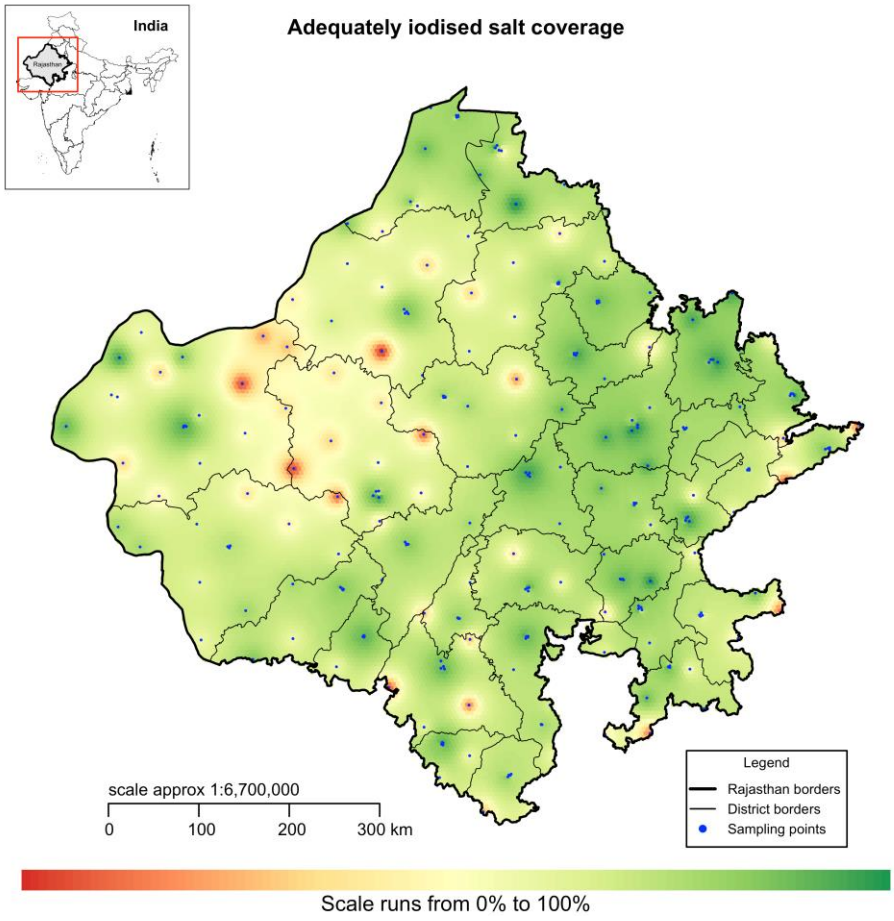
REPORT ON PHASE 1 OF THE SPATIAL MAPPING OF NUTRITION PROGRAMMING PROJECT

MQSUN REPORT



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Valid International, November 2014

ABOUT MQSUN

MQSUN aims to provide the Department for International Development (DFID) with technical services to improve the quality of nutrition-specific and nutrition-sensitive programmes. The project is resourced by a consortium of seven leading non-state organisations working on nutrition. The consortium is led by PATH.

The group is committed to:

- Expanding the evidence base on the causes of undernutrition
- Enhancing skills and capacity to support scaling up of nutrition-specific and nutrition-sensitive programmes
- Providing the best guidance available to support programme design, implementation, monitoring and evaluation
- Increasing innovation in nutrition programmes
- Knowledge-sharing to ensure lessons are learnt across DFID and beyond.

MQSUN partners are:

Aga Khan University
Agribusiness Systems International
ICF International
Institute for Development Studies
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PATH
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About this publication

This report was produced on behalf of Valid International by Ernest Guevara, Alison Norris and Safari Balegamire to provide output for Phase 1 of DFID's Spatial Mapping on Nutrition Programming Project.

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Acronyms

AIDS	Acquired Immune Deficiency Syndrome
CERSGIS	Centre for Remote Sensing and Geographic Information Services (University of Ghana)
CIESIN	Center for International Earth Science Information Network
CSO	Central Statistics Office (Yemen)
DHS	Demographic and Health Surveys Programme
DFID	Department for International Development
EBF	Exclusive Breastfeeding
EPI	Expanded Programme on Immunisation
FEWS NET	Famine Early Warning Systems Network
FAO	Food and Agriculture Organisation
GADM	Global Administrative Areas
GAHI	Global Atlas of Helminth Infections
GAIN	Global Alliance for Improved Nutrition
GSS	Ghana Statistical Service
HMIS	Health Management Information System
IFPRI	International Food Policy Research Institute
IMCI	Integrated Management of Childhood Illness
INS	National Statistics Institute (Niger)
JICA	Japan International Cooperation Agency
IYCF	Infant and Young Child Feeding
LSMS	Living Standards Measurements Survey
MAP	Malaria Atlas Project
MDG	Millennium Development Goals
MICS	Multiple Indicator Cluster Survey
MOPIC	Ministry of Planning and International Cooperation (Yemen)
MOPP	Ministry of Public Health and Population (Yemen)
MQSUN	Maximising the Quality of Scaling Up Nutrition
NBS	National Bureau of Statistics (Tanzania)
OTP	Outpatient Therapeutic Programme
PATH	Formally known as the Program for Appropriate Technology in Health. As of 2014, known simply as PATH.

PMI	President's Malaria Initiative
PHC	Population and Housing Census
REACH	Renewed Efforts Against Child Hunger and undernutrition
SEEG	Spatial Epidemiology and Ecology Group
SRTM	Shuttle Radar Topography Mission
STH	Soil Transmitted Helminths
TFNC	Tanzania Food and Nutrition Centre
UN	United Nations
UNICEF	United Nations Children's Fund
UNOCHA	UN Office for the Coordination of Humanitarian Affairs
USAID	United States Agency for International Development
WASH	Water, Sanitation and Hygiene

Glossary

Acute Malnutrition. A form of undernutrition caused by infection and/or a decrease in food intake or uptake, resulting in rapid weight loss (wasting) or bilateral pitting oedema. *See undernutrition, SAM.*

Choropleth mapping. A thematic map in which areas are distinctly coloured or shaded to represent classed standardised values of a particular phenomenon. *See polygon-based mapping approach.*

Community-based Management of Acute Malnutrition (CMAM). Refers to a programme delivering therapeutic feeding to the majority of cases of severe wasting as outpatients. Effective CMAM programmes include community mobilisation to ensure early detection, referral and recruitment of cases and the follow up of cases in the community.

Coverage. The proportion of all people needing or eligible to receive a service that actually receive that service.

Dasymetric mapping. A technique in which attribute data that is organised by a large or arbitrary area unit is more accurately distributed within the area unit by the overlay of geographic boundaries that exclude, restrict, or confine the attribute in question. For example, a population attribute organised by census tract might be more accurately distributed by the overlay of water bodies, vacant land, and other land-use boundaries within which it is reasonable to infer that people do not live.

Geolocation. Short form for *geographic location*. It is the process of finding and assessing geographic features based on its position according to a specified coordinate reference system.

Georeference. Short form for *geographic reference*. It is the alignment of particular geographic features to a specific coordinate system so it can be viewed, queried, and analysed with other geographic data of the same coordinate system.

Geostatistics. Refers to the sub-branch of spatial statistics that deals with a finite set of data of measured values relating to an underlying spatially continuous phenomenon. The term was first used by Georges Matheron and colleagues in their work addressing problems of spatial prediction in the mining industry. This field of study initially developed independent of mainstream spatial statistics which led to its own set of terminology and style.

Geographical Information System (GIS). A system (usually computerised) designed to capture, store, manipulate, analyse, manage, and present geographically referenced data. GIS merges cartography (mapping), statistical analysis and database management.

Global Positioning System (GPS). A space-based global navigation satellite system that provides accurate and precise location information (latitude, longitude, altitude and time) anywhere on the earth. The system is maintained by the United States government and is freely accessible by anyone with a GPS receiver. Other satellite navigation systems are available, but not in common use.

