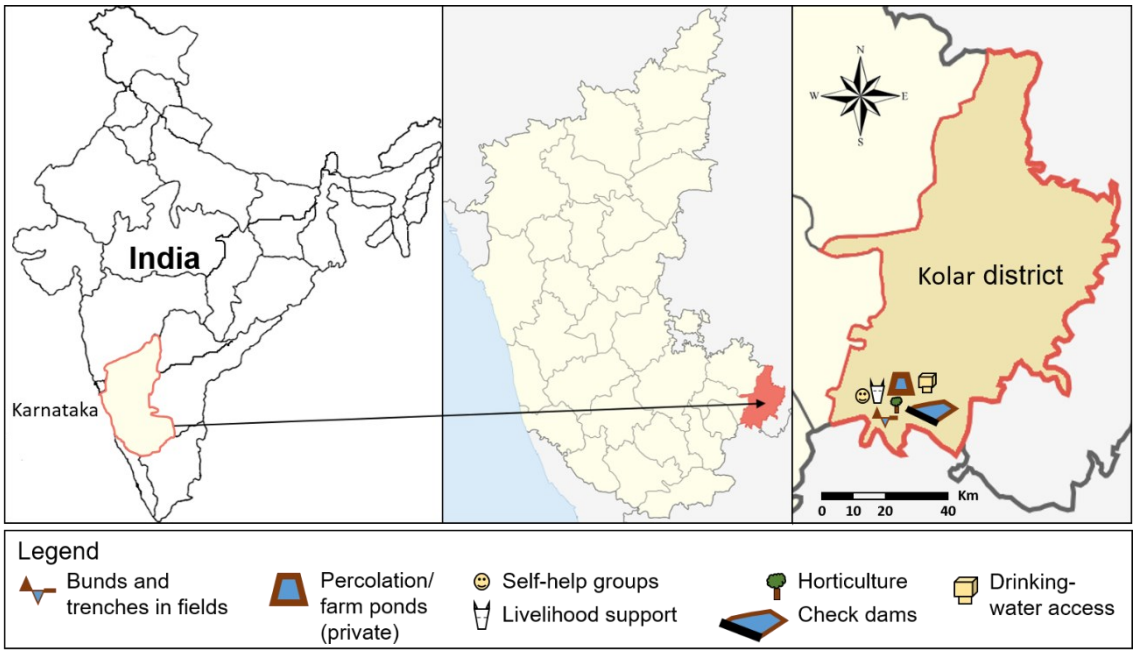

Figure 4.1. Location and components of the planned WSD project (modified from images by 3xK and PlaneMad respectively, distributed under a CC-BY 2.0 license)

Box 1. Main components of proposed WSD project in Kolar district, South India:

(1) soil and water conservation: creation of earthen bunds, gully plugs, check dams, revetments, cattle ponds, recharge pits and percolation ponds on private and community lands;
(2) farm forestry: on degraded lands and tank foreshore areas;
(3) improvement of soil fertility: through support for silt application, bund plantation, vermi-compost and mulching for farmers;
(4) on-farm livelihood activities: support to horticulture with controlled irrigation systems;
(5) off-farm livelihood activities: trainings and provision of support to economically weaker sections through credit linkages;
(6) village infrastructure and sanitation activities: improving drinking water access, provision of community hall and improving cleanliness of drains; and
(7) building people's institutions: capacity building and networking of community-based organisations including self-help groups, farmers groups and watershed development committees.

4.4. HIA approach and overview of innovations

The HIA followed the methodological approach put forth by Winkler and colleagues (2010, 2011, 2012), which was specifically designed for, and validated in, tropical settings in low- and middle-income countries (LMICs) where there is a paucity of readily available data for supporting the HIA. Of note, the methodology has already been applied successfully to agricultural developments (Knoblauch et al., 2014; Winkler et al., 2014). Key steps in the HIA approach are briefly summarised in Box 2. In the following sub-chapters, methodological features considered particularly relevant for the given context, are described.

Box 2. Steps of the process

- Screening: potential significant health impacts associated with the WSD project identified and, thus, decision for undertaking HIA taken
- Scoping: review of proposal documents, desktop literature review, group discussions with local people and interviews with healthcare providers in project villages; potential health impacts identified, while a gap analysis indicated a need for baseline survey. Terms of reference for HIA agreed upon
- Baseline survey: included a household survey (emphasised socio-demographic aspects, and knowledge, attitudes and practices related to health, and household health concerns), and an anthropometric survey of children under the age of 5 years in project and comparison villages; ethical clearance obtained and written informed consent taken before the survey
- Impact assessment: semi-quantitative risk assessment based on various criteria (extent, age group, duration of health effect, level of disability, prevention and remedy) and for different scenarios (baseline, pre-mitigation and residual), alongside identification of mitigation measures; performed by the first author
- Reporting/dissemination: HIA report submitted to NGO, and dissemination meeting held
- Revision of project plan: incorporation of HIA recommendations
- Initiation of project with health considerations

While the decision on undertaking the HIA was done together with the project proponent, the study design and reporting was carried out independently by the authors.

Involvement of project proponent in HIA

In a deviation from usual practice, the baseline health survey was administered to local people by staff of the NGO. Several reasons guided this decision: (i) the NGO already conducted the socio-economic assessment, and hence, it was logistically and financially efficient to add the baseline health data collection to these activities; (ii) the HIA had to be completed in a short period of time, and so the familiarity between NGO staff members and local people facilitated relatively quick data collection; and (iii) it was recognised as an opportunity for capacity building

of NGO staff members on health and surveys (discussed later). This decision was acceptable because WSD projects are inherently welfare and empowerment oriented, rather than for the profit of a private entity.

Health census of all households

Another unusual feature was that the baseline health survey covered all households in the project villages because (i) the socioeconomic assessment was being conducted across all households and (ii) the total number of households was relatively small. A sample survey would have yielded imprecise estimates and added challenges in comparing project villages with comparison villages. The detailed methodology and findings of the baseline survey are available in Pradyumna and colleagues (2021a).

Managing data gaps

Several gaps were found in secondary health data, which were systematically assessed through approaches described by Winkler and colleagues (2011). Resource limitations only allowed for some of the data gaps to be addressed through the baseline survey. Hence, a semi-quantitative risk assessment approach was employed here (adapted from the framework used before (Winkler et al., 2010)). The risk assessment approach proved particularly relevant and useful in the context of poor availability of secondary health data, which would be the case in most situations in India, especially if data are needed at village level or for diseases that are not part of the routine surveillance and reporting systems. The assessment for each environmental health area was done by the first author under the guidance of the other co-authors.

4.5. Salient findings from the HIA

4.5.1. Results from the scoping exercise

The geographic boundary for the HIA pertained to the four villages potentially impacted by the WSD project. In terms of temporal boundary, a seamless transition between the construction and operation was pre-defined in view of the WSD project to be implemented in a stepwise manner within and across villages between 2019 and 2024. The scoping review of secondary data and literature on Kolar district can be summarised as follows:

- dengue and chikungunya outbreaks have occurred in the recent past (Balakrishnan et al., 2015);
- in rural Kolar, in 2016, the prevalence of anaemia in women of reproductive age was 45.9% (IIPS, 2016c);
- drowning in farm ponds were reported from neighbouring sub-districts in Kolar in 2019 (Kanathanda, 2017);

- dental fluorosis prevalence ranged between 1.9% and 13.1% in prior surveys (Shruthi and Anil, 2018), and skeletal fluorosis was approximately 5% among adults in nearby sub-districts in 2012 (Shruthi et al., 2016);
- among individuals aged 15-49 years, high blood pressure was recorded in 10.7% of women and 10.2% of men in Kolar district in 2016 (IIPS, 2016c); and
- the reported levels of groundwater fluoride levels for project villages was 3.1 mg/l (range 2.7-3.6 mg/l, as compared to the reference standard of 1.5 mg/l (Bureau of Indian Standards, 2012)).

In addition, the group discussions with local people and an interview with a healthcare provider pointed to challenges of VBDs, water quality (fluoride contamination), agricultural injuries and access to healthcare (inadequate transport facilities) in the local area. Table 4.1 summarises potential health impacts of concern identified during the scoping step. For each potential health impact, key health indicators for the HIA were defined, covering both determinants of health and health outcomes.

Table 4.1. Potential health impacts, pathways and proposed indicators of the planned WSD project in India

Potential health impacts	**Principal impact pathways**	**Proposed key health indicators**
Vector-borne diseases (VBDs)	Increase in breeding sites through new check dams, farm ponds, cattle ponds and troughs	Incidence of VBDs[a], perceived mosquito menace[b]
Zoonotic diseases	Increase in livestock, especially dairy cows, goats and sheep	Proportion of households owning livestock[b]
Soil- and water-sanitation-related diseases	Reliable water access during summer months and enhanced awareness	Occurrence of diarrhoeal diseases[b], ownership of latrine[b] and access to purified water[b]
Food- and nutrition-related issues	Better nutrition through ownership of livestock, better income among poor families and increased production of staple crops and vegetables	Prevalence of undernutrition among children[b] and self-reported food insecurity[b]
Accidents and injuries	Drowning in farm ponds	Number of farm ponds made[c] and incidents occurring during project period[c]
Exposure to potentially hazardous material	Increase in commercial cultivation of vegetables	Prevalence and frequency of pesticide use[b] and fluoride level in groundwater[b]
Social determinants of health	Awareness and empowerment of women through participation in self-help groups (SHGs)	Proportion of households participating in SHGs[b]

[a]secondary data available; [b]data gaps; [c]recommended to be included in project impact monitoring

The baseline survey revealed several aspects regarding local population health. About one of seven households (13.8%) were woman-headed. Some households belonged to scheduled tribes (ST; 30.8%) or scheduled castes (SC; 7.7%). Agriculture was the main source of income

(67.2%). One out of five households depended primarily on wage labour (19.5%). Most of the households owned less than 10,000 m^2 (1 ha) of land (66.2%). Access to irrigation was available to 39.5% households. Most households (57.9%) owned at least one type of livestock (15.4% among SC households). Almost 37% households had a member in self-help groups (SHGs) (7.7% for SC households). Most households (86.2%) owned some form of motorised transport. Most households used gas stoves for cooking (88.2%), though many also occasionally used firewood. Median distance for collecting water was 100 m (range: 0-1,000 m). Most households (90.3%) depend on groundwater for domestic use. More than half of the households (56.9%) did not use any method of purification. Most households owned a private toilet (92%). Soap was observed only at around half of the hand-wash facilities (48.7%).

The proportion of households with individuals who were smoking, consumed alcohol or chewable tobacco were 15.9%, 13.8% and 23.6%, respectively. Spraying pesticides was done by individuals in 43.6% of households at least once a month. Most households (79.5%) opined that it was convenient to access healthcare, and all households opined that local healthcare was satisfactory. Over 20% households reported having experienced food insecurity in the previous 2 years, and 26% having not consumed fruits during the previous month. Only 6.7% of the respondents were unable to mention any one iron-rich food. Two-third of the respondents (64.1%) had knowledge of at least one effect of exposure to high fluoride levels. The anthropometric survey revealed the prevalence of underweight and undernourishment (based on mid-upper arm circumference) among children below the age of 5 years as 26.5% and 14%, respectively in the project villages.

4.5.2. Results from impact assessment

After defining the impacts and impact pathways for all EHAs, semi-quantitative risk assessment was applied (Table 4.2). Based on the impact assessment, the factors that emerged as the greatest concerns in the “without mitigation” scenario were VBDs, accidental drowning and pesticide exposure. The factors presenting opportunities for positive health impacts were women’s empowerment, nutrition, access to healthcare and water quality.

4.5.3. Recommendations towards risk mitigation and health promotion

Potential mitigation measures for the main health concerns are summarised in Table 4.3. Suggested measures primarily pertained to awareness building on specific health issues in collaboration with the local governmental department, keeping in mind the availability of resources. In addition, process monitoring and post-project impact evaluation of the HIA were also suggested to benefit learning from the experience.

Table 4.2: Summary of impact assessment of the planned WSD project

Environmental health areas	**Significance**		
Specific health concerns	**Baseline**	**Without mitigation**	**Residual**
1. Vector-related diseases			
Malaria transmission	*	**↑	*
Transmission of arboviral diseases	***	***↑	**↓
2. Respiratory and housing issues	*	NR	NR
3. Veterinary medicine and zoonotic issues	**	**↑	*↓
4. Sexually transmitted infections	*	NR	NR
5. Soil- and water-sanitation-related diseases	**	**↓	*↓
6. Food- and nutrition-related issues			
Child malnutrition	***	***↓	**↓
Maternal anaemia	***	***↓	**↓
7. Accidents and injuries			
Occupational injuries	*	**↑	*
Drowning in farm ponds	*	**↑	*
8. Exposure to potentially hazardous material			
Fluoride in drinking water	**	**↓	*↓
Exposure to pesticides	*	**↑	*
9. Social determinants of health			
Women's disempowered situation	***	**↓	**↓
10. Cultural health practices	*	NR	NR
11. Health services infrastructure and capacity			
Inadequate access to healthcare	***	**↓	**↓
12. Non-communicable diseases	**	**	**↓

*low, **medium, ***high, ****very high; ↓reduced compared to baseline score; ↑increased compared to baseline score; NR, not relevant

Table 4.3: Key recommendations to project managers based on the HIA

Potential health impacts	Recommendations
Key mitigation measures	
Vector-borne diseases	Awareness to local people including children about control of vector-breeding, symptoms of VBDs (collaborating with the health department), mapping of newly created water-bodies and instituting larval monitoring of all waterbodies
Pesticide exposure	Awareness about personal protective equipment, safe storage of pesticides, and about low input agriculture (in collaboration with the agriculture department)
Zoonotic diseases	Awareness among farmers and healthcare providers about brucellosis (in collaboration with the local dairy)
Injuries/drowning	Fences for farm ponds and safety awareness for children, increased awareness about safe use of agri-equipment, first aid and promoting gender-appropriate equipment
Key health promotion opportunities	
Food and nutrition	Awareness to SHG members and crèche workers on local nutritious food sources, support fruit trees and kitchen gardens, promote sanitation and hygiene involving SHGs and schools
Fluorosis and groundwater quality	Support water purification and rain-water harvesting at community and household level
Non-communicable disease	Awareness about the effects of alcohol consumption, and about symptoms of chronic diseases (in collaboration with the health department)

4.6. Discussion

Novel aspects of this HIA case study

To our knowledge, this is the first reported HIA of a WSD project proposal, and hence, it makes a contribution to the sparse literature on HIA on food systems projects. In addition, this may be the first reported comprehensive HIA from India for any kind of project. These two factors have important implications for the practice of HIA in India (discussed later).

Some features of WSD projects contributed to an unusual context for the HIA. For instance, impact assessments are not routinely conducted on projects that are inherently oriented towards community wellbeing, and so this case study shed light on how community development projects could incorporate health considerations in planning. Also, the size of the individual projects is small, covering only few villages (constituting a micro-watershed). Hence, this is an example of an HIA conducted for a small project. Finally, project proponents are usually not directly involved in conducting the HIA, but in the current case, as profits and private investments were not factors, their participation was possible and was also fruitful.

Utility of HIA for the WSD project

Taken together, the predicted health risks of the proposed WSD project were relatively few and of low magnitude, but the HIA helped to systematically identify, acknowledge and plan towards addressing them. For instance, potential impacts on vector ecology, risk of accidental drowning and zoonotic diseases would not have been considered without the current HIA.

WSD project objectives are, in principle, inherently health promoting (e.g., water access, food security and income). Additionally, locally relevant opportunities for health promotion were also identified, for example, by specific recommendations on access to potable water to reduce exposure to fluoride and incorporating nutrition-enhancing activities. The HIA made the NGO aware that developmental projects have health implications, and this may render them more likely to be systematically addressed in future projects. The post-project evaluation will provide further insight on adoption of the recommendations and potential impacts on people's health and wellbeing. Additional HIA case studies could also further inform the "must-have" and "good-to-have" aspects of a comprehensive HIA for WSD projects.

Opportunities and implications for practice

Capital-intensive projects, such as mining projects, are politically contentious (Kalshian, 2007), which is a challenge for impact assessment practice. Corruption too was identified as a problem (Paliwal, 2006) besides low capacity for HIA in India (Cave et al., 2013; Pradyumna, 2015). WSD projects are non-controversial, and hence, offer a safe platform for capacity building and clarifying the utility of HIA in India. This is besides addressing health concerns in remote areas, and building capacity on health and health surveys among community development NGOs in often marginalised settings. Organisations with a primary objective of community development – such as governmental departments and NGOs – are in a good position to embrace HIA. These organisations and also WSD projects mainly have a social and environmental basis for their work. The present HIA case study demonstrates how the opportunity for community health enhancement can also be used as an additional strong argument for these projects, especially on critical outcomes such as nutrition and vector-borne diseases. It is worth mentioning that the HIA approach used here was found to be suitable for settings with inadequate secondary health data, such as would be seen in most rural parts of India.

Our findings and reflections are also relevant to HIA practice in other comparable geographical contexts such as other South Asian and sub-Saharan African countries. For example, there have been collaborative capacity-building arrangements for WSD between NGOs in India and organisations in Nepal, Sri Lanka, Kenya, Sudan, Tanzania, Ethiopia and Uganda (MYRADA,

2020; WOTR, 2020). Hence, lessons from the present case study have the opportunity to diffuse.

Limitations of the case study

Coverage of the baseline survey in these villages was universal, and therefore creates a representative picture of health in the community surrounding the WSD, but this would contribute to challenges while comparing with the comparison villages during evaluation. However, other comparative methods, as employed in a prior HIA of a biofuel project in Sierra Leone, could be used (Knoblauch et al., 2014). NGO workers implementing the health survey were from project villages and were hesitant in asking sensitive questions on alcohol consumption and hygiene practices, indicating the importance of a strong prior training and planning. As time and resources were limited, no biological samples were collected from the study population. This would require that the baseline survey was further supported by a health research and laboratory team. While this would lead to additional costs, it would also reduce any perceived conflict of interest in data collection. Also, time permitting, further exploration of relevant health concerns could have been undertaken, for instance, more detailed stakeholder perceptions of drowning risk in farm ponds. Finally, this HIA was proposed and conducted by the authors at no financial cost to the project-implementing NGO. Further insights on the effects of the HIA process will be gained over the next few years through an in-depth evaluation.

4.7. Conclusions

The HIA of a planned WSD project in India was conducted in a setting with limited secondary data. The process facilitated a deeper understanding of baseline health conditions, identifying potential project-related health risk (e.g., increase in vector breeding sites) and opportunities for risk mitigation (e.g., fencing of farm ponds to prevent accidental drowning) and health promotion (e.g., raising awareness about locally available nutritious food sources) in the context of proposed activities. In addition, the exercise benefited the local NGO through capacity building on how to conducted a cross-sectional survey and run an HIA. An evaluation will shed further light on acceptability and adoption of the HIA process and recommendations.

To our knowledge, there are no other reported HIAs of WSD projects. Moreover, HIA have largely been neglected in impact assessment practice in India. There is a strong argument to consider HIA for WSD projects due to their geographic scope and to foster HIA practice in non-controversial project environments. There is ample opportunity for governmental departments and NGOs to adopt and further validate the presented HIA approach in the context of future WSD projects to be implemented in rural areas of India and also other LMICs.