Hybrid polygon and pixel mapping method. Model-based mapping method incorporating both aggregated data used in polygon-based mapping approaches and geolocated and georeferenced data used in pixel-based mapping approaches. *See pixel-based mapping method, see polygon-based mapping method.*

Mid Upper Arm Circumference (MUAC). The circumference of the upper arm measured at the mid-point between the tip of the shoulder and the tip of the elbow. The MUAC is the best available and practical indicator of mortality risk associated with acute malnutrition. *See wasting, SAM.*

Nutrition specific. Specific actions for nutrition are 1) feeding practices and behaviours; 2) fortification of foods; 3) micronutrient supplementation and; 4) treatment of acute malnutrition.

Nutrition sensitive. Nutrition sensitive strategies involve work on 1) agriculture; 2) clean water and sanitation; 3) education, employment and social protection; 5) health care and; 6) support for resilience.

Pixel-based mapping method. A pixel (small dot) is the smallest single component of a digital image. Thousands (or millions) of pixels are arranged in rows and columns to form a series of grids, which produce a picture, in this case a map image, on a display screen. The smaller the area size represented by each grid, the more pixels there are within the area; and the more pixels, the higher the resolution of the image, and therefore the finer the detail of the map. Pixel-based mapping may be useful to depict the spatial variation of indicators in more detail across a programme area; a variety of techniques may be used to colour and distinguish the value of results of individual areas represented by the small grids. *See hybrid pixel and polygon-based mapping method, spatial resolution.*

Polygon-based mapping method. A polygon is a flat shape consisting of at least three straight, non-intersecting lines or 'sides' that are joined to form a closed path around an interior. The area enclosed by the polygon on a map may be coloured or shaded to represent the value of the result attributable to that polygon. A polygon-based mapping approach can be used to depict a phenomenon across demarcated boundaries of administrative units within a country or of regions of the world or delineated functional categories across a country such as zip codes, livelihood zones, or programme areas. *See choropleth mapping, hybrid pixel and polygon-based mapping approach.*

Prevalence. The proportion of a population with a given condition at a given time.

Raster. A spatial data model that defines space as an array of equally sized cells arranged in rows and columns, and composed of single or multiple bands. Each cell contains an attribute value and location coordinates. Unlike a vector structure, which stores coordinates explicitly, raster coordinates are contained in the ordering of the matrix. Groups of cells that share the same value represent the same type of geographic feature. *See vector.*

Scale. The ratio between the size of something real (e.g. a programme area or country) and a representation of it (e.g. a map). 'Small scale' refers to a map on which the objects depicted are relatively small (e.g. a country map divided into districts). 'Large scale' refers to a map on which the objects depicted are relatively large (e.g. a single district map showing a programme area). The larger the map scale the greater the detail portrayed. The map scale is determined by the ratio; for example the ratio 1:50 000 means that the size of objects on the map is 1/50 000 of their size on the ground, the ratio 1:200 000 means that the size of objects on the map is 1/200 000 of their size on the ground. As 1/50 000 is a larger fraction than 1/200 000, the 1:50 000 map is the larger scale map. *See spatial resolution.*

Severe Acute Malnutrition (SAM). Usually defined as MUAC < 115 mm and/or bilateral pitting oedema in children between 6 and 59 months old. Some programmes and survey reports may also use a weight-for-height case definition. See *acute malnutrition, MUAC.*

Simple Spatial Sampling Method (S3M). Large scale area sampling method used to estimate and map survey results of regional up to national programmes. Results may be reported at the local area level and overall for the region or country.

Small area estimation. The provision of survey results at local area level by using data from existing census or population sample surveys to extrapolate and indirectly estimate the phenomenon of interest at much lower administrative units of a country: from second level i.e., district even down to census enumeration area levels.

Spatial. Methods or findings regarding the relationship between phenomena (e.g. programmes, indicators, determinants of malnutrition) and their geographic location. *See spatial analysis, spatial distribution, spatial interpolation, spatial mapping.*

Spatial analysis. The process of examining the locations, attributes, and relationships of features in spatial data through overlay and other analytical techniques in order to address a question or gain useful knowledge for programming or other purposes. *See spatial, spatial distribution, spatial interpolation, spatial mapping.*

Spatial distribution. The pattern of a phenomenon or indicator of interest over space. *See spatial, spatial analysis, spatial interpolation, spatial mapping.*

Spatial interpolation. Methods which estimate the phenomenon of interest at unobserved locations in space based on the values at observed locations. *See spatial, spatial analysis, spatial distribution, spatial mapping, geostatistics.*

Spatial mapping. The process of creating a symbolic depiction (a map) to highlight the relationship between phenomena (e.g. regions, programmes, indicators), and their geographic location.

Spatial resolution. Refers to the accuracy with which the location and shape of features on a map can be depicted at a given scale. It is based on the size and number of pixels used to produce the image - typically pixels may correspond to square grid areas ranging in size. The more pixels used to represent an image, the more accurately the smallest map feature is displayed, and the higher the resolution. The larger the map scale the higher the possible resolution. As scale decreases, and fewer pixels compose each grid, resolution, and therefore fine detail, diminishes and boundaries between features are smoothed, simplified, or not shown at all. *See pixel-based mapping approach.*

Spatio-temporal modelling. Refers to the use of data that can be geolocated and georeferenced and that are collected at different periods of time

Child stunting. Height for age <-2 Standard Deviations (SDs) from the WHO child growth standards median; cut off point for public health problem ≥ 20% of population affected.

Tabular / matrix analysis. A method of organising, analysing and presenting data using tables.

Undernutrition. Malnutrition related to all forms of inadequate food and nutrient intake or excessive losses. *See acute malnutrition*

Child underweight. Weight for age <-2 Standard Deviations (SDs) from the WHO child growth standards median, cut-off point for public health problem ≥ 10% of population affected.

Vector. A coordinate-based data model that represents geographic features as points, lines, and polygons. Each point feature is represented as a single coordinate pair, while line and polygon features are represented as ordered lists of vertices. Attributes are associated with each vector feature, as opposed to a raster data model, which associates attributes with grid cells. *See raster.*

Wasting. A form of acute malnutrition. It is defined by a MUAC < 125 mm (or a weight-for-height z-score of < -2). *See acute malnutrition, MUAC.*

Executive Summary

This report provides output for Phase 1 of DFID's spatial mapping of nutrition programming project. The overall project comprises two discrete phases and aims to better understand if and how spatial analysis can help to coordinate and co-locate nutrition relevant programmes.

The rationale for the project is based on the recognition that cross-sector actions are essential to achieve sustained reductions in undernutrition, yet to date limited information is readily available on the spatial overlap of interventions funded by DFID and others to tackle the problem. In addition, data on the determinants of malnutrition is rarely accurately mapped and prevalence data is often only specified at regional or district level.

To determine the potential and scope for spatial mapping and analysis to address these issues the focus of the initial phase was a feasibility analysis and assessment of data availability. Based on the findings a second phase will subsequently undertake a detailed country level analysis and synthesis.

The results for Phase I presented here detail 1) the methods and results of a literature review on the use to date of spatial mapping techniques in nutrition programming; 2) a review of the availability of data on nutrition specific and nutrition sensitive programming; and 3) a synthesis of the two reviews and a feasibility study with recommendations to support Phase 2 of the spatial mapping agenda which will entail the development of 'heat maps' of intervention intensity and accuracy of programme targeting in 4 countries.

The literature review identified two major groups of actors using spatial mapping: firstly, academic units and research institutions that often pursue an information only mandate providing national level data; secondly, typically non-governmental and UN organisations who were initially consumers, but are now increasingly becoming producers of spatial data due to the more widely available spatially-oriented and GIS-based technologies. The majority of data used in mapping comes from existing datasets and is multi-indicator.

The rationale for the current use of spatial mapping for health and nutrition largely matches the key elements of a project management cycle but with particular focus on the first stage: identification of the problem, making prevalence maps by far the most common. Coverage maps have been produced recently for evaluation purposes, but as yet, on-going, active monitoring using spatial data is not widespread. The key attraction and advantage of spatial analysis to proponents is its capacity to unmask variability and show accurate, detailed and differentiated patterns on multiple indicators across a programme area in a striking visual format. This is in contrast to the limited practical value at programme planning level of the current highly aggregated data available on health and nutrition indicators. The use of spatial maps to coordinate cross sector projects is as yet infrequent (mostly matrix type) but offers the potential to identify areas of overlap between interventions as well as areas of need or 'hotspots', hence promoting the coherent programming and appropriate intervention, which is essential to ensure a sustainable reduction in undernutrition.

Although spatial mapping is a powerful tool, case studies have demonstrated that in order to ensure that programmes are able to make effective and active use of spatial data, 'buy-in' and direct long-term engagement is essential at the political and practitioner level.

The data review identified three mapping methods used for reporting spatial data; polygon, pixel and hybrid polygon and pixel. The polygon-based approach using small area estimation, although not providing the highest resolution, appears to be the most accessible and available and does not require other ancillary geospatial data. It is, however possible to trial model based mapping in one country during Phase 2 of the project given the availability of ancillary data for all four focus countries. This will enable a useful comparison of the output of two different methods.

Based on a list of data requirements for each approach and the likely availability of that data in a given country, Tanzania, Ghana, Zambia and Yemen were selected as the focus for Phase 2. Survey and census data from nationally representative surveys is readily available for these countries with the exception of Yemen, where it is hoped this will soon be obtained. In terms of the secondary data requirements, action is needed in a few cases, particularly for a list of nutrition interventions by area for Ghana, Zambia and Yemen in order for their locations to be mapped; but otherwise much has already been obtained or requested. The relevant

DFID country offices and country contacts have been provided with a checklist to retrieve and assess data to see if it can be mapped and can measure nutrition and nutrition sensitive indicators.

Despite the increased interest and capacity in spatially oriented approaches they are as yet seen as peripheral or novelty methods. Programme planning and resource allocation continue to be dominated by highly aggregated results from traditional nationally representative surveys. This is underpinned by the fact that goals tend to be set at country level without taking account of in-country spatial variation. The technological shift needs to be matched by a corresponding paradigm shift in the assessment of health and nutrition achievements, with equal importance attached to spatial homogeneity of results as to national aggregates. To meet need, effective programmes must be able to identify where it is most acute and target cross sector interventions to ensure a cohesive and effective response. Spatial mapping can identify hotspots and overlap, and orient planning, implementation, monitoring and coordination of programmes. This needs to be highlighted and evidenced by leading development actors to ensure the commitment of partners to capitalise on this essentially practical tool. Moving forward with Phase 2 of this DFID project will provide an opportunity to explore and demonstrate the value of spatial mapping and engage a wide audience as well as a wide number of active participants. Ensuring coordination with existing initiatives in the focus countries is recommended as is encouraging that the (geo)location (village name) be specified for all future routine or survey data collection.

Background

This report provides output of Phase 1 of DFID's spatial mapping of nutrition programming project. Overall, the project aims to better understand if and how spatial analysis can help to coordinate and co-locate nutrition relevant programmes. The project is divided into two discrete phases. Phase 1 of the project is a feasibility analysis and data availability assessment, while Phase 2 is the detailed country level spatial data collection, analysis and synthesis.

Phase 1 Objectives

Phase 1 of the project aims to assess the feasibility of the application of spatial mapping to programming nutrition. Specifically, phase 1 aims to answer the following questions:

- What examples (in published or 'grey' literature exist) of where spatial mapping techniques have been applied to nutrition programme planning or evaluation? What was the aim of these initiatives? What are the key lessons from the experience of applying these techniques to nutrition to date? What other approaches have been used to deliberately support geographical coherence of nutrition programming?

- To what extent is spatial data on nutrition specific and nutrition sensitive programming available in the areas selected? With what level of granularity is this information available?

- To what extent is spatial data on undernutrition (stunting and wasting) prevalence available?

- What relevant spatial data sets are available, which map immediate or underlying determinants of undernutrition?

Organisation of the Report

This report is divided into three chapters based on the key deliverables expected from Phase 1 as stated in the project's Terms of Reference (see Annex 1).

The first chapter addresses objective 1 of Phase 1 and describes the methods and results of the literature review conducted. The second chapter addresses objectives 2 to 4 of Phase 1 and presents the approach and results of the data review performed. The third chapter provides a synthesis of the literature review and data review as well as an assessment of the feasibility of Phase 2 of the project, setting out recommendations for actions and future data needs required to support the agenda of spatial mapping of nutrition programming.

Chapter 1: Literature Review

1.1 Introduction

Nutrition is multi-dimensional and multi-causal (UNICEF, 1990). Programmes and interventions that aim to reduce malnutrition, therefore, require multi-sectoral action. The Scaling Up Nutrition (SUN) movement provides a good example of this multi-sectoral action in its work to promote the effective implementation of both specific actions for nutrition[1] and nutrition-sensitive strategies[2] (SUN Movement, 2011; 2014).

As such, measuring the impact of malnutrition reduction programmes and interventions requires demonstrating whether or not nutrition, nutrition-related and nutrition-sensitive programming are implemented in a concerted and coherent manner. The spatial dimension – geographical location, scope and scale – of nutrition programming coherence is an important aspect that contributes to this impact.

This literature review aims to lay a knowledge base on existing (past and current) approaches to the use of spatial mapping for nutrition and nutrition-sensitive programming and to see why and how it may be useful. Specifically, this literature review will answer the following questions:

- What examples can be found (in published or 'grey' literature) in which spatial mapping techniques have been applied to nutrition programme planning or evaluation?
- What was the aim of these initiatives?
- What are the key lessons from the experience of applying these techniques to nutrition to date?
- What other approaches have been used to deliberately support geographical coherence of nutrition programming?

1.2 Methods of the Literature Review

We applied a meta-narrative framework to this literature review similar to that implemented by Collins and Hayes (Collins & Hayes, 2010), because we expected considerable heterogeneity among the techniques and initiatives on spatial mapping as applied to nutrition programming. Our meta-narrative approach does not, in the strictest sense, follow the classical meta-narrative approach as described by Greenhalgh and colleagues (Greenhalgh, Robert, Macfarlane, *et al.*, 2004) when they pioneered the method as an alternative to standard systematic reviews in assessing a topic of interest that would entail reviewing mixed literature (i.e., qualitative vs. quantitative, technical and policy-orientated).

The first stage of the literature review is a wide search for published literature produced in the past 10 years using search words 'spatial', 'spatial mapping', 'health' and 'nutrition' on Scopus.[3] The addition of 'health' widens the search to the use of spatial mapping on health topics related to nutrition. The purpose of the first stage search is to cast a wide net across the database of published literature on any articles related to spatial mapping in relation to health and nutrition. The first stage also aims to collect literature that gives an overview of technical and methodological approaches to spatial mapping and provides information on what types of data to look for in the data review (see Methods section of data review chapter).