5. Health of farming communities prior to modification of the occupational environment through a watershed development project in Kolar, India

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5.1. Abstract

Background: Watershed development (WSD) projects, aimed primarily at enhancing soil and water conservation and supporting livelihoods in semi-arid areas, have the potential to impact health by modifying the occupational and household environments in agrarian communities. To identify and address potential health concerns arising from a planned WSD project in Kolar district, India, a health impact assessment (HIA) was conducted. This necessitated understanding the health status and concerns in the project villages. **Objective:** To characterize health of households in the vicinity of the planned WSD project. **Methods:** We conducted a cross-sectional survey between April and July 2019 and comprised: (i) a household survey covering the four project villages and two comparison villages (e.g., socio-demographic characteristics, occurrence of vector-borne diseases (VBDs), access to safe water, sanitation and hygiene and utilization of healthcare); and (ii) an anthropometric survey for children under the age of 5 years in the four project villages and four comparison villages. **Results:** Respondents (n=333) reported household-level occurrences of VBDs (chikungunya, 3.3%; and dengue, 1.5%), consuming unsafe water (54.5%) and frequent pesticide application in fields (26.7%). The prevalence of child underweight was 23.8%. **Conclusions:** VBDs, water quality and child undernutrition were found to be important local health concerns, amenable for preventive and promotive measures through the planned project. Occupational environments in agricultural settings affect the workers and their households, and comprehensive projects such as WSD can seize the opportunity for improving health of farming and other rural households.

Keywords: Agriculture, health impact assessment, India, nutrition, vector-borne disease, watershed development

5.2. Introduction

Almost 55% of the total workforce and their households depend on agriculture for livelihood in India (Government of India, 2019). Agriculture is also a critical determinant of nutrition for this population (Kadiyala et al., 2014). Occupational health of farmers has received some attention in the National Health Policy 2017 with agricultural injuries indicated as a priority concern (Government of India, 2017a). Most farmers depend on rainfall for cultivation, contributing to uncertainty and distress. Farmer suicides are the tip of the iceberg of the prevalent distress in the community (Manjunatha and Ramappa, 2017). Soil erosion and water insecurity have further affected agricultural productivity (Government of India, 2011). These, and other factors such as vulnerability to climate change (INCCA, 2010), have created a precarious occupational environment for farmers and wage labourers in semi-arid rural India.

In response to these challenges, watershed development (WSD) projects have been conducted with the support of governmental and development agencies towards soil and water conservation, and sustainable livelihoods (Smyle et al., 2014; Technical Committee on Watershed Programmes in India, 2006). Interventions include structures such as check-dams (Meenakshi and Ramanathan, 2010), tree planting (Government of India, 2011), support for livestock rearing and creating local management institutions (Technical Committee on Watershed Programmes in India, 2006). It was envisioned that WSD projects would integrate schemes from across sectors, including nutrition-related schemes (Technical Committee on Watershed Programmes in India, 2006). Common guidelines for WSD projects were revised in 2011 (Government of India, 2011).

WSD projects have reportedly impacted positively on the health of local communities through improved sanitation and water access, enhanced dietary diversity and increased livelihood opportunities, leading to reduction in diarrhoeal disease, better nutrition and overall wellbeing (Pandit, 2010; Nerkar et al., 2013, 2015, 2016). However, modification of the occupational environment has led to some potential negative impacts, through changed vector ecology (increased surface water bodies), pesticide use (increase in commercial cropping) and accidents (drowning in farm ponds) (Pradyumna et al., 2020).

A WSD project was proposed by a non-governmental organization (NGO), MYRADA Kolar Project, for four villages in Kolar district, India in 2019. While a baseline socio-economic study is usually conducted prior to conducting WSD projects, the idea for conducting a health impact assessment (HIA) of this proposed WSD project arose through discussion between the first author and the NGO to (i) deepen the understanding of local health concerns; (ii) identify potential project-related health concerns; and (iii) recommend approaches to mitigate potential risks and maximize health promotion through the planned project. The literature review during

the HIA (Pradyumna et al., 2021b) revealed vector-borne diseases (VBD) (Ghosh et al., 2005; Balakrishnan et al., 2015), undernutrition (IIPS, 2016c) and fluorosis (Shruthi et al., 2016, 2018) as district-level concerns. However, due to inadequate village-level health data for conducting the HIA, primary data collection was carried out to estimate these key indicators prior to the WSD project. In this paper, we present the status of selected health indicators in the local population, as identified through primary data collection within the frame of the HIA prior to the planned WSD project.

5.3. Material and methods

Study area

The WSD project site is located approximately 65 km east of Bengaluru city, and 30 km south of Kolar town (geographic coordinates: 12º53'-12º54 N latitude; 78º3'-78º6' E longitude). The planned WSD project will cover four villages (Figure 5.1). People's main occupation is agriculture, and the main produce is finger millet (Directorate of Census Operations Karnataka, 2014). This semi-arid area has been designated as vulnerable to climate change (IISc, 2014).

Study design

A cross-sectional study design was used, and the modular survey approach suggested by Winkler and colleagues for HIA in tropical contexts was applied (Winkler et al., 2012). Two modules were included: (i) household survey; and (ii) anthropometric survey. The survey sites are depicted in Figure 5.1. The household survey was conducted in the four project villages (n = 195 households) and two comparison villages (n = 138 households). Comparison villages were chosen based on geographic proximity to study villages and similarities in socioeconomic conditions. In terms of sample size, all households were invited to participate, enabling a complete census of the included project and comparison villages. The anthropometric survey was conducted with children under the age of 5 years in the four project villages (n = 83 children) and four comparison villages (n = 77 children). All eligible children in these villages were included for the survey.

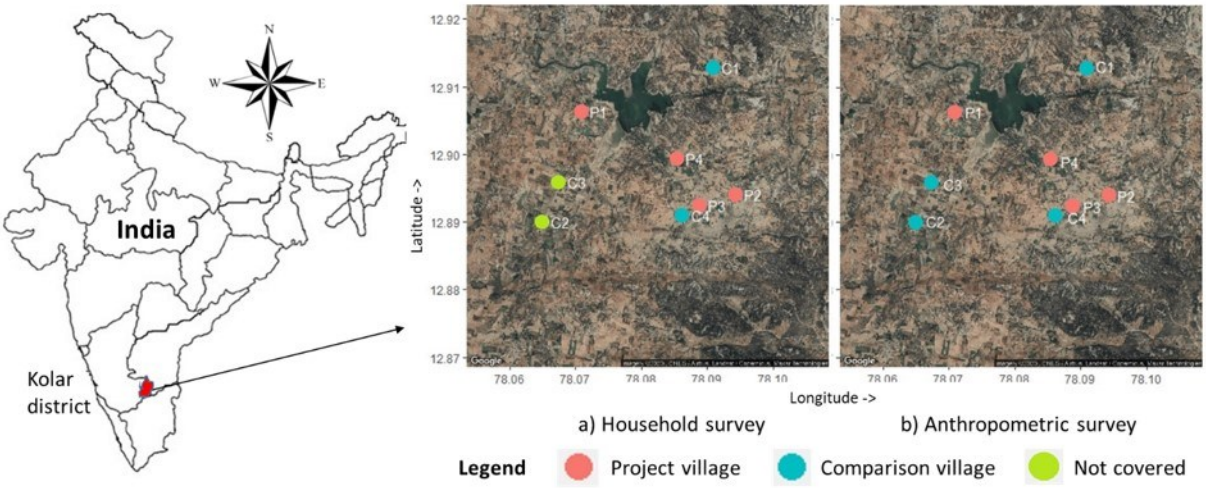

Figure 5.1: Study sites – location of project and comparison villages (source of satellite imagery: Google Earth (dated 29.03.2020, mapped using the 'ggmap' package in R Statistical Software)

Data collection

The survey was conducted between April and July, 2019. Women of age 15 years or more were requested to participate on behalf of their households. After obtaining written informed consent, the survey was administered on an electronic tablet using the Open Data Kit (ODK) platform (Hartung et al., 2010) by a member of the trained survey team. The structured questionnaire contained questions on socioeconomic status, agriculture, water and sanitation, disease risk factors, experience of various diseases and access to health services. Some environmental observations were also made at each household (i.e., toilet condition, soap availability and open drains). The topics were based on needs identified in the scoping stage of the HIA (Pradyumna et al., 2021b). Due to human resource constraints, a few data points were not covered in the comparison villages (indicated in the respective tables).

The anthropometric assessment was done at the local governmental crèches. Few home visits were made for children who could not be brought to the crèche at the time of the survey. Weight on the nearest 0.1 kg (digital scale, Eagle EEP1007A; Pune, India) and mid-upper arm circumference (MUAC) on the nearest mm (using a standard tape) were measured. In addition, sex, date of birth, date of measurement and village location of the child were noted. Data were directly entered into a template developed on ODK.

Statistical analysis

Data was analyzed using R Statistical Software version 3.5.1 (on RStudio version 1.1.456) (R Core Team, 2018). As the sample included all households and all children under the age of 5 years in the project and comparison villages, confidence intervals were not calculated and statistical tests were not performed between comparison groups. The household survey data were summarized descriptively for project and comparison villages using proportions, means and medians. The anthropometric survey data were analyzed using the "anthro package" (Schumacher et al., 2019) to determine z-scores for weight-for-age and MUAC-for-age based on the World Health Organization (WHO) Child Growth Standards. Moderate and severe undernutrition and undernourishment were defined as < -2 standard deviations (SD) and < -3 SD, respectively. The prevalence of underweight and undernourishment among the under-5 children in the study population were estimated.

Ethical considerations

Ethical clearance was received from the Padmashree Institute of Clinical Research in Bengaluru, India (reference no. IEC-BIO-004; date of approval: 10 August 2018) and the Ethics Commission of Northwest and Central Switzerland (EKNZ; reference no. BASEC Nr Req-2018-00839, date of approval: 19 October 2018). Study details were provided to the participants and guardians, following which written informed consent was taken in the local language prior to administering the questionnaire and conducting the anthropometric assessment. An information sheet in the local language was given to participants. Data were stored in an anonymized manner on a server of the host institute.

5.4. Results

Socio-demographic characteristics

A total of 195 households from four project villages and 138 households from two comparison villages were included in the household survey. The anthropometric survey included 83 children from project villages and 77 from comparison villages. Socio-demographic characteristics of the complete study population are summarized in Table 5.1. Most of the respondents were illiterate (57.1%), and a sizeable proportion were of Scheduled Tribes (35.7%).

Table 5.1: Socio-demographic characteristics of participants in the household and anthropometric surveys conducted between April and July 2019 in the study villages, Kolar district, India

Variable	Household survey Project (*n1* = 195), *n* (%)	Comparison (*n2* = 138), *n* (%)	Total (*n* = 333), *n* (%)
Median age in years [P25 – P75]	35 [28 – 45]	39 [28 - 50]	35 [28 – 48]
Sex			
Female	182 (93.3)	111 (80.4)	293 (88.0)
Male	13 (6.7)	27 (19.6)	40 (12.0)
Education			
Illiterate	111 (56.9)	79 (57.2)	190 (57.1)
Up to 4th grade	27 (13.8)	15 (10.9)	42 (12.6)
5th - 10th grade	48 (24.6)	37 (26.8)	85 (25.5)
Pre-university and above	9 (4.7)	7 (5.1)	16 (4.8)
Caste			
General	120 (61.5)	43 (31.2)	163 (48.9)
Scheduled Tribe	60 (30.8)	59 (42.8)	119 (35.7)
Scheduled Caste	15 (7.7)	7 (5.1)	22 (6.6)
Other Backward Class	0 (0.0)	29 (21.0)	29 (8.7)
	Anthropometric survey		
	Project (*n*3 = 83), *n* (%)	**Comparison (*n*4 = 77), *n* (%)**	**Total (*n* = 160), *n* (%)**
Age groups			
0 to 1 year	12 (14.5)	23 (29.9)	35 (21.9)
1 to 2 years	19 (22.9)	9 (11.7)	28 (17.5)
2 to 3 years	16 (19.3)	16 (20.8)	32 (20.0)
3 to 4 years	14 (16.9)	10 (13.0)	24 (15.0)
4 to 5 years	22 (26.5)	19 (24.7)	41 (25.6)
Sex			
Female	39 (47.0)	32 (41.6)	71 (44.4)
Male	44 (53.0)	45 (58.4)	89 (55.6)

Vector-borne diseases

The situation of VBD and related determinants and strategies have been summarized in Table 5.2. One quarter of the respondents reported that their households had ever experienced a VBD. During the year prior to the survey, some respondents claimed occurrences of malaria (10.5%), chikungunya (3.3%) and dengue (1.5%) in their households. Mosquitoes were perceived as a regular nuisance by one in five respondents. The most common approach to cope with mosquito menace was using repellent vaporizers (73.9%). Almost one in two households also reported using bed nets. Over 25% of households usually visited private practitioners for managing fever. Potential vector-breeding sites, such as domestic waste (36.4%) and stagnant water in open drains (16.9%) outside the household were observed in several situations.

Table 5.2: Vector-borne diseases (VBD) occurrence, risk perception and strategies (n (%)) in select villages of Kolar district, India from survey conducted between April and July 2019

Variable	Project (*n*1 = 195), *n* (%)	Comparison (*n*2 = 138), *n* (%)	Total (*n* = 333), *n* (%)
Mosquitoes perceived as nuisance			
Always	37 (19.0)	31 (22.5)	68 (20.4)
During the rainy season	68 (34.9)	62 (44.9)	130 (39.0)
Sometimes	71 (36.4)	5 (3.6)	76 (22.8)
Never	19 (9.7)	40 (29.0)	59 (17.7)
Household member ever affected by a vector-borne disease (self-reported)			
One VBD	51 (26.2)	24 (17.4)	75 (22.5)
Two VBDs	4 (2.1)	0	4 (1.2)
Self-reported malaria occurrence past year	17 (8.7)	18 (13.0)	35 (10.5)
Self-reported chikungunya occurrence past year	10 (5.1)	1 (0.7)	11 (3.3)
Self-reported dengue occurrence past year	4 (2.1)	1 (0.7)	5 (1.5)
Measures used against mosquitoes			
Repellent vaporiser (liquid/mats/coils)	154 (78.6)	92 (65.7)	246 (73.9)
Bed net	95 (48.5)	64 (45.7)	159 (47.7)
Ceiling fan	79 (40.3)	63 (45)	142 (42.6)
Closing the windows	60 (30.6)	64 (45.7)	124 (37.2)
Insecticide spraying	2 (1.0)	19 (13.6)	21 (6.3)
Other methods	9 (4.6)	6 (4.3)	15 (4.5)
Nothing done	2 (1.0)	1 (0.7)	3 (0.9)
First choice of health service for fever			
Local government hospital	141 (72.3)	NR	-
Local private doctor	49 (25.1)	NR	-
Domestic waste around the house	71 (36.4)	NR	-
Open drain outside home	131 (67.2)	NR	-
Drain had stagnant water	33 (16.9)	NR	-

NR – not recorded

Drinking water quality, sanitation and hygiene

The status of WASH and related health characteristics are summarized in Table 5.3. Groundwater was the main source of drinking water for nine in ten households. Drinking water from a village-level water purifier was only utilized by 42.1% of the households. The quality of unfiltered groundwater was perceived as satisfactory for drinking by 31.2% of the respondents.

Members with teeth discolouration was reported in 12.3% households. Health impacts of chronic fluoride exposure were not known to 33% of the respondents. While most households in project villages had their own toilets (92.8%), soap was only observed at hand-wash facilities in 48.7% of the households.

Almost seven in ten households still occasionally used firewood or kerosene stoves for cooking, often alongside natural gas. Monthly pesticide spraying for agriculture was reported by 23.4% households, with a small proportion (3.3%) applying pesticides weekly.

Table 5.3: Drinking water, sanitation and hygiene (n (%)) in select villages of Kolar district, India from survey conducted between April and July 2019

Variable	**Project (*n*1 = 195), *n* (%)**	**Comparison (*n*2 = 138), *n* (%)**	**Total (*n* = 333), *n* (%)**
Community bore-well as source of drinking water	176 (90.3)	119 (86.2)	295 (88.6)
Perceived adequacy of water for domestic use	166 (85.1)	122 (88.4)	288 (86.5)
Method used to purify drinking water			
Community RO filter	82 (42.1)	66 (47.8)	148 (44.4)
Personal filter	2 (1.0)	2 (1.4)	4 (1.2)
None	111 (56.9)	70 (50.7)	181 (54.5)
Perceived that unfiltered water quality is fine	53 (27.2)	51 (37.0)	104 (31.2)
At least one family member reportedly with teeth discoloration	21 (10.8)	20 (14.5)	41 (12.3)
Knowledge about at least one health effect of fluoride exposure	125 (64.1)	98 (71.0)	223 (67.0)
Ownership of latrine	181 (92.8)	125 (90.6)	306 (91.9)
Maintenance of latrine	167 (85.6)	NR	-
Soap was available at hand-wash facility	95 (48.7)	NR	-
Kitchen fuel			
Using only LPG	38 (19.5)	63 (45.7)	101 (30.3)
Using LPG and other fuels	134 (68.7)	53 (38.4)	187 (56.2)
Only using other fuels	23 (11.8)	22 (15.9)	45 (13.5)
Frequency of pesticide application			
> 4 times a month	6 (3.1)	5 (3.6)	11 (3.3)
Up to 4 times a month	62 (31.8)	16 (11.6)	78 (23.4)

LPG, Liquefied petroleum gas; RO, Reverse Osmosis

Nutritional status and underlying determinants

The prevalence of underweight (based on weight-for-age) and undernourishment (based on MUAC-for-age) among children under 5 years of age across eight study villages were 23.8% and 11.3%, respectively (Table 5.4). Over 64% households with eligible children regularly sent them to the governmental crèche, but some households did not, for reasons that the child was too young (15.6%) or because the crèche was located in a neighboring village (15.6%).

Table 5.4: Prevalence of anthropometric failure among children under 5 years of age, and crèche utilization in select villages of Kolar district, India from survey conducted between April and July 2019

Indicator	Project, *n* (%)	Comparison, *n* (%)	Total, *n* (%)
Underweight	(*n*3 = 83)	(*n*4 = 77)	(*n* = 160)
Severe	8 (9.6)	3 (3.9)	11 (6.9)
Moderate	14 (16.9)	13 (16.9)	27 (16.9)
Not	61 (73.5)	61 (79.2)	122 (76.3)
Undernourished	(*n*3 = 79)	(*n*4 = 71)	(*n* = 150)
Severe	1 (1.3)	0 (0.0)	1 (0.6)
Moderate	10 (12.7)	6 (8.5)	16 (10.7)
Not	68 (86.1)	65 (91.5)	133 (88.7)
Households sending children to local crèche	29/45* (64.4)	NR	-
Reasons for not sending			
Crèche located in neighboring village	7/45* (15.6)	NR	-
Child too young	7/45* (15.6)	NR	-
Food insecurity during past 2-year period	40/195 (20.5)	31/138 (22.5)	71/333 (21.3)

*Only 45 households with children aged under 5 years in the project villages; NR, Not recorded

5.5. Discussion

Our cross-sectional survey before the planned implementation of a WSD project in Kolar district, India revealed similar socio-demographic, VBD, WASH conditions and nutritional conditions in the designated project and comparison villages. Few indicators, such as prevalence of severe undernutrition, were slightly higher in project villages, although likely not beyond what can be attributed to random variation. This similarity between project and comparison villages before project initiation is ideal for longitudinal monitoring and evaluation of project impacts (Winkler et al., 2012). The availability of baseline health data from comparison villages will enable a trend analysis (increasing, decreasing or stagnant) or the application of the difference-in-differences approach for indicators that are dissimilar at baseline, after project completion (Knoblauch et al., 2014).

Influence of occupational environment on local health

Structures such as farm ponds, wells and troughs, created to sustain rainfed farming and livestock have been demonstrated to foster mosquito breeding in Kolar district (Balakrishnan et al., 2015; Pradyumna et al., 2020), and hence are of concern for the planned WSD project. Malaria has largely been eliminated from these sub-districts in the past two decades (Ghosh and Dash, 2007), but dengue and chikungunya outbreaks continue to occur (Pradyumna et al., 2021b). While personal protective measures such as mosquito coils were mainly used here, similar to elsewhere in India (Babu et al., 2007), the opportunity for source reduction in the occupational environment exists. Just over a quarter of households in the project villages

reported using private healthcare services for managing fever, which is considerably lower than the rural average (63.2%) reported for all ailments in India (Ministry of Statistics and Programme Implementation, 2019). This observation may indicate the presence of a functional governmental healthcare service.

A sizable proportion of households reported at least monthly application of pesticides (23.4%), probably for vegetable cultivation commonly done in the area (Pradyumna et al., 2020, 2021b). WSD projects increased cultivation of commercial crops such as vegetables, due to enhanced irrigation capacity and land quality (Pradyumna et al., 2020). However, use of personal protective equipment was reported to be low from elsewhere in India (Mohanty et al., 2013). This indicated an opportunity for awareness about safe pesticide application.

Occupational-household environment continuum influencing health impacts

Groundwater is the source for irrigation and domestic use, and reportedly contained high levels of fluoride (Pradyumna et al., 2021b). Access to purified water was found to be limited (54.5%), and evidence of dental fluorosis were reported from a neighbouring sub-district (Shruthi and Anil, 2018). The WSD project, besides increasing water for agriculture, would also improve water quality through rainwater harvesting and groundwater recharge which would contribute to better health (Pradyumna et al., 2020).

The prevalence of underweight among children below the age of 5 years in the study area (23.8%) was slightly lower than for rural Kolar in 2016 (28.5%) (IIPS, 2016c). Over 64% households regularly sent their children to the governmental crèche, higher than the Indian rural average of 42.3% in 2016 (IIPS and ICF, 2017). WSD projects are known to improve food security, access to vegetables, fruits and animal source foods (Nerkar et al., 2015; Pradyumna et al., 2020), and also access to sanitation, and so the planned WSD project can be expected to enhance local nutritional status (Pradyumna et al., 2021b).

Limitations

A few eligible children could not be surveyed as they were unavailable despite two follow-up visits upon absence in the initial survey date. The reason provided was that they were visiting relatives in other areas. Few houses were also found to be locked during the survey and two follow-up visits. However, these numbers were small and so the potential bias on our results may be minimal even if these households were systematically different from those included in the survey. Also, most of the respondents were illiterate (56.9%). This may have impacted the accuracy of their responses on disease occurrence. Finally, as this was a pilot study with limited resources for a relatively small developmental project with potentially minor health implications, clinical examinations were not conducted and biological samples were not

collected for testing infectious, chronic and nutritional diseases in the study population, as is typical for HIAs of large projects (Knoblauch et al., 2014).

5.6. Conclusions

The results of the cross-sectional baseline survey provided insights into various local health concerns relevant to the project context. VBDs, water quality, hygiene and child nutrition were found as important concerns. Relatively high utilization of governmental health and child welfare services indicated presence of functional services of good quality. These findings contributed to the impact assessment of the planned WSD project, based on which mitigation strategies for the identified risks were suggested in the HIA report submitted to the implementing agency. The data collected set a benchmark against which the project interventions and the HIA will be evaluated during and after the project completion in four years' time when a similarly designed survey will be conducted. It is for this purpose that comparison villages were included in the baseline survey – which were largely similar to project villages based on our findings. The modular survey approach adopted here holds promise for impact assessments of other development projects in India, as it is being done in other settings internationally (Winkler et al., 2020b).

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6. Association of livestock ownership and household dietary quality: results from a cross-sectional survey from rural India

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6.1. Abstract

Abstract: Studies from India and several eastern African countries found that the impact of dairy animal ownership on household nutrition varied greatly, depending on the socio-geographic context. The purpose of this study was to examine the association between livestock ownership and household dietary quality in rural Kolar district, India. We collected data from a household survey in four study villages (n=all 195 households of the four villages) of Kolar district, applying a cross-sectional design. Kendall's rank correlation coefficient was employed to determine the correlation between milk consumption and other dietary variables. Multivariable logistic regression was used to describe the relationship between dairy animal ownership and household milk consumption. Households owning dairy animals more often had access to irrigation (58.3% vs 25.2%) and were less often woman-headed (2.4% vs 22.5%). Household milk consumption was significantly correlated with consumption of vegetable variety, egg and meat (all p-values <0.05). After adjusting for multiple confounders, the odds ratio of milk consumption between dairy animal-owning households as compared to other households was 2.11 (95% confidence interval 0.85, 5.45). While dairy animal ownership was found to be associated with improved dietary quality, larger households were in a better position to adopt dairy animals, which, in turn, might contribute to better household nutrition.

Key words

Dairy animal, dietary diversity, India, livestock, milk consumption, nutrition

6.2. Background

The period 2016–2025 has been declared the Decade of Action on Nutrition by the United Nations (UN, 2017). The underlying reason is that child and maternal malnutrition continues to be a major global challenge as a top risk factor for morbidity and mortality worldwide (GBD 2019 Risk Factors Collaborators, 2020), including India (India State-Level Disease Burden Initiative Collaborators, 2017). Although considerable progress has been made over the past several years, in 2016, high prevalence of stunting (38%), wasting (21%) and undernutrition (36%) among children under 5 years of age were recorded in India (IIPS and ICF, 2017). Dietary diversity is an important determinant of nutritional status of children (Kadiyala et al., 2014; Kim et al., 2019). Milk is an important source of animal protein, especially for under 5-year-old children (Hoddinott et al., 2015; Pritchard et al., 2017). However, analysis of nationally representative data revealed that 5–15% of children in rural areas were at risk of quality protein deficiency, worsening to 26-42% among adults in poor households (Minocha et al., 2017). Livestock ownership, especially dairy animals, has been promoted in rural India to support livelihood and nutrition (Government of India, 2016b).

Literature on the impact of dairy animal ownership on diet and nutrition is available from India and several eastern African countries. Livestock ownership was estimated at 59.7% for households across rural households in India in 2016 (IIPS and ICF, 2017), and was deemed an important factor determining consumption of animal-sourced foods (Kadiyala et al., 2014). The linkage between dairy animal ownership and milk consumption was specifically emphasized (Bhagowalia et al., 2012). This was corroborated by studies from Ethiopia (Hoddinott et al., 2015) and Uganda (Kabunga et al., 2017). However, several factors such as globalisation, urbanisation, changing access to education, livelihood and progressive reduction in farm sizes are impacting agriculture as a viable livelihood option, complicating its linkages with food security and dietary quality in rural areas, as was found in a study in northern India (Pritchard et al., 2017). Also, little is known regarding the association between dairy animal ownership and household milk consumption in villages in southern India.

When we recently conducted a qualitative study in Kolar district, a rural semi-arid area in southern India, we found that households that adopted dairy animals for livelihood through the support of watershed development (WSD) projects perceived positive impacts on milk consumption and dietary quality (Pradyumna et al., 2020). This pointed to a need for additional quantitative research to deepen the understanding of context-relevant factors, especially keeping in mind the planned promotion of livestock rearing as part of WSD projects in India (Government of India, 2011). Hence, the basis for the current paper was set, and the opportunity for this analysis presented itself when we conducted a cross-sectional baseline survey as part of a health impact assessment (HIA) of a planned WSD project in four villages

of Kolar district (Pradyumna et al., 2021b). The specific objectives of this paper are: (i) to assess the baseline status of socio-demographic factors based on dairy animal ownership; (ii) to assess health determinants of households based on dairy animal ownership; (iii) determine the correlation of milk consumption with other dietary variables; and (iv) examine the association between livestock ownership and milk consumption in the designated project area.

6.3. Materials and methods

6.3.1. Study design and study setting

A cross-sectional survey was conducted in the study area during April to July 2019 to characterise socio-demographic factors and health determinants. As the number of people living in each village was relatively small, all households were invited to participate. Data from the cross-sectional survey were used for multivariable logistic regression analysis.

The study was conducted in four neighbouring villages in the southern part of Malur sub-district of Kolar district in Karnataka state, India. The total population of these villages was officially enumerated at 1,340 individuals in 2011 (Office of the Registrar General & Census Commissioner, 2011). The main economic activity is agriculture, with finger millet being the most important crop (Office of the Registrar General & Census Commissioner, 2011). The region is drought-prone and vulnerable to climate change (O'Brien et al., 2004; BCCI-K, 2011). The sub-district is in close proximity to Bengaluru, but is largely rural, and has a literacy rate of 62.6%. One out of 10 people (9.4%) belong to scheduled tribes (ST), and one quarter (25.4%) belong to scheduled castes (SC) (CensusIndia2011, 2021). In the study villages, 30.8% were of ST and 7.7% were of SC. These villages had access to water, electricity and sanitation, whereas one village did not have an *anganwadi* (creche). Only 2.1% of households in the project villages reported never consuming meat (Pradyumna et al., 2021b, 2021a). There was a perception among some households that milk of cattle of high-yielding varieties was not healthy to consume (Pradyumna et al., 2020). Often it was the women of the household who were involved in managing the cattle and milking them. The richer households grew fodder crops, and poorer households used finger millet fodder and also bought fodder to feed the cattle (Pradyumna et al., 2020), while some pastures were also reportedly available in these villages (6.3% of total land) (Office of the Registrar General & Census Commissioner, 2011). Almost all the collected milk was sold to the local dairy, with a little bit for household consumption, or sold to neighbours if they requested (Pradyumna et al., 2020). The road connectivity to the nearby town was good, though some of these villages were heavily dependent on private vehicles to access the town (Pradyumna et al., 2021b). The prevalence of underweight among children was found to be 26.5% in these villages (Pradyumna et al., 2021a, 2021b), which is comparable to the rest of rural Kolar (28.5%, in 2015) (IIPS, 2016c).

Among 15-49-year-old women in rural Kolar, the prevalence of overweight or obesity was 15.2%, and that of anaemia was 45.9% (IIPS, 2016c). Often one or more members of the household, especially from SC background, travelled outside the village for livelihood and better remuneration (Pradyumna et al., 2020, 2021b).

These four villages were chosen for this study because a WSD project was planned for the villages by a local non-governmental organisation (NGO). These specific villages are geographically part of a micro-watershed, which had been identified for future WSD interventions by local governmental departments. As part of the baseline studies prior to implementing the WSD project, a survey was carried out by our team to deepen the understanding of the social and health situation in the villages, and the relevant data were used for the current research. As several similar villages in this semi-arid region would be subjected to WSD projects, studies of this nature can provide context-specific insights. In addition, the potential of WSD projects to incorporate health aspects such as nutrition was identified by a technical committee in 2006 (Technical Committee on Watershed Programmes in India, 2006), and hence, such studies can guide nutrition-related activities of WSD projects.

WSD projects have been carried out in semi-arid areas of India by the government, often in partnership with NGOs, aiming to enhance soil and water conservation, improve agricultural productivity and support livelihoods through approaches such as livestock rearing, especially among the landless households (Government of India, 2011). There are other context relevant interventions conducted as part of these projects by the local project-implementing NGOs, for instance, supporting self-help groups (Meenakshi and Ramanathan, 2010). It was opined by project managers that beneficiaries often opted for high-yielding milch cattle as they were perceived to be a sustainable livelihood source (Pradyumna et al., 2020).

6.3.2. Data collection

A structured and pilot-tested questionnaire covering topics of household demography, occupation, agriculture, diet, sanitation and access to healthcare was used. The questionnaire was administered by trained field enumerators, and data were directly entered into electronic tablets on the Open Data Kit (ODK) platform (Hartung et al., 2010). Any woman of the household (aged ≥ 15 years) was requested to be the respondent (in some cases this was not possible, so a man became the respondent). Further details of the baseline survey methodology are available elsewhere (see reference (Pradyumna et al., 2021a)).

6.3.3. Statistical analysis

Data were downloaded from the ODK Aggregate platform and read into R statistical software version 3.5.1 (on RStudio Version 1.1.456) (R Core Team, 2018). Variables were summarised to find missing and inappropriate values. Categorical variables were checked for small cell sizes. We examined the associations of socio-demographic factors and other health determinants with ownership of dairy animals - which is the main explanatory variable (binary) for the regression analysis. Dairy animals were defined as high-yielding variety cows, local variety cows and/or buffaloes. Because all households in the study area were included in the study, confidence intervals were not calculated for the descriptive statistics. Kendall's rank correlation coefficient (tau) was used to calculate the correlation between milk consumption (binary) and other dietary variables (i.e., vegetable consumption, fruit consumption, egg consumption and meat consumption; each with four ordered categories).

Crude odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for describing the relationship between household milk consumption (the main outcome; binary variable) and a set of pre-determined covariates (i.e. ownership of dairy animal, household size, sex of household head, existence of children in household, caste (scheduled caste or SC, scheduled tribe or ST and other; with SC and ST considered as marginalised groups in most regions in India), land ownership, access to irrigation, self-help group (SHG) membership and a dummy variable for wage labour as main income source. Household income (self-reported) data were available but not used as a covariate in our analysis because of high potential for measurement errors, and literature from India suggesting that income was an unsuitable predictor of nutrition in rural areas (Bhagowalia et al., 2012). Several included covariates are proxies for income, for instance, land ownership, access to irrigation and ownership of motorised vehicles. The covariates were based on a hypothesised causal model of household milk consumption in rural areas in southern India, as ascertained from literature (Bhagowalia et al., 2012; Kadiyala et al., 2014; Azzarri et al., 2015; Hoddinott et al., 2015; Kabunga et al., 2017; Pritchard et al., 2017) and knowledge of the local context (Figure 6.1).

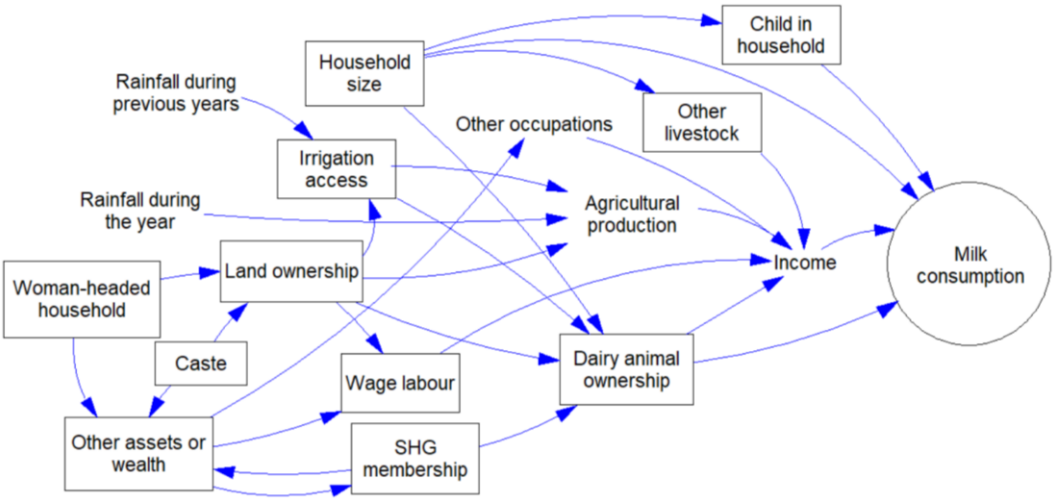

Figure 6.1: Factors potentially influencing milk consumption at household level in the study area (boxed variables have been included in the analysis); SHG, self-help group

A multivariable logistic regression model adjusting for various covariates was fitted to the data to better understand the causal relationship between dairy animal ownership and household milk consumption. Variables (ownership of other livestock) showing high correlation with the main explanatory variable were eliminated from the final model (Phi coefficient = 0.69). The ORs and 95% CIs were reported and interpreted. Results were considered significant at $p < 0.05$. CIs were reported only for the ORs despite having conducted a census, to provide an impression of the uncertainty around the estimate, especially keeping in mind the small population size, to aid in generalisability of study results outside of the study population.

Sensitivity analysis was performed by using propensity score matching (PSM) through nearest neighbour matching (NNM) with replacement, using the MatchIt package in R statistical software, to increase the comparability of the two groups based on the following covariates: household size, sex of household head, child in household, caste, land ownership, access to irrigation, SHG membership and wage labour. The quality of matching was assessed through quantile-quantile (QQ) plots and two sample t-tests for each covariate. As the matching was deemed to have improved comparability (though having expectedly reduced the sample size), multivariate logistic regression was carried out on this data subset to better understand the association between dairy animal ownership and household milk consumption.

6.4. Results

6.4.1. Sociodemographic characteristics of the study population

A total of 195 households were included in the four project villages (response rate: 100%). Over 93% of the respondents were adult women. The median age of all respondents was 35 years (25th–75th percentile: 27–45 years). Most of the respondents were illiterate (56.9%).

Characteristics of the respondents are summarised in Table 6.1. Less than half of the households (43.1%; n=84) owned at least one dairy animal. Households owning dairy animal(s) were more often larger than households not owning a dairy animal (median of 5 persons vs 4), had greater land-holdings (2.75 acres vs 2.09 acres), increased access to irrigation (58.3% vs 25.2%), more frequent ownership of a motorised vehicle (92.9% vs 81.1%) and higher ownership of other livestock (95.2% vs 26.1%). Households owning dairy animal(s) were also less likely to be woman-headed (2.4% vs 22.5%), SC (2.4% vs 11.7%) or have recent history of seasonal migration (2.4% against 9.0%). Details on ownership of livestock in the study population are shown in Figure 6.2. Those owning dairy animals more often had greater variety of livestock.

Table 6.1: Socio-demographic characteristics of the study population from a household survey conducted between April and July 2019 in four villages in Kolar district, India

Variable	**Owns dairy animal(s) (n=84)**	**Does not own dairy animal(s) (n=111)**	**Total (n=195)**
Respondent details			
Age (median [P25 – 75])[a] in years	34.5 [26–41.3]	35 [28–47]	35 [27–45]
Respondent is female	75 (89.3%)	107 (96.4%)	182 (93.3%)
Respondent is illiterate	42 (50.0%)	69 (62.2%)	111 (56.9%)
Household characteristics			
Household size (median [P25 – 75])	5 [4.8–7]	4 [3–5]	5 [4–6]
Under-5 child in household	23 (27.4%)	22 (19.8%)	45 (23.1%)
Woman-headed household	2 (2.4%)	25 (22.5%)	27 (13.8%)
Caste			
General category	52 (61.9%)	68 (61.3%)	120 (61.5%)
Scheduled caste (SC)	2 (2.4%)	13 (11.7%)	15 (7.7%)
Scheduled tribe (ST)	30 (35.7%)	30 (27.0%)	60 (30.8%)
Primary income source			
Agriculture	61 (72.6%)	70 (63.1%)	131 (67.2%)
Daily wage	14 (16.7%)	24 (21.6%)	38 (19.5%)
Livestock rearing	3 (3.6%)	2 (1.8%)	5 (2.6%)
Other	6 (7.2%)	15 (13.5%)	21 (10.8%)
Land ownership in acres[b] (mean [SD])	2.75 [1.47]	2.09 [1.46]	2.37 [1.49]
Access to irrigation	49 (58.3%)	28 (25.2%)	77 (39.5%)
Owns non-dairy livestock	80 (95.2%)	29 (26.1%)	109 (55.9%)
Regular travel for wage labour	33 (39.3%)	49 (44.1%)	82 (42.1%)
Undertook seasonal migration	2 (2.4%)	10 (9.0%)	12 (6.2%)
SHG membership	35 (41.7%)	37 (33.3%)	72 (36.9%)
Owning a motorised vehicle	78 (92.9%)	90 (81.1%)	168 (86.2%)
Social welfare card	84 (100%	110 (99.1%)	194 (99.5%)

[a] 25th and 75th percentile; [b] one acre = 4046.86 m^2; SD, standard deviation

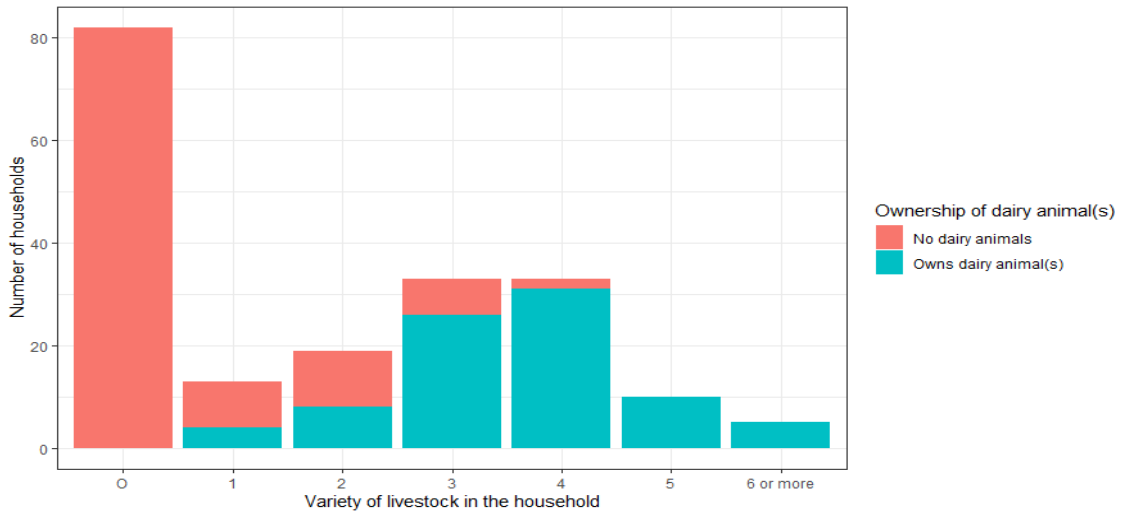

Figure 6.2: Ownership of livestock in the study population based on survey conducted between April and July 2019 in four villages in Kolar district, India

6.4.2. Status of health determinants and correlation of household milk consumption with other dietary variables

The status of health determinants is summarised in Table 6.2. One in five households (20.5%) have experienced food insecurity during the past two years. A higher proportion of households owning dairy animal(s) consumed milk (88.6% vs 62.2%). Latrine ownership was high across both groups (92.8%). Dairy animal-owning households more commonly opted for private healthcare services in case a household member had fever (38.1% vs 15.3%). Health insurance coverage was only reported by 44.1% households.