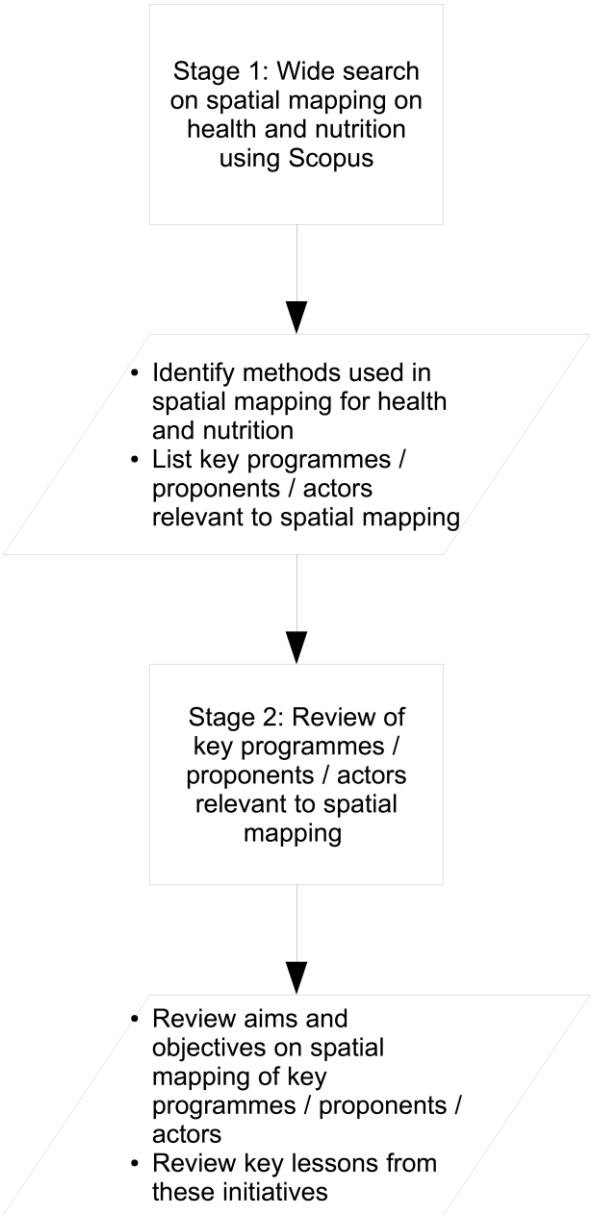
The second stage of the literature review uses the wide search of the first stage as a reference point to identify and list key programmes / proponents / actors relevant to spatial mapping and the organisations that fund them. Further review has been done through an Internet search to obtain additional information on the programmes / proponents / actors based on the list created from the first stage, which included the aims / objectives of, and key lessons learned from, these initiatives on spatial mapping. Figure 1 presents the general algorithm used for the literature review of Phase 1 of the project.

[1] Specific actions for nutrition are 1) feeding practices and behaviours; 2) fortification of foods; 3) micronutrient supplementation; and, 4) treatment of acute malnutrition.

[2] Nutrition-sensitive strategies involve work on 1) agriculture; 2) clean water and sanitation; 3) education; 4) employment and social protection; 5) health care; and, 6) support for resilience.

[3] Scopus is the largest abstract and citation database of peer-reviewed literature: scientific journals, books and conference proceedings.

Figure 1: Literature review algorithm



1.3 Results

Table 1 presents the results of Stage 2 of the literature review summarising the various key programmes / proponents / actors on spatial mapping on health and nutrition and indicating their aims / objectives for spatial mapping and the key lessons to date on their work.

1.3.1 Key programmes / Proponents / Actors

From the literature review, there seem to be two general types of programmes or actors involved in spatial mapping on health and nutrition and related factors. The first type can be described as organisations that aim to provide information or serve as information portals on maps of indicators or data of interest related to health and nutrition, but do not necessarily take action or intervene themselves in relation to the maps that they produce. These organisations are either academic research units with a very focused and narrow set of indicators or data and a specific spatial mapping component to their research agenda; or institutions that are not purely academic (though they may have academic links) but are research- or data-orientated and conduct large-scale, national surveys across various indicators or hold large national or sub-national datasets. These organisations in general have great internal capacity and expertise on spatial mapping. Examples of these are the International Food Policy Research Institute (IFPRI), the Demographic and Health Surveys Program (DHS Program), Famine Early Warning Systems Network (FEWS NET), Food and Agriculture Organisation (FAO), Spatial Epidemiology Unit of the KEMRI-Wellcome Trust research programme, the Global Atlas of Helminth Infections (GAHI), and the Malaria Atlas Project (MAP) of the Spatial Epidemiology and Ecology Group (SEEG) of the Department of Zoology, University of Oxford to name a few (see Table 1).

The second type of programmes or actors can be described as organisations that are active consumers of information or data that come from their own research or surveys or routine programme monitoring and from secondary sources (such as those from the first type) in order to inform and guide the design, planning and implementation of their projects. In relation to spatial mapping, they may have their own in-house expertise (i.e., geographic information systems or GIS specialists, epidemiologists) but would generally require external third-party support for their spatial mapping requirements. Some of these organisations are non-governmental organisations (NGOs), UN organisations and funders. This literature review found examples from World Vision International and Concern Worldwide, UNICEF, particularly the country office in Sudan, Ethiopia and Niger, USAID particularly in Nepal, DFID and the World Bank.

However, this difference between the two types of organisations in terms of capacity and expertise on spatial mapping is rapidly disappearing. This is attributable to disruptive technologies related to mapping that have allowed for the lowering of capital and start-up costs for producing decent spatially-orientated and GIS-related products, which in turn has made these technologies ubiquitous and widely-used. Spatially orientated data is becoming cheaper to collect and therefore becoming more readily available than previously. So, those oranisations of the second type – consumers – are becoming less reliant on the outputs of the research groups or institutions, and are able to produce their own map products specific to their needs. As spatial analysis and mapping techniques become more accessible to programme providers and funders, so their utility and the possibilities for cross-sectoral coordination in their use increase. The role of the academic and research groups then becomes more of the originator of new approaches and methods to spatial mapping that improve both spatial resolution and spatial analytics.

Table 1: Summary of key programmes / proponents / actors

Programme / Proponents / Actors	**Funders**	**Countries**	**Aims / Objectives**
Nutrition Mapping in Tanzania (Simler, 2006) International Food Policy Research Institute (IFPRI) Food Consumption and Nutrition Division http://www.ifpri.org	Rockefeller Foundation	Tanzania	Produce high resolution undernutrition maps of Tanzania that unmask the high within-country variability that exists, including pockets of severe undernutrition or "hunger hot spots"
Atlas of African Agriculture Research and Development (IFPRI, 2014) International Food Policy Research Institute (IFPRI) http://agatlas.org	Bill and Melinda Gates Foundations, HarvestChoice, CGIAR Consortium for Spatial Information, CGIAR Research Program on Climate Change, Agriculture and Food Security	Countries in Africa	Provide a picture of the increasingly diverse geospatial data resources to inform work and guide decision-making on agricultural development in Africa. Provide a better understanding of current and evolving growing conditions and how to increase productivity, despite obstacles, in order to aid in tailoring more pragmatic solutions for poor smallholder farmers
Vulnerability Analysis and Mapping (VAM) Food Security Atlas World Food Programme http://www.foodsecurityatlas.org	ECHO, DFID, GTZ, CIDA, Citigroup Foundation, Danish government, French government	WFP countries	Analyse and map food insecurity
Famine Early Warning Systems Network (FEWS NET) http://www.fews.net	USAID	37 countries	Provide objective, evidence-based analysis to help government decision-makers and relief agencies plan for and respond to humanitarian crises
Spatial information management for food and agriculture Food and Agriculture Organisation (FAO) http://www.fao.org/spatl/index_en.asp		FAO countries	Improving decision-making through provision of geo-referenced information and assessments
FIVIMS Food and Agriculture Organisation (FAO) http://www.fao.org/docrep/w5849t/w5849t09.htm		FAO countries	Develop a national food insecurity and vulnerability information and mapping system, indicating areas and populations, including at local level, affected by or at-risk of hunger and malnutrition, and also indicating those elements contributing to food insecurity, making maximum use of existing data and other information systems in order to avoid duplication of efforts