Milk consumption was significantly correlated with vegetable consumption (Kendall's tau=0.16, p=0.017), egg consumption (Kendall's tau=0.27, p<0.001) and meat consumption (Kendall's tau=0.14, p=0.049). The correlation statistics are summarised in Table 6.3.

6.4.3. Association between ownership of dairy animal(s) and milk consumption

Of the 195 households, 52 (26.7%) reported that they did not consume milk. Covariates that showed strong crude associations with milk consumption include owning dairy animal(s) (OR: 4.50, 95% CI: 2.17, 10.14), household size (OR: 2.00, 95% CI: 1.56, 2.66), woman-headed households (OR: 0.19, 95% CI: 0.08, 0.43), land ownership (OR: 1.67, 95% CI: 1.23, 2.35), access to irrigation (OR: 3.19, 95% CI: 1.57, 6.99) and owning a motorised vehicle (OR: 9.72, 95% CI: 4.04, 25.4) (Table 6.4).

The full model for the relationship between dairy cow ownership (primary explanatory variable) and milk consumption (main outcome) was adjusted by household size (count), woman-headed household (binary), whether general caste (binary), child in household (binary), wage labour as main income source (binary), land owned (continuous), access to irrigation (binary),

membership with SHG (binary) and ownership of motorised vehicle (binary). The multivariate logistic regression model output indicated that the adjusted OR for household milk consumption was 2.11 (95% CI: 0.87, 5.45) between households owning and not owning dairy animals. Evidence of association was found for household size (adjusted OR: 1.88, 95% CI: 1.34, 2.77), ownership of motorised vehicle (adjusted OR: 4.08, 95% CI: 1.23, 14.31) and wage labour as primary income source for family (adjusted OR: 2.89, 95% CI: 1.04, 9.03).

Table 6.2: Select health determinants in the study population based on a survey conducted between April and July 2019 in four villages in Kolar district, India

Variable	**Owns dairy animal(s) (n=84)**	**Does not own dairy animal (n=111)**	**Total (n=195)**
Experienced food insecurity in the past two years	15 (17.9%)	25 (22.5%)	40 (20.5%)
Consume any milk regularly	74 (88.1%)	69 (62.2%)	143 (73.3%)
Variety of vegetables consumed previous week (median [P25 – P75][a]	6 [5–7]	6 [4–7]	6 [5–7]
Egg consumption frequency in a month (median [P25 – P75]	2 [2–4]	2 [1–3]	2 [1–4]
Meat consumption frequency in a month	4 (4–4.3)	4 (3–4)	4 (4–4)
Fruit consumption frequency in a month (median [P25 – P75]	2 [1–3]	1 [0–2]	1 [0–2]
No knowledge of any iron-rich foods	2 (2.4%)	11 (9.9%)	13 (6.7%)
Latrine ownership	79 (94.0%)	102 (91.9%)	181 (92.8%)
Any member consumes alcohol	7 (8.3%)	20 (18.0%)	27 (13.8%)
Any member smokes	11 (13.1%)	20 (18.0%)	31 (15.9%)
Any member chews tobacco	21 (25.0%)	25 (22.5%)	46 (23.6%)
First choice healthcare provider for fever			
Local government hospital	50 (59.5%)	91 (82.0%)	141 (72.3%)
Local private doctor	32 (38.1%)	17 (15.3%)	49 (25.1%)
Health insurance cover			
Governmental schemes	34 (40.5%)	51 (45.9%)	85 (43.6%)
Private	1 (1.2%)	0 (0.0%)	1 (0.5%)
None	49 (58.3%)	60 (54.1%)	109 (55.9%)

[a] 25th and 75th percentile

Table 6.3: Correlation of milk consumption with other dietary variables based on data from survey conducted between April and July 2019 in four villages in Kolar district, India

Factor related to dietary quality	**Kendall's tau**	**p-value**
Variety of vegetables consumed	0.163	0.017*
Frequency of fruit consumption	0.016	0.816
Frequency of egg consumption	0.265	<0.001*
Frequency of meat consumption	0.139	0.049*

*Significant at p-value <0.05

The sensitivity analysis included 128 households (84 households owning dairy animals and 44 not owning dairy animals). Previously observed imbalances between households owning and

not owning dairy animals were minimised through the matching for all included covariates, except for household size (difference persisted after matching at p=0.03). The adjusted OR for milk consumption was 2.20 (95% CI: 0.77, 6.45) in this subsample.

Table 6.4: Crude and adjusted odds ratios and a sensitivity analysis (SA) comparing household milk consumption with the explanatory variables based on data collected between April and July 2019 from four villages in Kolar district, India

Variable	Crude OR (95% CI)	Adjusted OR (95% CI)	SA: adjusted OR (95% CI)
Owns dairy animal(s)	4.50 (2.17–10.14)***	2.11 (0.87–5.45)	2.20 (0.77–6.45)
Household size	2.00 (1.56–2.66)***	1.88 (1.34–2.77)***	1.62 (1.06–2.77)
Woman-headed household	0.19 (0.08–0.43)***	0.78 (0.25–2.58)	NA
Whether SC[b]	2.50 (0.66–16.35)	-	-
Whether ST[b]	1.13 (0.57–2.32)	-	-
Whether general caste	0.71 (0.36–1.37)	0.71 (0.31–1.58)	0.36 (0.1–1.14)
Child in household	1.92 (0.86–4.73)	0.48 (0.16–1.45)	0.73 (0.15–4.16)
Wage labour main income source	0.87 (0.4–1.97)	2.89 (1.04–9.03)	2.01 (0.52–9.17)
Land owned	1.67 (1.23–2.35)**	1.06 (0.8–1.47)	1.8 (0.96–3.92)
Irrigation access	3.19 (1.57–6.99)**	1.30 (0.53–3.29)	1.75 (0.55–5.74)
SHG member	1.29 (0.67–2.56)	1.04 (0.47–2.37)	3.38 (0.97–14.98)
Owns motorised vehicle	9.72 (4.04–25.4)***	4.08 (1.23–14.31)*	1.21 (0.19–6.53)
Any non-dairy livestock owned[c]	3.71 (1.92–7.42)***	-	-

***p-value <0.001; **p-value <0.01; *p-value <0.05; [a] standard deviation; [b] due to small cell sizes, only dummy variable for general caste was used in final model; [c] highly correlated with ownership of dairy animal, hence not included in final model; NA, not available; SHG, self-help group; SC, scheduled caste, ST, scheduled tribe; SA, sensitivity analysis with data subset determined by propensity score matching

6.5. Discussion

Milk consumption was found to be both significantly correlated with other markers of a diverse and high-quality diet (i.e., vegetable, egg and meat consumption) and elevated among households owning dairy animal(s) (OR: 2.11), even after controlling for multiple confounders. The association between dairy animal ownership and milk consumption was not statistically significant after adjusting for all covariates (see the column “Adjusted OR” in Table 6.4), which might be explained by the relatively small sample size (n=195). Of note, we included all households in the four villages that will be affected by the project. It is conceivable that families owning dairy animals would consume milk when the dairy animal is producing milk. However, families owning dairy animals were, in general, different from those not owning dairy animals. For example, they often owned greater assets (land, access to irrigation and motorised vehicle(s)) than those that did not. This was also consistent with the finding that woman-headed and SC households owned dairy animals far less frequently. This suggests ownership of dairy animals was associated with an overall higher socioeconomic status in the study area.

The investment of purchasing and managing a high-yielding dairy animal may be prohibitive to those without assets (Kabunga et al., 2017; Pritchard et al., 2017). However, even after matching for these socioeconomic covariates through PSM, a positive association was found between dairy cow ownership and milk consumption, suggesting that this finding is not entirely dependent on socioeconomic status.

The advantage of owning land and irrigation access for meeting fodder and water needs of dairy animals was reported by other studies (Kabunga et al., 2017; Pritchard et al., 2017). Indeed some local farmers from nearby villages revealed cultivating only fodder crops in their irrigated fields, focusing solely on dairy for livelihood (Pradyumna et al., 2020). This indicates that while dairy animals have the potential to contribute dietary quality and diversity, the impact may be disproportionately higher for richer households, as has been shown in an earlier study (Kabunga et al., 2017).

6.5.1. Interpretation from a household nutrition perspective

The main finding of association between dairy animal ownership and household milk consumption was corroborated by a large study from India (Bhagowalia et al., 2012), and also smaller studies from Ethiopia (23% increased frequency) (Hoddinott et al., 2015), Uganda (Fierstein et al., 2017; Kabunga et al., 2017) and Kenya (Nicholson et al., 2004). This was found to be especially important in areas without access to markets (Hoddinott et al., 2015), which was not the case in our study area where dairies have been established.

While milk was significantly correlated with other markers of a diverse and high quality diet, it was not the only source of protein and micronutrients in the study area, as has also been reported in literature (Minocha et al., 2017). There is also consumption of finger millet, pulses (a regular feature in meals), eggs and meat, the latter two being more frequent among households owning dairy animals. These findings are in contrast to what was observed in some villages in northern India where consumption of milk and milk products were found to be more critical to dietary quality (Pritchard et al., 2017). The importance of understanding local context in the contribution towards household nutrition is emphasized (Pritchard et al., 2017).

The proportion of households that reported having experienced food insecurity during the last two years was similar for households with or without dairy animal(s) (17.9% vs 22.5%). These percentages do not indicate the frequency and severity of the experienced food insecurity. In addition, it is difficult to draw causal inferences in the context of dairy animal ownership as this is a cross-sectional study.

Food consumption at household level cannot be extrapolated to nutritional status of individuals within the household, as shown before (Bhagowalia et al., 2012; Kim et al., 2019). A study from

Ethiopia indicated positive impact on reducing stunting (Hoddinott et al., 2015). Studies from Uganda found significant positive impact (Kabunga et al., 2017), no impact (Fierstein et al., 2017) or even negative impact (Azzarri et al., 2015) of dairy animal ownership on child nutrition, and hence, there must be other contextual factors, such as availability and use of sanitation and intra-household competition for resources. Small ruminants (e.g. goats and sheep) were found to contribute to better nutrition outcomes in Uganda (Azzarri et al., 2015) and the poorest households in Kenya (Romeo et al., 2016). Several other factors complicating this relationship have been elucidated in the literature, including wealth, resource constraints and experience of financial shocks (Hoddinott et al., 2015).

6.5.2. Interpretation in the light of WSD projects

WSD projects locally have helped overcome the obstacle of high initial investment by providing grants and loans to procure livestock, preferentially to poor woman-headed households through SHGs (Pradyumna et al., 2020). Currently SHG membership was somewhat lower among households without dairy animals (33.3% against 41.7%), and this can be expected to improve through the planned WSD project (Pradyumna et al., 2021b). Beneficiaries in earlier local WSD projects perceived financial and nutritional benefits following the adoption of dairy animal(s) (Pradyumna et al., 2020). On similar lines, an intervention study in Rwanda on donation of livestock to households was able to demonstrate impact on child nutrition (Rawlins et al., 2014). However, keeping in mind that managing dairy animals is labour-intensive and harbours various costs (Sharif and Dixit, 2015; Sunil et al., 2016) – including accessing water and feed (Pritchard et al., 2017), all households may not be able to adopt it. The varying success of dairy programmes in villages in northern India due to the role of availability of land and labour in the household has also been reported (Basu and Chakraborty, 2008).

Interventions encouraging dairy animal ownership as part of the WSD project should take into account whether it is feasible for low-income households to maintain a dairy animal long-term. Additionally, challenges of water and feed are worsened during droughts (Pritchard et al., 2017), which occur regularly in Kolar district. Local anecdotal evidence (assimilated during a recent study (Pradyumna et al., 2020)) reported that several households sold their dairy animals a few years ago following a period of intense drought. Financial returns from dairy animals were also reportedly lower in areas with high groundwater exploitation (Sharif and Dixit, 2015), such as in the study area. Also, in Tamil Nadu, an “economically transforming” state, it was observed that smallholder farmers had downsized dairy farming in the 10 years prior to the 2018 study for various economic and cultural reasons (Thirunavukkarasu et al., 2019), and this may have bearing for Kolar, which is a neighbouring district of Tamil Nadu. In addition, promotion of dairy animals comes with health and ethical challenges such as

antimicrobial resistance, especially for high-yielding varieties (Joshi and Gokhale, 2006). Therefore, this strategy could be reviewed accordingly.

6.5.3. Interpreting effects of household size and wage labour

We found a strong association of milk consumption and household size (OR: 1.88, 95% CI: 1.34, 2.77) (Table 6.4), which is in contrast to findings from a large Indian dataset (Bhagowalia et al., 2012). Two factors might explain this observation. First, wealthy households in the study area lived as joint families, as they have the financial and human resources to buy and manage dairy animals. Second, the poorest households were those of elderly women living alone. The strong association between wage labour and milk consumption (OR: 2.89, 95% CI 1.04, 9.03) may also be related to few households consisting only of elderly poor women living alone unable to engage in wage labour. Reportedly, regular wage labour in construction industry and domestic work in nearby cities was providing adequate returns to young people from this area (Pradyumna et al., 2020).

6.5.4. Limitations of the study

It is not possible to draw conclusions on causal relationships from cross-sectional data. Reverse causality between household milk consumption and dairy animal ownership is plausible if milk consumption be considered a proxy for wealth/income. Keeping the literature and context in mind, this is unlikely. However, as ownership of cattle was strongly associated with wealth indicators, the association with household milk consumption should be interpreted with caution. Another limitation of the analysis was the lack of data on other milk products. In our preceding work in the same region, we found that part of the milk was consumed in fermented form (curd) (Pradyumna et al., 2020). As this curd was made from fresh milk within the household, we assumed it was represented within the data on milk consumption. Finally, the findings of the present study mainly apply to the study area, but may also provide insights on what can be expected in the drought-prone rural regions in southern India.

6.5.5. Scope for future research and practice

Further research could adopt a prospective mixed-method design, focus on differential benefits experienced by various types of adopting households and also study challenges being faced by each in taking up and managing dairy animals. Adding outcome measures (e.g., nutritional status among children within the household, haemoglobin levels among adults) as part of the survey would be good to indicate the size and distribution of direct health impacts of these interventions. This kind of evidence is currently lacking (Kadiyala et al., 2014). The experience from Gujarat also indicates the need to consider larger economic aspects and cultural

dynamics in dairy promotion (Daftary, 2019), and such studies with social science perspectives need to be conducted in Kolar's context.

Keeping in mind that the data for the study came from a baseline survey, the additional benefits of conducting comprehensive health impact assessments for agricultural projects was revealed – fostering empirical research in neglected settings (Winkler et al., 2020a). Indeed, baseline survey data can be leveraged to better understand agriculture and nutrition linkages, besides other locally relevant health outcomes.

6.6. Conclusions

Our study revealed that dairy animal ownership was quite common in the study area (55.9% of the households, as compared to 59.7% for rural India on average (IIPS and ICF, 2017)). We found evidence suggestive of causal relationship between dairy animal ownership and household milk consumption in the four villages in the southern part of Kolar district. Households consuming milk were found to have a better dietary quality in terms of vegetable variety, frequency of meat consumption and frequency of egg consumption. In terms of the factors associated with adoption of dairy animals, we found that wealth, household size, land ownership and access to irrigation were important. Our findings also illustrated how context plays a role in determining effects of interventions in rural areas, for instance, the effect of household size.

Health- and equity-sensitive rural development schemes are needed for achieving the Sustainable Development Goals 3 (good health and well-being) and 10 (reduce inequalities). More specifically, a call has been made for development policies to be nutrition-sensitive (Ruel et al., 2013; IFPRI, 2015). Both WSD projects and the livestock mission have been recognised for the potential to also address nutritional challenges. Based on our findings and the literature, we recommend that, while there is merit for continued support for livestock programmes, there is a need for incorporating contextual insights into programme design to ensure that it is relevant and to have realistic expectations of returns in the form better nutrition and/or improved livelihood. This emphasises the role of district offices, local organisations and research institutions in the process. The type of livestock would also be an important factor. As considerable resources are put into these initiatives, careful monitoring and evaluation of these interventions and schemes is essential, with periodic revision of interventions based on key findings. One-size-fits-all approaches cannot be expected for diverse contexts.

We used the opportunity of a baseline survey of a planned project to contribute to literature and local planning. Further social science-oriented studies can provide further insights on the utility and appropriateness of livestock interventions for improving nutrition. Similar studies

from other parts of the country could also further enhance our understanding about agriculture-nutrition interlinkages towards addressing undernutrition.

Declarations

- Ethics approval and consent to participate: Ethical clearance was obtained from the Padmashree Institute of Clinical Research in Bengaluru, India (reference no. IEC-BIO-004; date of approval: 10 August 2018) and the Ethics Commission of Northwest and Central Switzerland (EKNZ) in Basel, Switzerland (reference no. BASEC Nr Req-2018-00839, date of approval: 19 October 2018). Study details were explained to the participants and written informed consent (in the local language) was taken prior to the interviews and survey. An information sheet prepared in local language with contact details of the researcher was handed over to participants. The data were stored on a server of the Swiss Tropical and Public Health Institute in Basel, Switzerland in an anonymised manner.
- Acknowledgements: We would like to thank Shiva Shankar and his team at MYRADA Kolar Project for their support in data collection.

7. Discussion

This chapter, presented in four sections, weaves together issues and emergent ideas from across the individual papers. The first section addresses the utility and limitations of the methods adopted in this thesis. The second section synthesises the themes from across chapters. The third section highlights the contribution of the thesis to public health research and practice in India and globally (an overview of this section is provided briefly in Table 7.1). The final section elaborates the possibilities of building on what has been done in this thesis: avenues that can be leveraged, roles that can be played by various actors and ways in which potential barriers towards "Health in All" could be overcome.