3W / 4W matrix UNOCHA https://www.humanitarianresponse.info/home		Worldwide	Coordinate interventions in humanitarian emergencies by identifying overlaps and gaps in humanitarian aid delivery using mapped information
mHealth with GIS vulnerability modeling World Vision in partnership with ESRI http://www.wvi.org/health/mhealth-gishttp://www.cgu.edu/pages/9417.asp		Senegal, Mali, Ghana, Sierra Leone, Tanzania, Peru	Develop a comprehensive awareness of community resilience, on-going vulnerabilities, and measurements of the effectiveness of community level interventions; Provide evidence to inform decision making, reduce redundancy, and ensure that the right community interventions are provided where they are truly needed
USAID Nepal GIS unit (USAID Nepal, 2013) USAID Nepal http://www.usaid.gov/nepal	USAID	Nepal	Share and analyse information using maps and images. Improve program design and management, achieve results, secure more development funds, and improve communication and collaboration among stakeholders
Spatial Data Repository The DHS Program http://spatialdata.dhsprogram.com/index.html	USAID	DHS countries	Provide geographically-linked health and demographic data from The DHS Program and the U.S. Census Bureau for mapping in a geographic information system (GIS)
Mapping for results initiative (Gigler, Tanner & Kiess, 2011) The World Bank http://maps.worldbank.org/maps/	The World Bank	World Bank countries	Better monitor their impact on people; Improve aid effectiveness and coordination; Enhance transparency and social accountability; Empower citizens and other stakeholders to provide direct feedback on project results
Sudan Simple Spatial Sampling Method (S3M) Survey Sudan Federal Ministry of Health, UNICEF, Brixton Health, Valid International	DFID, Government of Japan, Government of France, Government of Denmark, Government of Switzerland, OFDA	Sudan	Obtain data for basic health, WASH and nutrition indicators for small areas (at sub-locality level) to allow mapping of results to show geographical areas of highest need and 'hot-spots' Enable better targeting of existing interventions and will inform program expansion.
Niger CMAM Coverage Survey using S3M Institute of National Statistics, UNICEF, Valid International	UNICEF Niger	5 regions of Niger	Produce high resolution map of CMAM coverage in 5 regions of Niger Produce high resolution map of IYCF indicators in 5 regions of Niger
Wolayita and South Wollo Zone Coverage Survey using S3M	UNICEF Ethiopia	2 zones of Ethiopia	Produce high resolution map of CMAM coverage in 2 zones of Ethiopia

UNICEF Ethiopia, Concern Worldwide, Valid International			Produce high resolution map of IYCF indicators in 2 zones of Ethiopia
Fortification Coverage Assessment in Rajasthan State, India Global Alliance for Improved Nutrition (GAIN) and Valid International	Bill and Melinda Gates Foundation	Rajasthan State, India	Produce high resolution maps of flour, salt and oil fortification coverage in Rajasthan
Coverage of nutritional porridge in three districts of Eastern Region, Ghana Global Alliance for Improved Nutrition (GAIN) and Valid International	USAID JICA Ajinomoto Co. Inc.	Three districts, Eastern Region, Ghana	Produce high resolution maps of nutritional porridge coverage in three districts, Eastern Region, Ghana
Spatial Epidemiology Unit KEMRI-Wellcome Trust Research Programme http://www.kemri-wellcome.org/index.php/en/study_page/17	Wellcome Trust, UNICEF, DFID, PMI	Kenya, Tanzania, Uganda, Malawi, the Republic of Sudan, Djibouti, Somalia, Namibia, Madagascar and Nigeria	Assembling, modelling and mapping of diverse malariometric data at regional scale and at national level in several countries. Use novel methodologies in model-based geo-statistics to provide maps of malaria parasite prevalence defined in space and over time; improve the interpretability of imperfect malaria case incidence data derived from Health Information Systems; develop high resolution mapping of vector control intervention coverage to define biologically targeted future resource needs; use as a monitoring tool to gauge the progress of malaria control and elimination within and across national borders.
Malaria Atlas Project Spatial Ecology and Epidemiology Group Department of Zoology, University of Oxford http://www.map.ox.ac.uk http://www.seeg.zoo.ox.ac.uk	Global Fund to Fight AIDS, Tuberculosis and Malaria University of Oxford-Li Ka Shing Foundation Global Health Programme The Government of the Republic of Namibia The Government of the Republic of Kenya and the Kenya Medical Research Institute UNICEF-Somalia and DFID-Somalia	Worldwide	Produce a comprehensive range of maps and estimates that will support effective planning of malaria control at national and international scales

Global Atlas of Helminth Infections (GAHI) London School of Tropical Medicine and Hygiene http://www.thiswormyworld.org	Wellcome Trust Bill and Melinda Gates Foundation	Worldwide	GAHI shows the geographical distribution of neglected tropical diseases transmitted by worms: soil-transmitted helminthiasis, schistosomiasis, and lymphatic filariasis.

1.3.2 Aims / Objectives of Proponents of Spatial Mapping

There generally seem to be four inter-related aims / objectives for the different proponents of spatial mapping.

1. Quantify and locate the problem or issue, or the condition or situation that is of interest and that is being assessed, and represent it in a map that illustrates the differences by location

2. Produce maps that inform and guide and support the design, planning and implementation of an appropriate intervention or programme

3. Use the maps as a monitoring tool to show either progress or success or non-progress or failure which would inform changes or revisions or improvements to the programme or intervention

4. Use the maps to coordinate projects / interventions

All these aims / objectives are typical elements of a programme management cycle that includes identification of the problem or description of the situation, planning, design and implementation of a programme, monitoring and then evaluation.

A common sentiment (either stated explicitly or implicitly) behind these aims / objectives is that current available data on health and nutrition indicators of interest are too highly aggregated to be truly useful in programme design, planning, implementation and monitoring. This highlights a key advantage of spatial data: its capacity to unmask variability and show accurate, detailed and differentiated variation and patterns in indicators across a wide programme area, and thus enable a more tailored design, focused planning, effective implementation and targeted monitoring.

The type of spatial maps currently produced reflect the nature of the proponents and the aims listed above.

The academic and institutional type of proponents of spatial mapping tend to work towards the quantification and location objective (objective 1 above), i.e. mapping the problem or condition or situation, so that those responsible for and relevant in addressing these issues are able to achieve the other aims / objectives.

NGOs, UN organisations and funders may also produce maps that quantify a problem but these are used more to inform programme planning (objective 2) or to evaluate the success of an intervention (objective 3).

Examples of these types of outputs are prevalence and coverage maps depicted respectively in sections 1.3.2.1 and 1.3.2.2.

The active use of maps as an on-going monitoring tool to continually inform programme revision is, as yet, limited to specific NGOs and funders. An example is shown in section 1.3.2.3.

Finally, proponents who by the nature of their organisation act as coordinating bodies appear to be the only ones who as yet create maps to coordinate interventions (objective 4). Examples of these, which are most commonly of a tabular type, can be found in section 1.3.2.4.

1.3.2.1 Prevalence Maps

Production of prevalence maps is probably the most common usage of spatial mapping, the main goal being to identify where the problems are. Following are some examples of prevalence maps of indicators on nutrition and nutrition-sensitive programming. These maps illustrate the prevalence for undernutrition, soil transmitted helminths, and infant and young child feeding and exclusive breastfeeding practices.

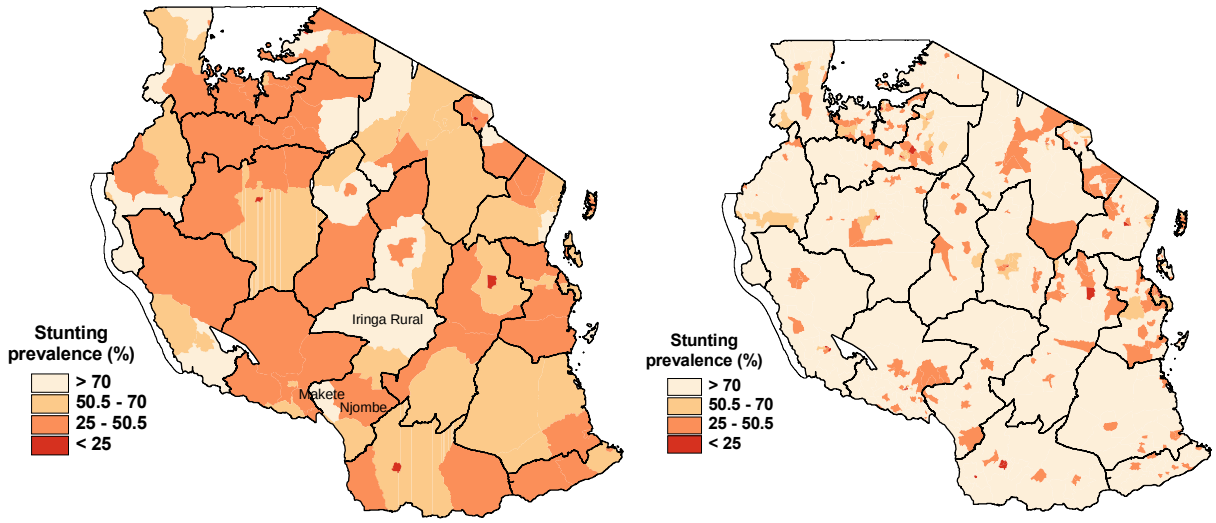
Prevalence of Undernutrition

Simler (2006) of IFPRI claims to have been the first to produce a map of undernutrition for a country in Africa that reported results at much smaller area units (district level and lower) compared to the typical regional level results provided by standard surveys such as the DHS (Simler, 2006). He mapped the levels of stunting and underweight at the district and ward level in Tanzania (see Map 1), using small area estimation techniques (Ghosh & Rao, 1994; Rao, 2003) previously used to map income and poverty (Elbers, Lanjouw &

Lanjouw, 2003; Hentschel, Lanjouw, Lanjouw, *et al.*, 1998). Simler noted distinct spatial patterns between districts and wards that would have been hidden from only regional results reported by the DHS (Simler, 2006).

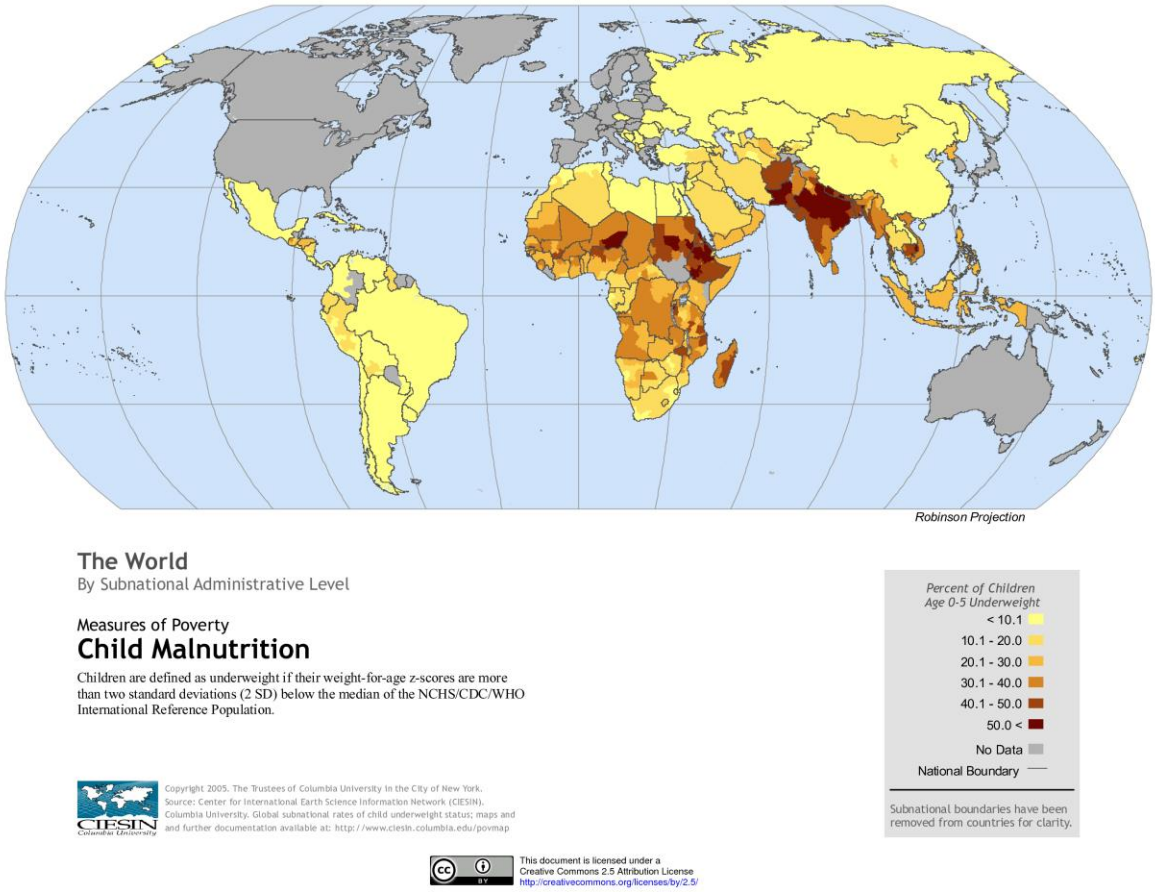
In 2005, the Center for International Earth Science Information Network (CIESIN) of Columbia University published a global map of small area estimates of childhood underweight using data available from various surveys conducted at the time (see Map 2).

Map 1: Prevalence of stunting at district and ward level in Tanzania, 1991-92



Note: Small area estimation techniques were used to indirectly estimate indicators down to the ward level. A choropleth map was then created based on the ward-level indirect small area estimates.
Source: Simler, 2006

Map 2: Global prevalence of underweight

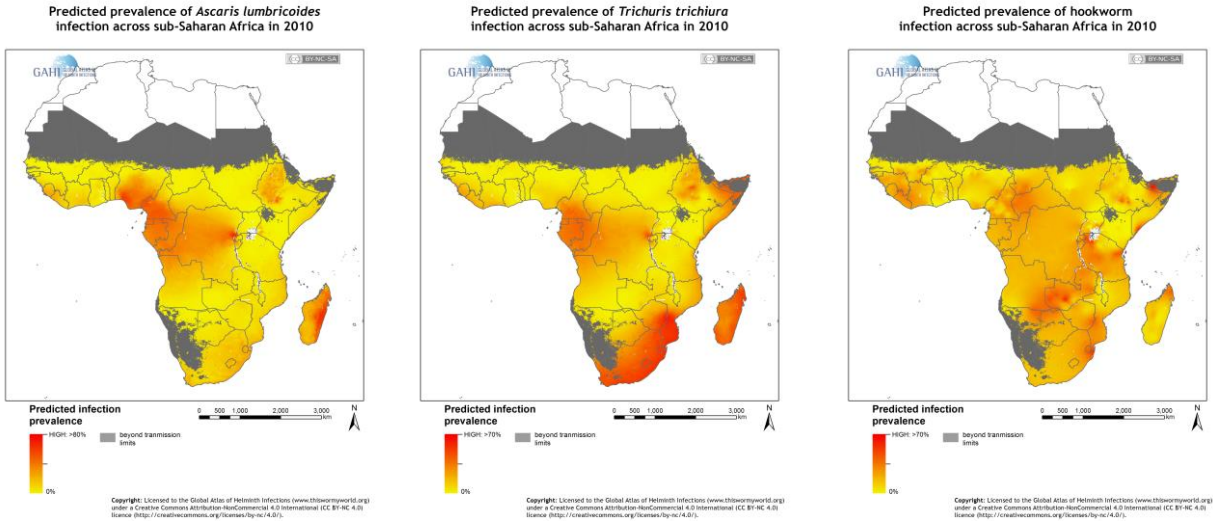


Note: Small area estimation techniques were used to indirectly estimate indicators down to the smallest administrative level possible. A choropleth map was then created based on the indirect small area estimates.
Source: CIESIN, 2005

Prevalence of soil-transmitted helminths (STH)

The Global Atlas of Helminth Infections (GAHI) produces prevalence maps of the three most common STH namely *Ascaris lumbricoides* (Global Atlas of Helminth Infections, 2010a), *Trichuris trichiura* (Global Atlas of Helminth Infections, 2010c) and hookworm (Global Atlas of Helminth Infections, 2010b) (see map 3).