Table 7.1: Summary of contributions of the PhD thesis based on the Swiss TPH *mantra* of "Innovation, Validation and Application"

Chapter	Innovation	Validation	Application
Chapter 2: Health in food systems policies in India: a document review	First study comprehensively exploring health concerns of food systems policies in India; combined thematic and content analysis; demonstrated an approach to study HiAP	While the methods were appreciated by peer reviewers, further validation needed through additional case studies	Identified gaps in health considerations and health sector involvement in food systems policies; recommendations made
Chapter 3: Perceived health impacts of watershed development projects in southern India: a qualitative study	Identified previously unreported health concerns of WSD projects: VBDs, pesticide exposure and accidental drowning	Findings validated through comparing data across four WSD projects and with literature	Findings were utilised in the scoping stage of the HIA for a planned WSD project (Chapter 4)
Chapter 4: Health impact assessment of a watershed development project in southern India: a case study	First reported comprehensive HIA case study from India; first reported HIA on a WSD project; utility of HIA for WSD identified	Feedback received from NGO on HIA report; further case studies will further validate methods	Further case studies will be planned based on this experience (Section 7.4); also used as a teaching case
Chapter 5: Health of farming communities prior to modification of the occupational environment through a watershed development project in Kolar, India	Baseline health survey conducted, which is unusual for impact assessments in India; village-level estimates on child underweight, self-reported VBD and household food insecurity	Findings were compared to existing literature; further case studies will establish feasibility and utility of baseline health surveys	Findings were applied to Chapter 4; modular approach to baseline surveys will be further developed during future case studies
Chapter 6: Association of livestock ownership and household dietary quality: results from a cross-sectional survey from rural India	Utilisation of baseline survey data for empirical research on agri-nutrition interlinkages; unusual association with household size identified; correlation of milk consumption with dietary quality	Sensitivity analysis was conducted; findings were compared with literature; further research proposed for future WSD projects	Recommendations were made regarding the livestock support component of the planned WSD project

7.1. Reflections on methods and data used

7.1.1. Chapter 2: health in food systems policies in India

The objective was to contribute to the evidence on the status of health consideration at policy level in India, examining the types of health concerns and involvement of the health sector in food policy governance. With the study aiming to cover all policies relevant to food systems at national level, it was inevitable that documents from several ministries and sectors would be included. While the paper was long and covered a diversity of topics, I perceived advantages of presenting all the findings together to provide a comprehensive insight on policy content, linkages and governance mechanisms in India for "Health in All".

The combination of methods used in this paper, thematic and content analysis, added to some challenges in presenting the findings. For instance, findings were presented under the themes identified through the thematic analysis, but efforts were made to incorporate relevant findings from content analysis under the appropriate themes. The findings from each of these methods contributed to strengthening the arguments made. Most components of the food systems definition were touched upon through this paper (Figure 7.1).

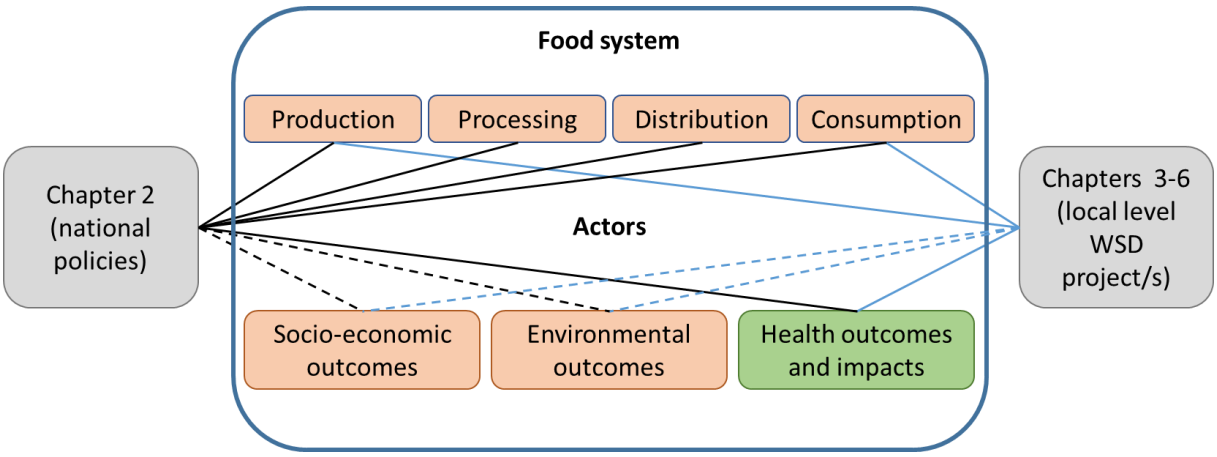

Figure 7.1: Themes covered in the thesis from a food systems lens; lines indicate aspects that have been touched upon in the various papers

The "what" and "how" of health considerations in the policy documents was addressed, but this will benefit from further empirical research. For instance, studying the power and capacity of health representatives within high-level advisory groups to influence decisions. This can be done through interviews with relevant policy makers and academicians, as was done by Thow et al. (2016), and also through discourse analysis of the policy documents. Interviews with academicians and policy-makers would also help enhance the list of included policy documents, for instance, the fisheries related policy was missed in this analysis. In addition, case studies on specific diseases could shed light further light on policy mechanisms.

7.1.2. Chapter 3: perceived health impacts of completed WSD projects

I used a qualitative study design to understand perceived health impacts of WSD projects. The original plan was to also include a quantitative component using a cross-sectional survey, by comparing areas with completed WSD projects with areas not exposed to these interventions. This was abandoned mainly because of the lack of baseline health data to make inferences about impact. However, the qualitative study satisfied the current need.

While this study was based on theoretical underpinnings of the determinants of health (Millennium Ecosystem Assessment, 2005; CSDH, 2008) and popular epidemiology (similar to what was done by Powers et al. (2015)), I did not use an established theoretical framework to guide this work. I wanted the findings to be as close to the objectives, data and context as possible, in a way that would directly contribute to the HIA that was to be conducted following this qualitative study.

However, social science theories could have offered opportunities to examine some aspects relevant to the study objectives. For instance, the “entitlement approach”, originally framed to understand the options available to an individual or household (assets and means of exchange) to cope with famine (Sen, 1976, 1987). One could interpret WSD projects as having added to the household “assets” (e.g., water availability, agricultural produce or livestock) and enhanced the “means of exchange” (e.g., wage labour opportunities or self-help groups) in the beneficiary population. This approach may have shed additional light on equity impacts of WSD projects, but would not have helped with the primary objectives of identifying specific health impacts in the participating community. Additional social science research can help deepen the understanding of how health impacts manifest within the household and between sub-groups in the beneficiary population. This study has taken me one step forward towards that direction. Figure 7.2 indicates the broad pathways of influence of WSD projects on community and household health, alongside other contextual factors.

As the topics covered in the interviews were non-controversial, there was no problem in conducting the interviews with local people and healthcare workers. The challenge, however, was in eliciting the perceived health impact of WSD projects. This challenge was also reported by Pandit (2010). This may indeed be a common occurrence for researchers trying to understand perceived health impacts of developmental interventions. To address this challenge, the approach used in our study was: (i) proceed from general open-ended questions on perceptions on the impacts of the project under study; then (ii) to questions on each project activity and their perceived impacts; and finally (iii) to prompt about specific potential health impacts (pre-determined from literature, brain-storming and responses from earlier interviews). Respondents were also asked about the reasoning behind their responses. The data from this

study and future case studies could contribute to social science theory about perceptions on health and about lay epidemiology in the context of developmental interventions.

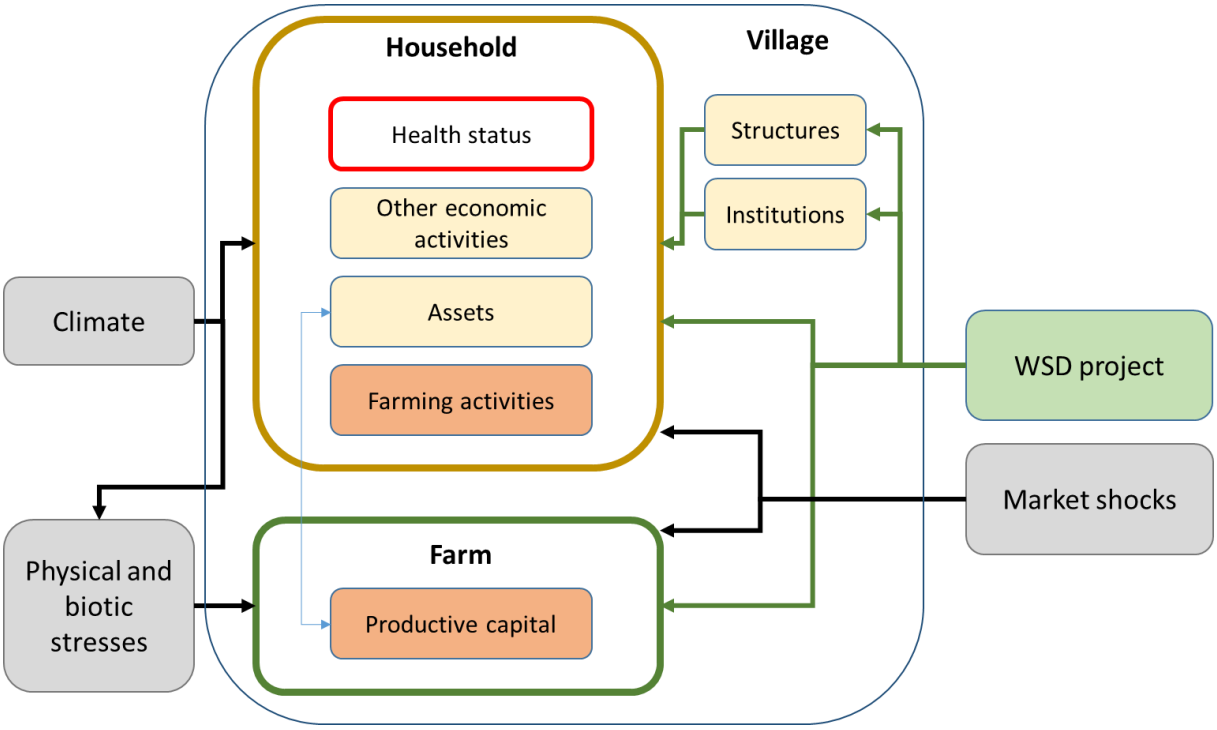

Figure 7.2: Household and farm system: situating WSD projects (adapted from Gitz & Meybeck (2012); originally developed to illustrate vulnerability and resilience to climate change)

A considerable amount of the collected data were not used, as they related to a rich contextual description of the general challenges being faced in agriculture. Issues such as nuisance of wildlife, pest attacks, groundwater exploitation, debt and migration were found to be important local concerns and these should be explored in their own right – in our study, we only touched upon them as they have bearings on how the impacts of completed WSD projects can be interpreted. Additional mixed-methods studies would be needed to further unpack these issues. The current study has opened the door for research on a variety of relevant health determinants in semi-arid rural areas in Kolar district, India.

7.1.3. Chapters 4, 5 and 6: HIA of a proposed WSD project

It was good fortune that a WSD project was planned by the partner NGO during the thesis period. The original plan was to use a hypothetical proposal (or one of their older proposals) for the HIA case study. Soon after I received information on the planned WSD project, the HIA design was put together in a short timeframe. This was one reason that the baseline survey was kept relatively simple. The tailored HIA approach allowed the close involvement of the NGO in each stage of the process: (i) to understand what was being done; (ii) to get involved in data collection; and (iii) to discuss the HIA report. This feature will potentially help the adoption of this HIA approach among NGOs (discussed in section 7.4). While local people

were also engaged through FGDs and baseline survey during the HIA, further innovations in stakeholder engagement could be expected with availability of adequate time and resources.

The literature review conducted in the scoping stage of the HIA revealed a lack of health data on two dimensions: inadequate data on some types of diseases (e.g., gaps in data on infectious diseases and injuries), and level of generalisability (e.g., applicable only at district level). The publicly available sources of health and nutrition data in India have been listed and discussed by various authors (Dandona et al., 2016; Rathi et al., 2018), and also specifically the sources that could be used to conduct "health technology assessments" (Downey et al., 2018). These data sources (Table 7.2) may provide adequate information for HIA of larger projects at the level of district and above, or for rapid HIA. These were also used in our HIA case study.

Table 7.2: Data sources* for HIA in India

Data source	Type of data	Coverage	Resolution	Generalisable at
National Family Health Survey	Socio-demographic details, material and child health, reproductive health, infections, chronic diseases and injuries	All states of India	Individual	District/State level
District Level Health Survey		Most states of India	Individual	District level
Annual Health Survey		Select states of India	Individual	District level
Census	Socio-demographic, occupational, environmental data	All states of India	Village	Village level

*Adapted from (Dandona et al., 2016; Downey et al., 2018; Rathi et al., 2018)

The NGO fieldworkers who were responsible for implementing the WSD project were also tasked with administering the household survey. This was done because of few reasons: (i) resource constraints; (ii) they already had trust with local people; and (iii) they would become aware about local health problems. However, this decision also added some challenges. The fieldworkers were primarily answerable for their WSD project deliverables. Therefore, allocating time, especially for the survey in the comparison villages, necessitated repeated requests and reminders. On the other hand, the team got the opportunity to learn about designing surveys and conducting HIA. Smartphones with mobile Internet was available with all fieldworkers, and so this can be considered as appropriate technology in accordance with the principles of primary health care in the Alma-Ata Declaration (International Conference on Primary Health Care, 1978).

From a research perspective, there would be advantages of recruiting health survey staff to administer the baseline survey. This is especially helpful for (i) sensitive questions on health (which local fieldworkers may be hesitant to ask); (ii) covering the comparison villages (which

project staff are not keen on doing); and (iii) increasing the scope of baseline surveys to include collection of biological samples.

In the current case study, due to time constraints, selection of comparison villages was done based on socio-economic characteristics and geographic proximity, in consultation with the local NGO staff. For larger projects with greater resources, the selection of comparison villages can employ methods such as propensity score matching, which will improve comparability and validity of results (Austin, 2011). This could be coupled with the sentinel-site sampling approach as employed by Winkler et al. (2014).

Collecting high quality anthropometric data had its own share of challenges. For instance, it was difficult to find a flat surface to measure the weight and height of children in the crèche in some villages. An even greater challenge was to receive the cooperation of children aged 1-3 years to measure height. Eventually, the analysis of the height data was not included in the papers due to sizable measurement error. However, I am confident about the quality of data on weight and MUAC, and these were used in the HIA.

The scope of the baseline data only allowed the usage of “household milk consumption” as a proxy nutrition outcome variable in our analytical paper (Chapter 6). It would have been ideal to use z-scores of weight-for-age measurements as the main health outcome, but I was unable to link the data from the anthropometric survey with their respective household units from household survey data. This was due to time constraints for planning and completing the surveys. Case studies in future should use methods to link survey modules, to be able to use collected data for much needed empirical research on health concerns in remote areas.

I used “household milk consumption” as a binary variable to assess the relationship with dairy animal ownership, though data on volume of milk consumption at household level was available. The reason was because the data did not behave like a typical numerical variable (for instance, assumptions of normal distribution as ascertained by a quantile-quantile-plot), dismissing the possibility of using linear regression. Also, because I was more concerned about households that did not consume milk, a binary variable was useful, and a logistic regression model was employed. Dairy animal ownership has been strongly pushed as part of WSD projects and so this study adds to the evidence on the utility of this approach to improve health.

7.2. Overarching reflections on results and methods

7.2.1. Concern for health impacts and equity

Gaps were found in health considerations in food systems interventions both at policy level (e.g., gaps in consideration for non-communicable diseases) and project level (e.g., unanticipated potential negative impacts of WSD projects such as changes in disease vector

ecology). While the Technical Committee on Watershed Programmes in India (2006) identified the potential of WSD projects in addressing the "*nutritional emergency*" in India, the guidelines issues by the Government of India (2011) did not mention any health-related concerns. However, a clear interest to address health concerns was found. For example, the NGO officials articulated concerns about local nutrition and WASH, and several policy-instituted inter-ministerial groups included representation from the health sector. HIA showed promise to bridge this interest with action, by systematically identifying and addressing health concerns in planned WSD projects through involvement of various stakeholders.

Equity is a shared core value of WSD projects (Government of India, 2011), HIA (WHO and ECHP, 1999) and public health (CSDH, 2008). The social determinants of health: gender, socioeconomic status and caste, featured in all five papers to varying degrees. In Chapter 3, it was operationalised through purposive sampling of sub-groups of the community and enquiring about their specific experience with completed WSD projects. As part of Chapters 4, 5 and 6, specific instances of disparity were reported (e.g., relatively low SHG membership among SC households) or modelled (e.g., gender of household-head as a covariate in the regression model). Chapter 2 also identified policy provisions for the poor and marginalised in terms of food security and nutrition-specific interventions. Our findings also highlighted the importance of considering social factors in addressing health impacts of food systems.

The challenges of equity considerations in the context of WSD projects was also discussed in Chapter 3 – keeping in mind the disproportionate benefit of traditional WSD projects for land-owning households due to the nature of the interventions (soil and water conservation). While the latest guidelines emphasise the need to also address the livelihood needs of households not owning land (Government of India, 2011), the project may not be successful in reducing disparities, while successfully improving the conditions of poor landless households. However, soil and water conservation have a standalone value as they have implications beyond the beneficiary households (through food and water security). Closer attention to both equity and disparity through nuanced baseline studies and project evaluations could help design equity-oriented WSD projects.

7.2.2. Interlinkage between food systems, environment and health

Efforts were made to illustrate the interlinkages between food systems, environment and health across the chapters. Indeed, several interlinked concerns were identified in the data, but were beyond the scope of the papers prepared for the thesis. The policy analysis (Chapter 2) revealed the interest in supporting sustainable agriculture. Even the WSD policy mentioned about the economic benefits of low-input agriculture (Government of India, 2011). However, whereas farmers were keen on adopting technologies such as drip irrigation, the use of

chemicals increased due to expansion of commercial cropping following WSD projects (Chapter 3). This indicates that reconciliation between policy aspirations and field realities are not straightforward. Recent papers have emphasised win-win scenarios for environment and health through fostering sustainable food systems and diets (Whitmee et al., 2015; Willett et al., 2019). This has also been encouraged by the 2030 Agenda for Sustainable Development (FAO and UNEP, 2016). However, having witnessed the challenges faced by farmers in Kolar, a lot remains to be done.

Livestock rearing was found to be an important intervention for local WSD projects, and also at policy level through the National Livestock Mission and WSD guidelines. During the literature review for the HIA in Chapter 4, reports of brucellosis outbreaks from Kolar were found, but only in popular media. There was no peer-reviewed literature or official data on the subject, though the government evidently responded to the specific outbreaks. The focus on animal health has increased, especially in the context of influenza epidemics, and a livestock health scheme has been instituted (Government of India, 2020b). Considering the prevalence and critical contribution of livestock ownership on food and income for a large section of the population in India, a stronger research programme on “health in socio-ecological systems” (Zinsstag et al., 2011) may benefit the population.

The importance of “context” in understanding health impacts was also evident across the thesis, especially when comparing findings with literature from other areas. For example, impact of WSD projects on income, migration and crop choices were experienced differently in our study area as compared to evidence from other areas. However, while focusing on context, it is important to be cognisant of larger factors such as globalisation and climate change (O’Brien et al., 2004; IPCC, 2014; Whitmee et al., 2015), which are especially relevant to food systems actors. The fluctuating nature of markets and rainfall add to agrarian distress. While various public schemes are trying to address these challenges, it needs further contextual attention.