Map 3: Prevalence maps of *Ascaris lumbricoides* (left), *Trichuris trichiuria* (middle) and hookworms (right)

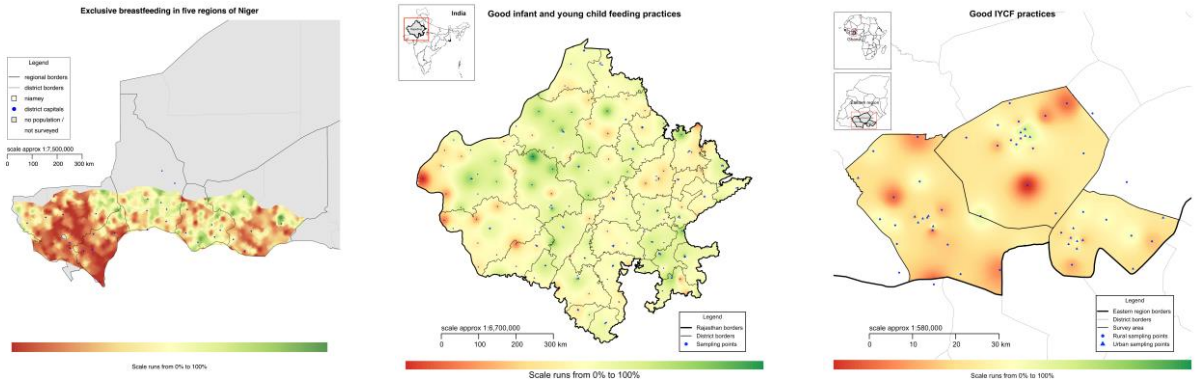


Note: Polygon-based and pixel-based data from existing population sample surveys were used to input into a spatiotemporal geostatistical model to indirectly estimate and predict indicators for each pixel in the map. Pixels were then coloured accordingly.
Source: GAHI 2010a, GAHI 2010b, GAHI 2010c

Prevalence of infant and young child feeding (IYCF) and exclusive breastfeeding (EBF) practices

Maps of feeding practices and behaviours which potentially impact on nutritional status have also been produced at various scales from national level in Niger, state level in India and district level in Ghana (see Map 4).

Map 4: Prevalence maps of exclusive breastfeeding in Niger (left), prevalence maps of good infant and young child feeding practices in Rajasthan (middle) and three districts of Ghana (right).



Note: Data were collected from spatially-selected sampling points and then analysed using inverse distance weighting spatial interpolation to predict indicator values at non-sampled locations.
Source: Valid International, 2014

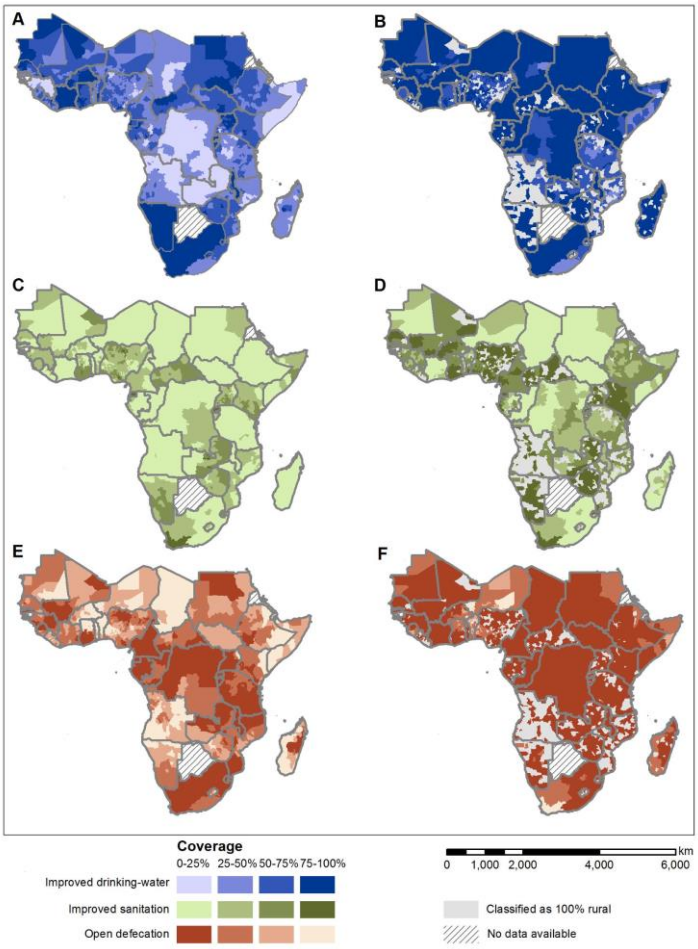
1.3.2.2 Coverage Maps

Maps showing coverage of interventions (e.g. food fortification, micronutrient supplementation, etc.) or coverage of services (e.g. improved water sources, improved sanitation facilities, etc.), which again may influence nutritional status, are used to show what interventions or services are currently achieving and are usually benchmarked against pre-set or agreed standards of clinical and/or programmatic significance. Following are some examples of these kinds of maps.

Coverage of improved water source and improved sanitation facilities

Researchers from the London School of Hygiene and Tropical Medicine, University of Oxford and KEMRI-Wellcome Trust produced predictive maps for 2012 of water and sanitation coverage for the whole of sub-Saharan Africa (see Map 5). The maps are resolved down to the second administrative level (typically called a district in most sub-Saharan African country) using data from existing cross-sectional surveys such as the DHS, the Multiple Indicator Cluster Survey (MICS) by UNICEF and the Living Standards Measurements Survey (LSMS) by the World Bank (Pullan, Freeman, Gething, *et al.*, 2014).

Map 5: Coverage of improved water sources (top), improved sanitation facilities (middle) and prevalence of open defecation (bottom) in sub-saharan Africa in 2012