7.2.3. Conceptualising health-sensitive food systems

There is increased interest in adopting systems thinking for solving real-world problems (Haynes et al., 2020). While systems thinking has not been fully adopted in this thesis, it has influenced the objectives, methods and analyses. Based on a typology offered by Carey et al. (Carey et al., 2015) on systems thinking in public health research, the “analytical lens” (e.g., causal diagrams on potential health impacts of WSD projects in Chapters 3 and 4) and “benchmarking” approaches (e.g., assessing which parts of the food system were addressed by policy in Chapter 2) were used in this thesis.

HIA has been described as compatible with systems thinking, and was recommended as an approach to institutionalise systems thinking into public health practice (Honoré and Scott, 2010). It would be the "terms of reference" document that elucidates the boundary and scope of the "system" in the context of the proposed project, and the scope is operationalised through EHAs. Health impacts can be considered as "emergent properties" of the planned project, as they are often unintended consequences of primary social and environmental impacts. HIA facilitates the identification of relevant health concerns and avenues for action, bringing together actors from various sectors that may not otherwise coordinate (Honoré and Scott, 2010).

Neff et al. (2009) utilised systems thinking to create a conceptual model on how food systems influence health disparities in the United States. This model has now been adapted to the findings of this thesis (Figure 7.3), especially keeping in mind the differences of the food systems between the United States (industrial food system) and India (rural food system) (IFPRI, 2015). If HIA is applied to a WSD project (placed in "Other social factors" in the model), it could be expected to positively influence household food production, improve dietary diversity, mitigate hazardous exposures, and potentially also directly affect health disparities through pathways such as awareness and empowerment (based on findings from Chapters 3 and 4). A project-level HIA may not influence the "broad food system", but a groundswell of such experiences could be expected to eventually impact higher levels of determinants.

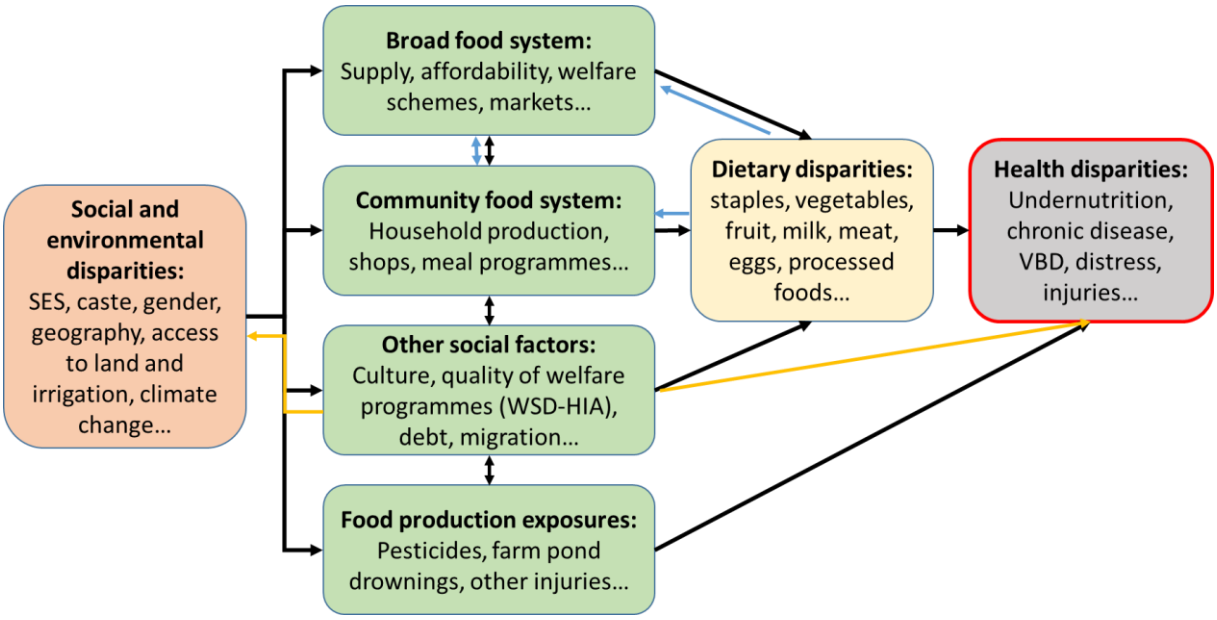

Figure 7.3: Locating HIA of WSD projects in the conceptual model of the influence of food systems on health disparities (adapted from Neff et al. (2009)); black arrows, impact pathways; blue arrows, demand feedback in the system; yellow arrows, newly identified impact pathways; SES, socioeconomic status; WSD-HIA, health impact assessment of planned WSD project; VBD, vector-borne disease

The complex nature of linkages between food systems and population health necessitated the creative use of the tools of public health to further understand the concerns and identify avenues for action. Both qualitative and quantitative methods were used extensively in this thesis, individually (Chapters 3, 5 and 6) and in combination (Chapters 2 and 4). Secondary data were used (Chapters 2, 4 and 6), and primary data too were collected (Chapters 3, 4 and 5). The specific combination of objectives and methods used in this thesis, viewed together, provides a template towards fostering health-sensitive food systems (Figure 7.4). This template could also be tested for rural development projects (further elaborated in section 7.4.2).

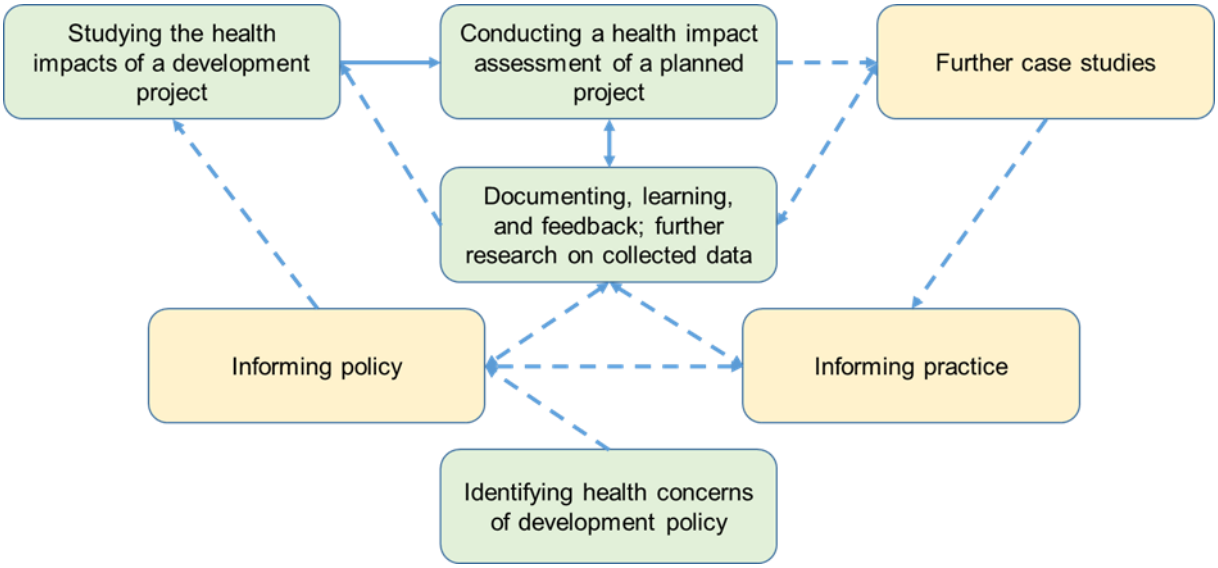

Figure 7.4: A template for studying and fostering health-sensitive food systems and development; green boxes and solid arrows indicate components addressed in this thesis

7.3. Contribution to public health in India and elsewhere

7.3.1. Gaps addressed in HIA literature and practice

By conducting an HIA on a WSD project in India, three goals were accomplished, all of which are key contributions to evidence and practice: (i) a best practice example of a comprehensive HIA conducted in India; (ii) HIA of a local food systems project, more specifically a WSD project; and (iii) an example of how HIA can be conducted for a relatively small project implemented by an NGO. Neither is HIA usually conducted as a stand-alone assessment in India, nor are WSD projects ever subjected to impact assessments. These arguments indicate the “innovation” dimension of the thesis.

A step was also taken towards addressing several concerns in impact assessment practice in India: (i) range of projects covered (Rajaram and Das, 2011; Pradyumna, 2015); (ii) quality of health assessment (Pradyumna, 2015); (iii) involvement of local institutions; and (iv)

participation of local people (Paliwal, 2006; Pradyumna, 2015; Rathi, 2017; Mishra, 2019). Stakeholders were involved (NGO, local people, staff from the local health system), vulnerable subgroups in the community were identified and addressed (woman-headed households, caste groups, landless), evidence was appropriately used (including collecting primary data to fill gaps) and all EHAs were covered. The method adopted for the HIA (Winkler et al., 2010, 2011, 2012, 2020b) was tailored to the needs of the planned WSD project, but followed the steps and principles articulated in these papers. Further case studies will help consolidate methods for HIA of WSD projects, and eventually for other types of projects in India.

7.3.2. Demystifying HIA through a safe option for increasing practice

The poor quality of impact assessments in India is related to the low accountability of EIA consultants, project proponents and regulatory agencies (Paliwal, 2006; Pradyumna, 2015). The quality of stakeholder engagements in the form of “public hearings” have also received criticism (Pradyumna, 2015; Mishra, 2019). There are strong vested interests for projects such as natural resource extraction projects. In extreme situations, violence has been perpetrated, for instance, against tribal populations in forested areas for planned mining projects in India (Kalshian, 2007). Several reasons have been suggested for this situation, including corruption and lack of capacity for impact assessment (Paliwal, 2006). Even as this thesis was being finalised, a new draft EIA notification was issued in India for comments from the public (Ministry of Environment Forests and Climate Change, 2020), and there was concern that the norms had been further diluted (Pinjarkar, 2020) in the wake of the COVID-19 pandemic.

The exclusive use of EIA for these kinds of projects which are characterised by strong vested interests may have confounded the purpose and potential of impact assessments in India. Therefore, conducting research and case studies on non-controversial projects such as WSD projects, as was done in this thesis, will contribute to a deeper understanding of the utility and scope of impact assessments. More importantly, this thesis has unveiled an entry point to create local experience and build local capacity in HIA, through the use of safe options such as WSD projects or other rural development projects.

7.3.3. A comparative risk assessment perspective on the utility of HIA of WSD projects

If one WSD project is compared with one mining project, the utility of HIA for the mining project would be far higher, simply because, intuitively, mining projects have much greater scope for negative impacts on the local community. Mining projects, if done ethically, may bring great wealth and health to local communities in disadvantaged areas. But WSD projects, planned for over 100 million ha in India, can bring definitive marginal increments in wealth and health across a very large population (Figure 7.5). This is akin to the risk of myocardial infarction (heart attack) due to air pollution, which has a small relative risk but a much larger population-

attributable risk fraction, simply because everyone is exposed to air pollution (Nawrot et al., 2011). While regulatory requirements are an important motivating factor for conduct of HIA (Birley, 2011), our case study reveals that grabbing the opportunity to optimise the positive impacts of a project can also be highly motivating for organisations that aim for local community development. Therefore, NGOs can be considered natural partners to HIA practice.

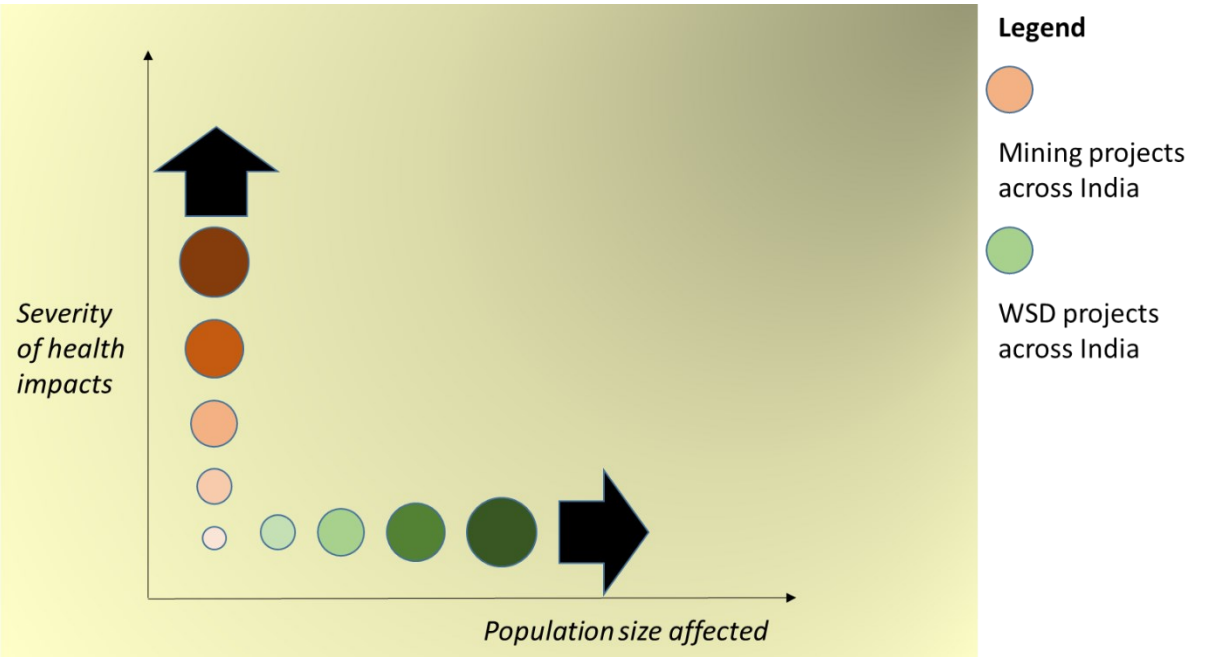

Figure 7.5: Comparative risk of mining projects and WSD projects in India (hypothesised)

It has been argued that population health is mainly determined by sectors other than the health sector (CSDH, 2008; Birley, 2011). The focus on the health system is important, and conversations around Universal Health Coverage are of great relevance to low- and middle income countries (Ghebreyesus, 2017), and now also to high-income countries especially in the light of the COVID-19 pandemic. However, there is also a need to focus on the larger determinants of health (CSDH, 2008; Whitmee et al., 2015). This is especially important for countries such as India where most health challenges are from preventable causes (India State-Level Disease Burden Initiative Collaborators, 2017). This thesis looked beyond the traditionally-defined health system, highlighting the importance of and approaches to study and address health determinants.

7.3.4. Adding value to collected data to further the cause of health-sensitive food systems

The thesis demonstrated the potential for using baseline survey data from HIA to answer empirical research questions in the area of agriculture and nutrition. There are several gaps in the literature on agriculture and nutrition (Kadiyala et al., 2014), and this is an important opportunity for agrarian nations such as India. Research and practice in agriculture-nutrition interlinkages is receiving attention through the establishment of communities of practice (such

as the Agriculture Nutrition & Health (ANH) Academy (2019)). Consideration of nutrition-related impacts of activities of other sectors has been encouraged to create “nutrition-sensitive” food systems (IFPRI, 2015). While nutrition was found to be the main health concern of food systems policies in India (Chapter 2), the effort here has been to broaden the focus to also include health concerns beyond nutrition, and move towards “health-sensitive” food systems and development.

7.4. Taking this work forward

7.4.1. Challenges and opportunities

Need for local evidence

One of the arguments usually made by policy makers in India for not updating environmental health policies with higher standards or best practices is the lack of local epidemiological studies on health impacts. For instance, the lack of local studies on the risk of mortality due to air pollution has routinely been offered as an excuse for inaction (Mordani, 2019). While this is not a scientifically defensible position, generating local evidence, both for health risks of developmental interventions and for HIA as a decision-making tool, may facilitate interest and uptake.

Evidence on the effect of stakeholder involvement would also benefit through local case studies. Participation has been enshrined as an important principle in the WSD programme guidelines (Government of India, 2011). Community-based NGOs often include strong stakeholder engagement for all types of projects (Smyle et al., 2014), and so HIA case studies can benefit from these existing mechanisms of participation (den Broeder et al., 2017). In addition, some implementing agencies have already attempted to incorporate nutrition-related activities into WSD projects (Pandit, 2010; Pandit and Zade, 2012), but not other health concerns. This evident interest would help facilitate further case studies on HIA of WSD and other rural development projects.

Need for competence

Consultants conducting health assessments as part of EIAs in India usually have a background in basic sciences or environmental sciences (Government of India, 2006a; Pradyumna, 2015). In addition, EIAs are financed by the project proponent, and budgets allocated may be inadequate for good quality work. The available evidence also suggests low level of involvement of EIA firms in monitoring and evaluation of projects once the EIA has been completed (Paliwal, 2006). So, at one level, there is little interest in EIA and HIA, and, at another level, there is inadequate capacity and opportunity for HIA.

Over the past two decades, the number of masters programmes in public health in India has increased to 44 (Tiwari et al., 2018). This is in response to the National Health Mission (previously National Rural Health Mission), but potentially also because of growth in the higher education sector. Graduates with public health degrees mainly find opportunities to work with government (Sharma and Zodpey, 2011), academic institutions, corporate social responsibility (CSR) initiatives and also NGOs (Sharma et al., 2013b). From what I know anecdotally, there are no regular courses on HIA in India as part of masters programmes in public health (sometimes they have been offered as workshops to broader audiences), though some courses on environmental health introduce the concept of HIA (I myself have done so for courses at three universities). This is potentially due to the lack of felt need for this skill set. However, systems thinking and environmental health sciences were identified as important competencies for public health masters programmes in India (Sharma et al., 2013a). This provides a clear avenue for including HIA.

7.4.2. Action points with relevant stakeholders

Inter-sectoral coordination has been encouraged to address key health concerns such as undernutrition in national policy. While there is a lot left to be desired in the operationalisation of this value and approach, HIA of WSD projects and other food production projects can show a way forward. The contribution of various actors would be needed towards fostering health-sensitive food systems and development.

Academic institutions

Universities and research institutions have several important roles to play. The first would be to conduct HIA and document these case studies, similar to what has been done in this thesis. Academic institutions would need to co-produce the HIA with NGOs and other institutions willing to try it. Support should be provided in monitoring and evaluation of the project and the HIA to draw lessons for wider practice. The willingness to try is already the first evidence of impact. The scope of activity will broaden with increasing experience, and familiarity with tools. After starting in one region, projects based in other states could be studied. This is also in accordance with the identified need for different approaches to watershed management in various agro-ecoregions (Joshi et al., 2008).

> "*Such a strategy needs to recognise the location-specific characteristics of different parts of India and also needs to be sensitive to the limits set by the ecosystem. This, we believe, is the broad strategy of watershed development"* (Technical Committee on Watershed Programmes in India, 2006)

The second important role would be to create courses on HIA. This would be most suitable for institutions offering programmes on development studies, public health and environmental sciences. The institution interested in planning such a course should first build in-house interest and competence by conducting and documenting a few case studies. Training packages will also be needed for NGOs, who are the project implementers, on topics such as health, HIA process, stakeholder engagement and use of appropriate technology.

As there is little felt need for HIA, there should be a clear argument and plan on why this course is introduced, and how the graduates could use this competence after completing their education. This may involve liaising with NGOs or even governmental institutions for opportunities to conduct HIA. This would only be possible by building some credibility in the field and also unravelling the usefulness of the method, which further highlights the need for additional local case studies. Finally, there may also be interest among early career and mid-career EIA consultants from several firms across India. This group will benefit from knowledge and skills in HIA.

The presence of enthusiastic graduate students is a great resource for academic institutions. HIA can be very useful projects for students for various reasons: (i) understanding the public health perspective; (ii) inculcating critical and systems thinking while visualising potential impacts of proposed projects; (iii) providing an avenue for use of qualitative and quantitative methods; (iv) use of technology such as electronic survey tools and mapping; (v) organizing a team; (vi) conducting field work; (vii) assimilating information; (viii) facilitating knowledge translation; (ix) networking with governmental officials; (x) understanding different socio-geographic settings; and (xi) preparing reports. HIA is like a microcosm of public health as it brings together a variety of tools and methods, involves science and art, engages data and people, and addresses health outcomes and determinants (WHO and ECHP, 1999; Birley, 2011; Winkler et al., 2020b).

Research should not only be restricted to HIA methods, but also to study health effects of development projects and policies, whether industrial, agricultural or natural resource extraction. This kind of diverse evidence further contributes to the argument for instituting HIA in India and elsewhere, as is being attempted by the ambitious HIA4SD project for countries in sub-Saharan Africa in the context of natural resource extraction projects (Winkler et al., 2019). Opportunities to perform HIA on planned policy changes should also be identified with relevant organisations. Various methods, including the one used in this thesis, could be adapted and tested. While I employed a comprehensive HIA approach in this thesis, integrated and rapid HIA approaches could also be tried based on the situation. As a starting point, I plan to prepare a policy brief of the thesis, and use it to elicit interest from NGOs working in rural development.

NGOs

NGOs, especially the ones that are already considered leaders in WSD projects, would be the best starting point. The idea is to generate additional case studies, build local expertise and experience in community-level health research and HIA. NGOs often have the experience of socioeconomic assessment as part of WSD projects, and so it will not be particularly difficult to integrate health assessment. NGOs also have a low-cost ethos, and this will help with efficient use of resources and also potentially contribute to innovation in HIA. Learning from each experience through monitoring, evaluation and discussion would be important if the aim is to influence practice and policy. After conducting a few case studies, the approach could be applied to other food production and rural development projects. In this way, the cycle of learning would expand. Additionally, WSD projects are periodically repeated in an area based on the need, and hence the scale of these projects and scope for population coverage is immense in India.

An earlier recommendation for WSD projects explicitly expressed concern about those unable to participate due to health and social challenges, such as persons who are frail, and suggested the need for making alternative arrangements for the benefit and participation of these groups (Technical Committee on Watershed Programmes in India, 2006). This health and equity-oriented paradigm of WSD projects would also align well with the ethos of NGOs and HIA.

Government

Several government agencies already have experience with EIA for large development and industrial projects. Government departments in rural areas often do not have this experience, but they have coordinated with NGOs over the past decades for planning WSD and other rural development projects. When a WSD project is proposed by an NGO, it requires approval from the local agriculture department. The local department maintains a register on villages eligible for new WSD projects. These networks and those developed through the HIA with local health officials would become important for knowledge translation about HIA.

At the national level, the National Rainfed Area Authority has been tasked to *"undertake all such activities which are useful for the purposes of ensuring that watershed programmes become major vehicles for the overall and all-round development of rain-fed areas in the country"* (Government of India, 2011). Engaging with this body would be necessary for incorporation of the health lens, but innovations could start further down the ladder. This could include the district planning committee which is responsible for convergence and the involvement of professional experts from various disciplines (Government of India, 2011).

The government regularly revises the EIA notification, as has been done recently in 2020, based on changes in economic policy. The health policy goal of “Health in All” (Government of India, 2017a) provides an avenue for further revision of EIA policy to strengthen the health component. Additional experience with HIA in rural development projects could contribute towards the necessary push.

The responsibility of health promotion in rural areas of India has largely been borne by lone health workers in difficult circumstances (Khetan et al., 2018; Saprii et al., 2015). The broad geographic reach and scope of activities under WSD programmes (Technical Committee on Watershed Programmes in India, 2006) can usher in another avenue for health promotion and risk mitigation in rural areas through the incorporation of HIA in project planning.

Based on the insights gained from this thesis, health-sensitive WSD projects could contribute towards the following health-related targets of the SDGs: 2.2 (ending all forms of malnutrition), 3.2 (reducing child deaths), 3.3 (reducing mortality from VBDs, water-borne diseases and other communicable diseases), 3.4 (reduce mortality from NCDs), 3.9 (reduce death from hazardous chemicals), 8.8 (occupational safety) and 13.1 (resilience to hazards of climate change), among others. This could be positioned as a motivating factor.

Corporations and businesses

The private sector, especially many corporate sector enterprises would already be familiar with EIA process and regulation. While there is a possibility that some of these companies are interested in ethical business, the incentives for good practice are few. “Image” of corporations is one of the supposed motivations for adoption of HIA (Birley, 2011) but this is unlikely to be the case in India. Therefore, engagement with this sector may be for a later date. It will require a groundswell of prior experience from other sectors to show the benefits of incorporating a health lens in policy and project planning, and potentially a change in governmental regulation on EIA and HIA.

Those within the private sector who may be most amenable to adopt HIA are social enterprises. These are companies that are for-profit, but with a social orientation and usually address social or environmental challenges through their products and services. For instance, organic agriculture and green energy companies. Another way to initiate engagement with corporations would be through their respective CSR wings. These are usually registered as non-profits that utilise the designated CSR funds (amounting to a small percentage of the annual profits of the corporation), for socially relevant projects. The type for projects allowed to be funded through CSR initiatives is listed by policy, including hunger eradication, rural development and natural resource conservation (Government of India, 2014). There may be interest among CSR organisations to adopt HIA, especially if the argument is backed by some evidence.

In effect, the broad roles and steps that can be taken towards fulfilling the vision of "Health in All" in India have been portrayed in Figure 7.6. The importance of each sectors contribution towards this vision is depicted. The steps indicated here build on the contribution of this thesis.

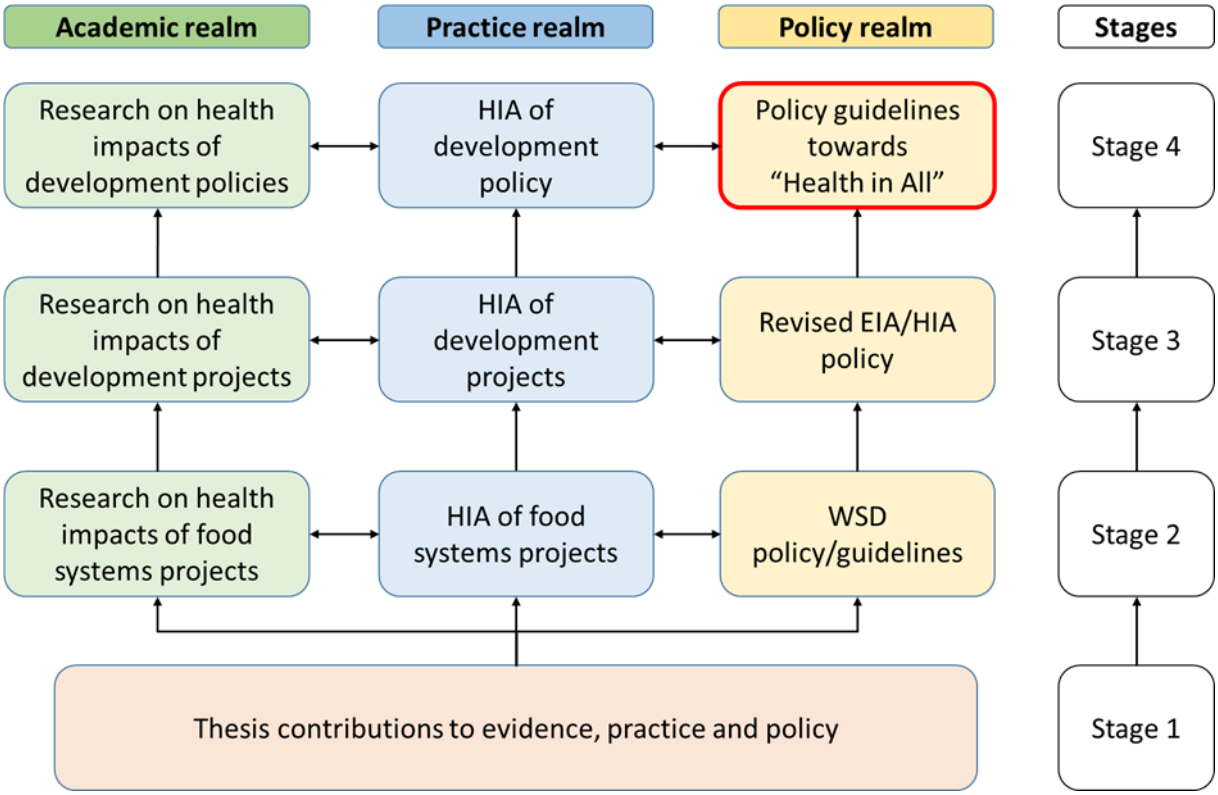

Figure 7.6: Moving towards "Health in All": next steps

8. Conclusions

Our understanding of the interlinkages between population health and food systems were deepened through the case studies of WSD projects in a semi-arid area in southern India and of food systems policies in India. While health was often an implicit concern, we found that health considerations were not systematically included during project conceptualisation or in governmental policy documents. However, a clear interest in addressing health concerns through inter-sectoral action was noted. We were able to demonstrate the use of HIA as an approach to identify and assess health concerns relevant to a planned WSD project. The added benefit of baseline surveys in contributing to the sparse health data at local level was also indicated. The valuable contribution that can be made by analysing data from baseline surveys towards contextual evidence on agriculture, nutrition and health was also illustrated. In addition, we exhibited the utility of the health lens to scrutinise policy to unravel gaps in health considerations across health-determining sectors.

By conducting a comprehensive HIA of a WSD project in India, we identified a non-controversial entry point for HIA practice and research in India. We also adapted and applied an HIA approach that could be used for assessing food production projects, and potentially also for rural development projects in semi-arid settings in LMICs. The potential roles of various actors in examining and addressing health impacts of food systems were also discussed, including the roles of academic institutions (capacity building, documenting evidence and knowledge translation), NGOs (partnering with academic institutions, participating in planning and implementing HIA), government (engagement at local and higher levels) and businesses.

The health sector and the population pay dearly for the failure of food systems. The interlinkages between health and food systems are concerns of growing global relevance. For instance, during the period of this thesis, there were ongoing conversations on sustainable diets (Willett et al., 2019) and food security during pandemics (Galanakis, 2020). The 2020 edition of the Global Nutrition Report emphasised the highly disproportionate impact of COVID-19 on those malnourished, besides highlighting malnutrition as the leading risk factor for mortality and morbidity in general (Development Initiatives, 2020). All these issues are linked to concerns that have been established and articulated in the SDGs. There is a strong case for integrating health concerns during the planning of food systems-related projects and policies. While several actions are being undertaken worldwide, a considerable amount of work remains to be done – especially catering to the unique needs of local food-environment-health contexts. This PhD thesis has presented an approach towards health-sensitive food systems.

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10. Appendix

10.1. Planetary health and food systems: insights from global SDGs

Comment

Planetary health and food systems: insights from global SDGs

An article by Pradhan and colleagues[1] in *Earth's Future* contributes to the empirical basis for planetary health action. The article, which looked at country-level trends of Sustainable Development Goal (SDG) indicators between 1983 and 2016 for 227 countries, showed the challenge of intersectoral coordination in the era of the SDGs. The key findings are that SDGs 3 (good health and wellbeing), 12 (sustainable consumption and production), and 15 (life on land) were the most prevalent country-level trade-offs, and this Comment further analyses the findings.

The first important finding in Pradhan's article from a planetary health perspective is that the trade-off between SDG 3 and 12 was the most prevalent one among countries assessed.[1] In other words, the health of a country's population has improved in the recent past and so has unsustainably generated wealth. This is directly relevant to a claim made in *The Lancet's* Commission on planetary health that recent health gains have come at the cost of health of future generations.[2] In fact, Pradhan and colleagues found that SDG 12 had trade-offs with several other SDGs. Therefore, sustainable consumption and production is a central concern of the SDGs and this has largely been neglected by global developmental discourse until now. The public health and development sectors have mostly focused on people with low incomes and less on people with high incomes, in both developed and developing countries—this should be an important agenda item for action.[3] One might also add that some of the health improvements in higher-income countries have come at the cost of shifting polluting industries to lower-income countries, and also that there might be lag effects for health outcomes for instance, of climate change. While the progress in the health sector is highly laudable, there is a need for serious reflection on the approach to improve and sustain population health.

A second very interesting and related finding in Pradhan's article is that the second most common trade-off pair was SDG 3 and 15.[1] SDG 15 focuses on terrestrial ecosystems, and the activity that has affected them the most is agriculture. While great improvements in food production and safety have led to reduction in under-nutrition and associated deaths, it has come at the cost of degradation and pollution of land (and water) ecosystems. My proposition is that the food system is the entity that primarily connects SDGs 3, 12 and, 15. A report by the UN Environment Programme[4] discussed that food systems have a central role for achieving the SDGs. Food systems were also a key concern in *The Lancet's* Commission on planetary health.[2] Interestingly, the main causes of ill health and mortality globally are dietary risks and undernutrition.[5] There continues to be inequitable access to wholesome and adequate food, while the epidemic of obesity and chronic disease continues to rise in developed and developing countries. Therefore, there is great incentive to focus on food systems at local and national levels, from both health and environmental sustainability perspectives—not just for future challenges but also to address current health challenges.

Finally, Pradhan and colleagues[1] have identified countries that have shown synergies between SDGs 3, 12, and 15, and suggest that they could be models for other countries. These countries could show how development and health can go hand in hand, and that there is no need to choose one over the other. This is especially important for developing countries that are de-prioritising health in order to realise economic growth—eg, the presence of toxic hotspots and the alarmingly high air pollution levels in several cities in developing countries. However, one needs to carefully examine whether those model countries have externalised environmental health costs by exporting polluting activities to other countries. I propose a more detailed exploration of the data from Pradhan's article from a health perspective.

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I declare no competing interests.

1 Pradhan P, Costa L, Rybski D, Lucht W, Kropp JP. A systematic study of sustainable development Goal (SDG) Interactions. *Earths Future* 2017; **5**: e1169-79.
2 Whitmee S, Haines A, Beyrer C, et al. Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation-*Lancet* Commission on planetary health. *Lancet* 2015; **386**: 1973-2028.
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10.2. Sustainable food systems, health and infectious disease: concerns and opportunities

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Sustainable food systems, health and infectious diseases: Concerns and opportunities

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ABSTRACT

Food systems have been identified as one of the key issues in the 2030 Agenda for Sustainable Development. Hence, food systems are embodied in the Sustainable Development Goals (SDGs) with a range of ramifications on different goals and targets. Current food systems practices are exposing the vulnerability of populations to various health issues. Indeed, several health challenges, such as malnutrition, infectious diseases, antimicrobial resistance and non-communicable diseases, are caused by existing food systems practices. There is growing awareness of the seriousness of the situation across sectors, including the public health community. The recommended paradigm shift in agriculture and diet are already underway at smaller scales through local efforts. Engaging with food systems towards health, equity, sustainability and resilience is a major opportunity for, as well as responsibility of, the public health community and asks for a training, research, monitoring and advocating role to be played towards policy reform and intersectoral action.

1. Introduction

Food systems have been described as "all the elements – environment, people, inputs, processes, infrastructures, institutions, etc. – and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes" (HLPE, 2014). Various sectors are associated with food systems, and the goals for each of these sectors are different. For instance, while agriculturists are concerned with production, yield and income of farmers, public health professionals aim to reduce malnutrition and disease (IFPRI, 2015). Broad food systems outcomes of relevance are food affordability, food consumption diversity, nutrition and health outcomes and environmental sustainability (IFPRI, 2015). However, food systems are currently not delivering appropriately on these desired outcomes.

The 2030 Agenda for Sustainable Development, built through international consensus, has strongly reflected concern for both food systems and health. The two targets in particular of interest are Sustainable Development Goal (SDG) target 2.2, that is to end all forms of malnutrition by 2030 (UN, 2017) and SDG target 12.1, that is a 10-Year Framework of Programmes (10YFP) on Sustainable Food Systems (UNEP, 2018). Some researchers have suggested that food systems are linked to all 17 SDGs (EAT-Lancet Commission, 2018) and so is health (Nunes et al., 2016). Network analyses of various targets and indicators have also been attempted (Le Blanc, 2015). Insights from SDG indicator data trends from the past two decades point to critical interactions between SDG 3 (good health and well-being), SDG 12 (responsible consumption and production) and SDG 15 (life on land), which link health, sustainability and food systems (Pradhan et al., 2017; Pradyumna, 2018). However, experience has shown that the food systems community and the health community did not adequately engage with each other.

This paper draws attention on the infectious diseases research and practice communities to the diverse challenges and opportunities that exist in the area of food systems and health, placing particular emphasis on infectious diseases in low- and middle-income countries (LMICs). The paper reiterates the need for proactive engagement from these communities to analyse the myriad potential health impacts of food systems policies and practices. It identifies potential pathways of influencing policy to support health protection and promotion, and how these can be jointly addressed with other sectors in context-appropriate projects and programmes.

2. Broad health concerns of food systems

For the purpose of simplicity, the food systems typology proposed

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by the 'High Level Panel of Experts' (HLPE) has been used to list the various health outcomes associated with food systems. This typology includes traditional, mixed and modern food systems (HLPE, 2017). It should be noted though that a territorial and bioregional approach (OECD/FAO/UNCDF, 2016; Harris et al., 2016), which prescribes addressing food systems challenges in socio-geographical context, might be particularly appropriate to address challenges related to food systems and health.

In traditional food systems, which are characterised by production by small-holders, small markets, poor transport and storage facilities, low processing and inadequate safety regulation (HLPE, 2017), the major health concern is child and maternal undernutrition, which accounted for over 20% of all disability-adjusted life years (DALYs) globally (GBD 2016 Risk Factors Collaborators, 2017), and is associated with 45% of under-five child mortality (Boerma et al., 2018). Small and marginal producers are also most vulnerable to the effects of climate change, for example, the impact of droughts and other extreme weather events (De Schutter, 2010; IPCC, 2014; Westhoek et al., 2016). This may contribute to an additional half million deaths through effects on food production (Springmann et al., 2016).

In settings with modern food systems, which are characterised by predominantly larger farms, availability of food from around the world, easy access to highly processed food and supermarkets (HLPE, 2017), dietary risks are of relatively greater concern, which have globally accounted for 18.8% of all deaths and 9.6% of all DALYs (GBD 2016 Risk Factors Collaborators, 2017). Obesity, and chronic diseases such as diabetes and some cancers are more prevalent in these settings (GBD 2016 Risk Factors Collaborators, 2017). Another aspect of concern is greenhouse gas emissions that are partially explained through increased ruminant livestock population, food storage and processing, and transport and waste disposal, which contribute to climate change and its consequences, including exacerbation of risks from extreme weather events (IPCC, 2014; Myers et al., 2017).

Mixed food systems, which have characteristics of both traditional and modern systems (HLPE, 2017), are associated with a host of health challenges. For example, prevalence of obesity has risen to match the burden of undernutrition among women in the Indian subcontinent, while overweight and obesity are expected to affect over half the adult population in the People's Republic of China by 2030 (Global Panel on Agriculture and Food Systems for Nutrition, 2016). These food systems also release greenhouse gases through deforestation for agricultural expansion, and flooded paddy fields, which contribute to climate change and associated health impacts (IPCC, 2014). Pesticide poisoning cases and deaths are also seen among farming households (Mew et al., 2017). Mental health impacts due to agrarian distress, which can lead to farmer suicides, have been documented in some regions (Mohanty, 2005).

3. Food systems and infectious diseases

Food systems are linked with various infectious diseases through several pathways, which are highly context specific. Fig. 1 depicts some of the common pathways through which food systems impact infectious disease risk and outcome.

In traditional food systems, undernutrition also aggravates the impacts of infectious diseases such as diarrhoea, pneumonia and measles (Black et al., 2013), as well as HIV/AIDS (Villamor et al., 2005.). In mixed food systems, there is elevated risk of malaria due to irrigation projects (Keiser et al., 2005). Due to deforestation for intensive agriculture, the risk of malaria has been seen to increase or decrease depending on the context, including factors such as local vectors and type of reforestation (Whitmee et al., 2015). The risk of schistosomiasis and food-borne trematodiasis is altered in face of major water resources development and management, such as large dams, irrigation systems and aquaculture projects (Keiser and Utzinger, 2005; Steinmann et al., 2006). In modern food systems, antimicrobial resistance (AMR) through

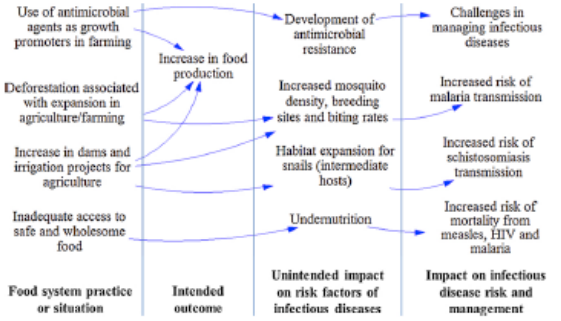

Fig. 1. Examples of pathways through which food systems are linked with infectious disease risk and outcome.

intensive use in animal farming and aquaculture is of concern (IFT Expert Report Panelists, 2006; Whitmee et al., 2015). Other production-related impacts include waterborne diseases, such as *Campylobacter* outbreaks due to multiple factors such as rapid changes in food systems, poor monitoring systems and extreme weather conditions (New Zealand Government, 2017).

4. Antimicrobial resistance as a major food systems-related public health challenge

As a major health threat relevant to the infectious diseases community, it is worthwhile to emphasis AMR. Food plays an important role in the development and spread of AMR. Indeed, over 60,000 tons of antimicrobial agents – up to 90% of which is excreted in the environment – are estimated to be used per annum to enhance livestock, aquaculture and crop production. It is expected that the use of antimicrobial agents will further rise due to the increased demand for food and, in particular, food stuffs of animal origin (FAO, 2018). This widespread use has fostered the selection and subsequent proliferation of resistant microbes, which have developed through mutation. Various routes for transfer of AMR during food production and processing through the prevailing food systems exist (IFT Expert Report Panelists, 2006; Verraes et al., 2013).

Food systems-related public health challenges, such as AMR, are complex, requiring strong intersectoral collaboration and, in particular, joint action between the agriculture and health sectors. Within the United Nations (UN) system, there has been a succession of joint programmes between the Food and Agriculture Organization (FAO) and the World Health Organization (WHO), from the Food Standards Programme in 1963, to the 2010 collaboration with World Organization for Animal Health (OIE) on animal-human-ecosystems interfaces (FAO et al., 2010). "One Health" approaches towards safeguarding animal and human health (including AMR), reducing infectious disease threats, ensuring a safe food supply and responsible management of natural resources are being taken up (Zinsstag et al., 2011; Robinson et al., 2016). The joint programme is currently making efforts to address AMR through a combination of hygiene, vaccination, food control and efficient use of antimicrobial agents. Rules and regulations towards controlling AMR are being set up and enforced at global and national levels, accompanied with capacity building and training of actors (WHO, 2015). However, the process remains largely top-down and is driven by a bio-medical and commodity perspective.

5. Principles for healthy and sustainable food systems

A sustainable food system has been defined as "a food system that ensures food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised" (HLPE, 2014).

Box 1
Key principles of sustainable food systems.

The recommended set of principles towards sustainable and healthy food systems, adapted from the report by Zero Hunger Challenge Working Groups (2015):

(i) efficient resource use;
(ii) reducing environmental and public health externalities of agriculture;
(iii) focus on equity and improvement in rural livelihoods and women's empowerment in those contexts;
(iv) enhance resilience at various levels; and
(v) effective and responsive governance for environmental and public health protection and promotion

Key principles of sustainable food systems are summarised in Box 1. However, the present institutional framework is not geared towards access to sustainable diets – nutritionally adequate, safe and healthy; culturally acceptable; accessible, economically fair and affordable; with low impact on biodiversity and ecosystems (FAO, 2010).

Experts underscore that options for sustainable food systems include sustainable intensification (Garnett et al., 2013), less resource-intensive diets (Garnett, 2011), improving feed efficiency, reduction of food losses, reducing food waste, recycling of nutrients and reducing the use of biofuels and natural fibres (De Schutter, 2010; Westhoek et al., 2016). An example of an initiative towards sustainable food systems is the Milan Urban Food Policy Pact that was signed by the mayors of 138 cities representing over 450 million inhabitants and presented to the UN Secretary General on World Food Day (16 October) in 2015. Mayors have committed to promote sustainable food systems through a combination of approaches, including intersectoral collaboration, ensuring coherence of municipal policies with national and global policies and processes, engaging all actors in planning, implementation and assessment, and city-to-city networking (Milan Urban Food Policy Pact, 2015). It acknowledges the responsibility of local authorities and will require the re-articulation of global food system and local food systems, and in particular the revision of the legislative and regulatory context (Milan Urban Food Policy Pact, 2015).

The power wielded by agri-business and mass distribution entities has made it difficult to create change in modern food systems (International Panel of Experts on Sustainable Food Systems, 2015). However, there are opportunities to change inappropriate agricultural and diet practices. A UN report has indicated the need for a paradigm shift in agricultural production towards agro-ecology to address and align goals of nutrition and sustainable development (De Schutter, 2010). The urgent need to address the increasing food waste and losses has also been emphasised, which would provide twin benefits of improving food security and mitigating greenhouse gas emissions associated with food waste (HLPE, 2014). Such interventions will have several positive ramifications on health outcomes (Whitmee et al., 2015). The public health community needs to be sensitive and nuanced in identifying and addressing local health and sustainability challenges, and also consider differentiated responsibilities towards making recommendations for sustainable and healthy diets (Whitmee et al., 2015).

6. Role of public health in fostering sustainable food systems

While the health co-benefits of potential actions towards sustainable food systems are being discussed (Friel et al., 2009; HLPE, 2017), the discourse on the critical role of public health actors towards sustainable food systems and the broader 2030 Agenda for Sustainable Development has not been adequate. The healthcare sector interacts regularly with those impacted by unhealthy food systems in clinical settings. The public health sector should seek effective collaborations with food and agriculture sectors to put health and equity as key dimensions of sustainable development in policy and programme design and management.

The above said, all sectors will need to relinquish some power and space, and learn to converse and work together more tightly. There should be continued learning from those experiences, besides trying out local strategies, generating practice-based evidence, building upon opportunities/entry points, adding value to, and ensure synergy of, existing processes, revisiting methodologies and being accountable. This is applicable irrespective of the type of food system in the country or region. This is not unprecedented, for example, as has already been seen in the joint programmes on tackling AMR at the international level.

Joint action-learning processes need partnerships across sectors, utilizing expertise from experienced grassroots workers. Experience has shown that convergence at local level is not straightforward because of differing approaches taken by various departments to address sector-specific challenges. However, convergence in planning, action and evaluation is most feasible and meaningful at local level due to the diversity of local contextual factors (Noack and Pouw, 2015; FAO, 2017). While joint programmes have been established for AMR at an international level, considerable efforts remain to be done contextually to ensure that this challenge is addressed in a timely manner. For instance, surveillance systems for detecting and responding to AMR have been in place in countries with modern food systems, but AMR has been largely unaddressed in LMICs (Lammie and Hughes, 2016). For instance, laws are being put in place more recently in India, but have still not addressed the full food system (e.g. poultry), and also implementation remains a challenge (Laxminarayan and Chaudhury, 2016). As factors contributing to AMR vary widely with context, a contextually relevant approach to addressing AMR has been recommended (Ayukekbong et al., 2017).

The reflection on health challenges in various food systems models showed that, while some health problems may be relatively more in one type of food system, other health problems cannot be ignored in the long-term planning and action towards addressing contextual food systems challenges. The public health community has been calling out for and identifying spaces for food policy reform (Shannon et al., 2015; Thow et al., 2016). There is a need for institutional arrangements at various levels of local and national governments to consider health impacts of projects, programmes and policies in all sectors, as has been proposed in the Health in All Policies (HiAP) approach (Box 2) (Marmot et al., 2008; Baum et al., 2014). Similar suggestions and approaches have also been provided towards "nutrition-sensitive" development (Gillespie et al., 2013).

Institutions such as the Agriculture, Nutrition and Health Academy (ANH Academy, 2018) are providing forums for encouraging research and leadership in building health and resilience into food systems. Other innovative academia-led examples include research on health accountability mechanisms for food corporations, such as McDonald's fast food company in Australia (Baum et al., 2016; Anaf et al., 2017). There is also scope for the health sector to advocate with donors to encourage calls for joint programmes on food systems and health, aimed at problem-solving in context. Public health institutes should see this as an opportunity for awareness and capacity-building in the fields

Box 2
Health in All Policy reflections for food systems.

> Based on recently reported local and national level experiences of HiAP in food systems and other sectors from low-, middle- and high-income countries, some of the broad approaches used were: transformation through highest level political action, transformed Ministries of Health, transformation through policy coherence, and transformation through participatory governance (Government of South Australia and World Health Organization, 2017).
>
> For successful implementation, HiAP also required good governance, developing partnerships between government and society through co-design and co-production towards shared goals, dedicated capacity and resources, and appropriate evidence generation and evaluation (Baum et al., 2014; Government of South Australia and World Health Organization, 2017).

of intersectoral action, policy analysis, and policy engagement and advocacy, with food systems as a useful case study, and to modify their social innovations and educational programmes accordingly in a contextually relevant manner.

Fig. 2 provides examples of potential linkages between SDG targets related to food systems, public health and infectious diseases, and thereby depicts the avenues for collaboration and advocacy.

7. Concluding remarks

Public health, by nature, is an interdisciplinary discipline, and hence, has potential to advocate for and facilitate collaborative and systemic approaches. The scope for partnerships and engagement between local authorities, governmental departments, non-governmental organisations, academia, civil society and the private sector to promote more sustainable food systems are immense and could potentially be

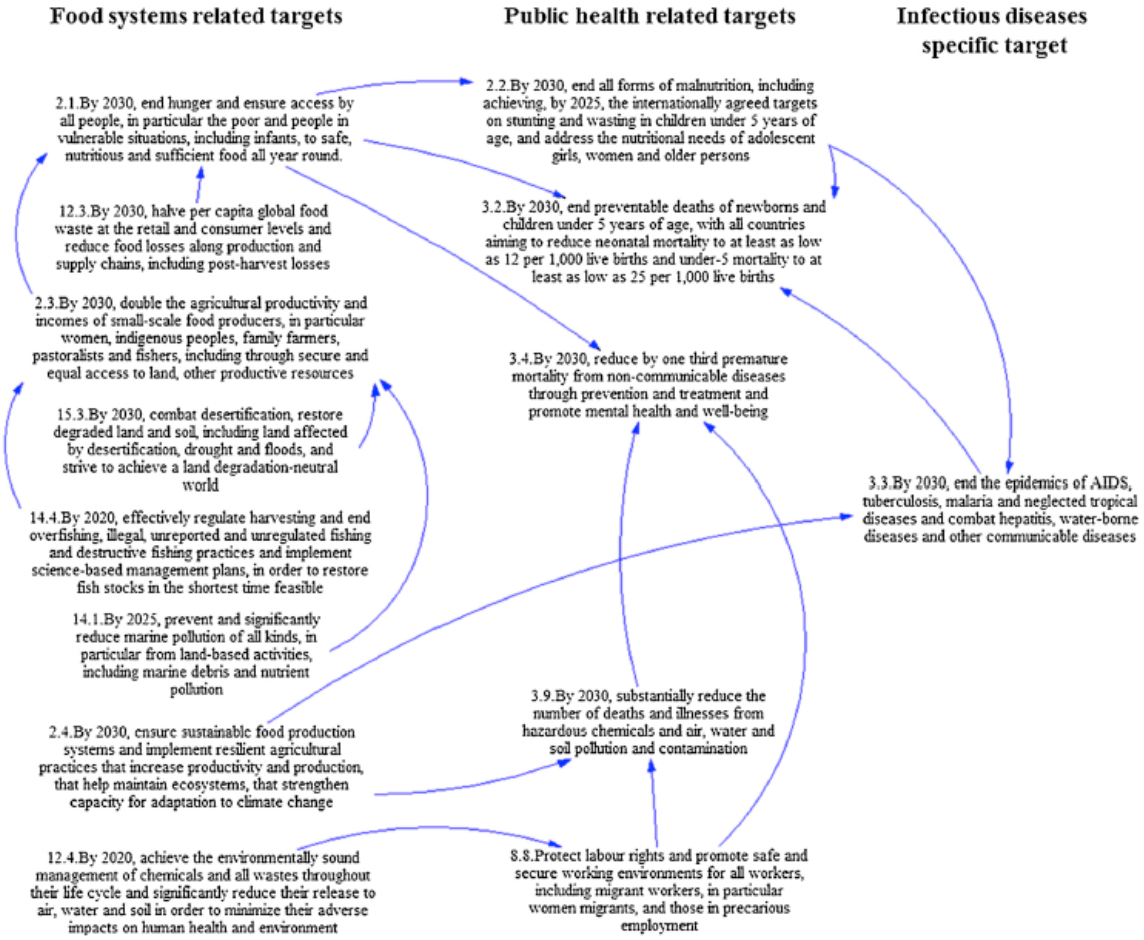

Fig. 2. Potential linkages between SDG targets related to food systems, public health, and infectious diseases.

very fruitful. On the other hand, promoting sustainable local food systems is also highly challenging.

The sector is at the threshold of an opportunity for several win-wins which include improved nutrition, lower risk of infectious diseases (e.g. malaria and schistosomiasis), reduced chronic disease prevalence (e.g. cardiovascular diseases), safer and sustainable rural livelihoods, mitigated climate change and safeguarding the potency of antimicrobial agents. Without this endeavour, it will be very costly for global health, and the most vulnerable people would suffer disproportionately.

Disclaimer

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Declarations of interest

None.

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10.3. Pandemic poetry

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Little that this crown brought was gold

ADITHYA PRADYUMNA

It fascinated me that several so-called nursery rhymes actually contained in a few simple sentences the essence of major historical events that occurred in medieval Europe. We are in the midst of a very historic event by way of the Covid-19 pandemic, and I was keen to capture it in a few sentences. The poem contains information on the onset and spread of the pandemic, the preparedness and response of governments and people, and identifies those disproportionately impacted both by the virus and the response measures. The term "crown" was used to represent both the virus and pandemic because of the literal translation of "corona" being crown, and also because it has indeed ruled the world and our minds for several months. The language is crude because of the style adopted. As a doctoral student at the threshold of completing a thesis in public health, holed up in a hostel room for over a month now, far from home, feeling a bit helpless to contribute otherwise, I used this opportunity to channel some of my creative energy into this poem.

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Little that this crown brought was gold

Little that this crown brought was gold,
Not all those who carry on are calm;
Deep were the warnings foretold,
Insidious was the cold night's storm.

While the crown sits tight on the broken,
The strong shall tide the spring;
The wretched face fire that is stoken,
For this crown has shaken kings.

Disclosure/Acknowledgement: *The poem was stylistically inspired by JRR Tolkien's "All that is gold does not glitter", from The Lord of the Rings.*

11. Curriculum vitae

Dr. Adithya Pradyumna

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EDUCATION AND ASSOCIATED AWARDS

Swiss Tropical and Public Health Institute (University of Basel) **Sep 2017 – Jun 2020**
PhD (Epidemiology)

London School of Hygiene and Tropical Medicine (University of London) **Sep 2010 – Sep 2011**
MSc Public Health (Environment and Health) GPA: 4.54, Distinction, ISEE Environmental Health Prize

St. John's Medical College, Bengaluru (Rajiv Gandhi Uni. of Health Sciences) **Sep 2002 – Apr 2008**
MBBS Result: 71.4%, best outgoing student prize

Other diplomas and certificates (selected)

- **Indira Gandhi National Open University, New Delhi** **Jan 2009 – Dec 2009**
  PG Diploma in Environment and Sustainable Development (dist. edu.) Result: 74% (Grade 'A')
- **Society for Community Health Awareness, Research and Action, Bengaluru**
  Community Health Learning Programme **Jun 2008 – Feb 2009**

OTHER SCHOLARSHIPS AND AWARDS

- ***Swiss Government Excellence Scholarship*** (2017-20) for doctoral studies at Swiss Tropical and Public Health Institute, Basel, Switzerland
- ***Second prize*** for conference poster titled "Neglect of health and health systems in the environmental impact assessment policy and process in India" at the 3rd Global Symposium on Health Systems Research at Cape Town, South Africa (2014)
- ***Inlaks Scholarship*** (2010-11) for postgraduate studies abroad (undertaken at LSHTM, London)
- ***JN Tata Endowment Scholarship*** (2010-11), for postgraduate studies abroad
- ***Pope Paul VI Prize and Medal*** (2010) at St. John's Medical College for best all-round MBBS student admitted in the year 2002
- ***DBT Medal and Scholarship*** from the Ministry of Science and Technology, Government of India, for performance in the Class 12 central board exams held in 2002

WORK EXPERIENCE

Azim Premji University, Bengaluru
Faculty member **Aug 2020 onwards**
Consultant (environment and health) **Nov 2019 – Jul 2020**
Visiting faculty (environment and health course) **Jul 2015 – Jun 2017**

Society for Community Health Awareness, Research and Action (SOCHARA), Bengaluru
Co-Convener; Research and Training Associate **Aug 2016 – Aug 2017**
Research and Training Assistant **Sep 2011 – Jul 2016**
Research Assistant (ad-hoc) **Feb – Sep 2010**

Interdisciplinary School of Health Sciences, Savitribai Phule Pune University, Pune
Visiting faculty (environmental health) **Aug 2014 – Jul 2016**

Regional Occupational Health Centre-Southern, ICMR, Bengaluru
Research assistant (ad-hoc) **Feb 2009 – Nov 2009**

SELECTED PUBLICATIONS

- Pradyumna, A.; Mishra, A.; Utzinger, J.; Winkler, M.S. Health in food systems policies in India – a document review. Int. J. Health Policy Manag. 2021; in press.
- Pradyumna A, Farnham A, Utzinger J, Winkler MS. Health impact assessment of a watershed development project in southern India: a case study. Impact Assess Proj Apprais. 2021;39(2):118–26.
- Pradyumna A, Egal F, Utzinger J. Sustainable food systems, health and infectious diseases: concerns and opportunities. Acta Trop. 2019;191:172-7.
- Pradyumna A. Planetary health and food systems: insights from global SDGs. Lancet Planet Health. 2018;2(10):e417-e8.
- Pradyumna A, Chelaton J. The endosulfan tragedy of Kasaragod: health and ethics in non-health sector programs. In: Mishra A, Subbiah K, editors. Ethics in public health practice in India. Singapore: Springer; 2018. p. 85-104.
- Pradyumna A, Bendapudi R, Zade D, D'Souza M, Tasgaonkar P. Managing the increasing heat stress in rural areas. In: Leal Filho W, editors. Handbook of climate change resilience. Cham: Springer; 2018.
- Pradyumna A. Surviving burns with care - a gender-based analysis of burns epidemiology and health system challenges in Bangalore. Bengaluru: Vimochana; 2016.
- Pradyumna A. Health aspects of the environmental impact assessment process in India. Econ Political Wkly. 2015;50(8):57-64.
- Pradyumna A, Narayan R. Examining environment and health interactions: responding with communities to the challenges of our times. Bengaluru: SOCHARA; 2012.

OTHER POSITIONS OF RESPONSIBILITY (VOLUNTARY)

On editorial board: Medico Friend Circle Bulletin (Apr 2016 – Mar 2018)

Reviewer: Cochrane Public Health, BMC Public Health, Globalization and Health, Impact Assessment and Project Appraisal, Acta Tropica, Indian Journal of Occupational and Environmental Medicine, Indian Journal of Medical Ethics, Current Science

Member of groups: Steering Committee member of Pesticide Action Network India; society member of SOCHARA, India; member of EV4GH; SJMC Alumni Association; Indian Public Health Association