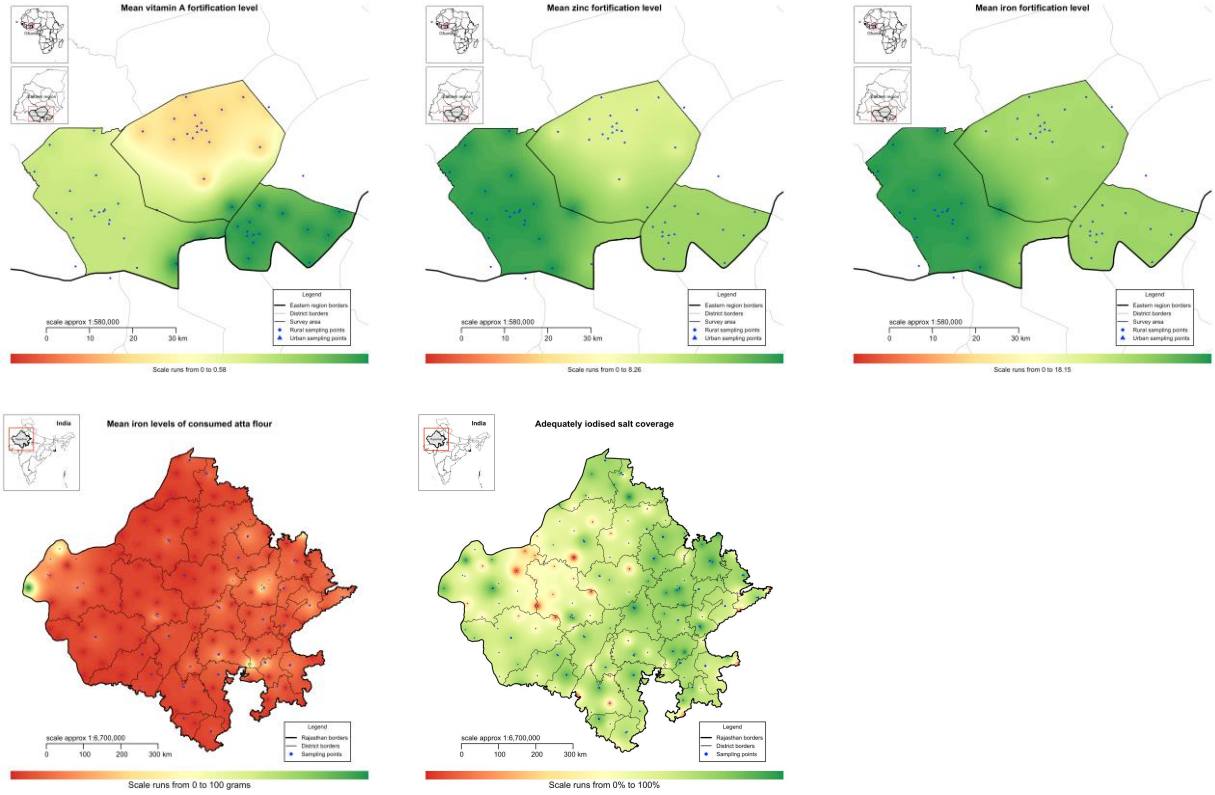
Note: Small area estimation techniques were used to indirectly estimate indicators at sub-country administrative levels. Choropleth map were then produced based on the predicted indicator values.

Source: Pullan et al 2014

Coverage of food fortification programmes

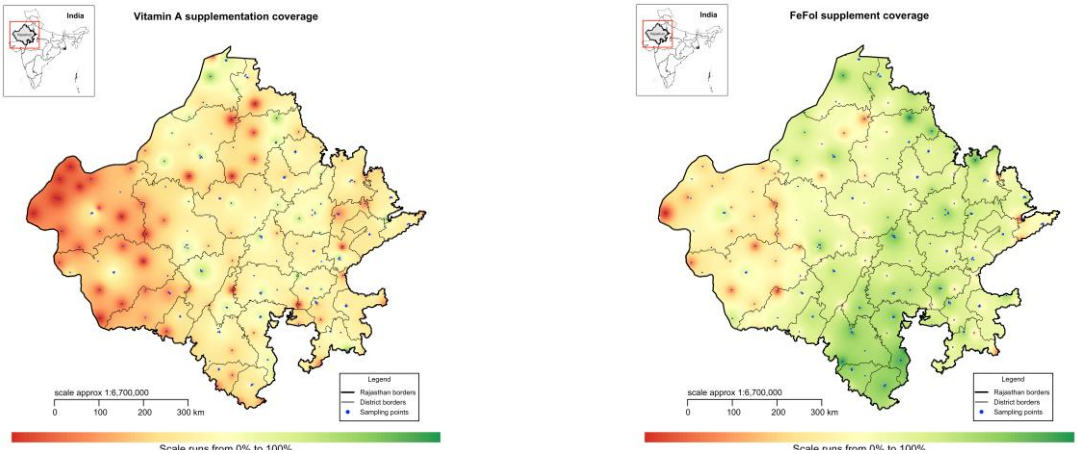
The Global Alliance for Improved Nutrition (GAIN) has conducted spatially-orientated surveys in select areas in Ghana and India to assess the coverage of their food fortification programme (see Map 6) and micronutrient supplementation (see Map 7).

Map 6: Mean flour fortification levels for vitamin A (top left), zinc (middle top) and iron (top right) for three districts in Eastern region of Ghana and mean iron fortification level of flour (bottom left) and adequately iodised salt (middle bottom) in Rajasthan State, India



Note: Data were collected from spatially-selected sampling points and then analysed using inverse distance weighting spatial interpolation to predict indicator values at non-sampled locations.
Source: Valid International 2014

Map 7: Vitamin A supplementation coverage (left) and ferrous sulphate-folate supplementation coverage (right) in Rajasthan State, India



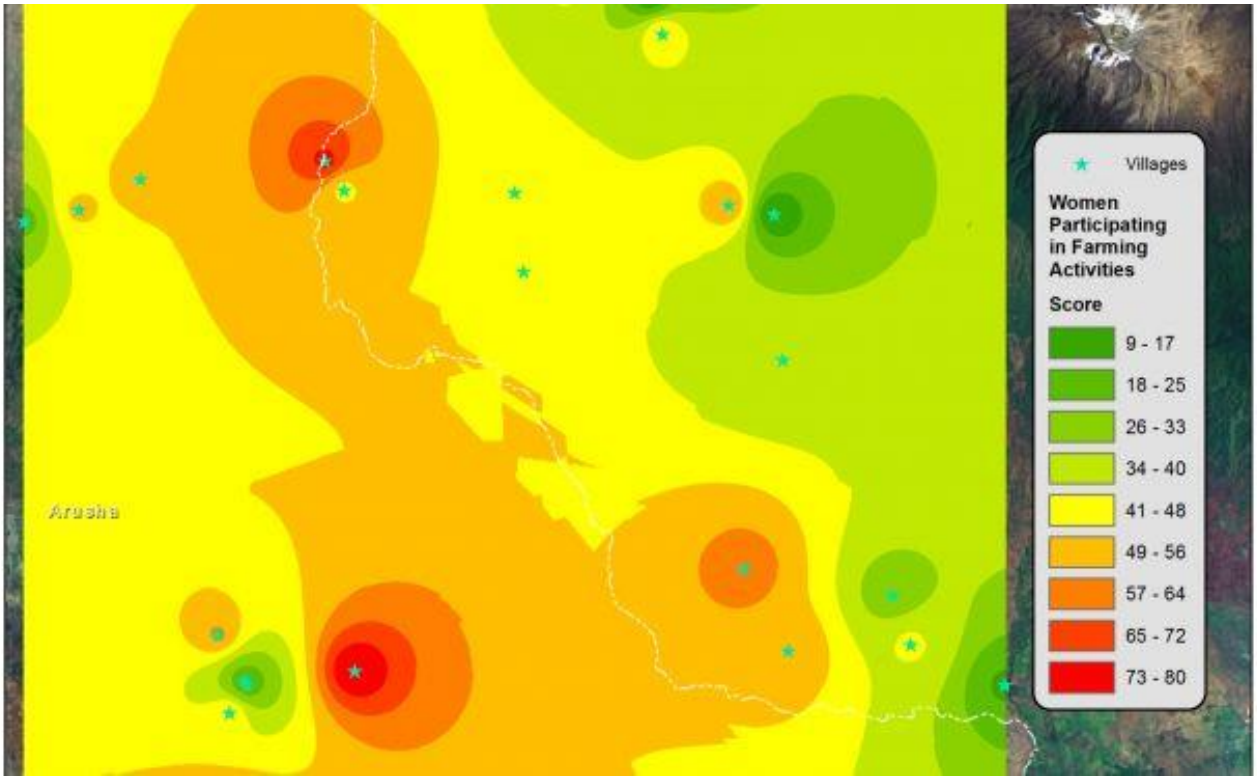
Note: Data were collected from spatially-selected sampling points and then analysed using inverse distance weighting spatial interpolation to predict indicator values at non-sampled locations.
Source: Valid International 2014

1.3.2.3 On-going programme monitoring and revision maps

NGOs, UN organisations and funders tend to address the first three aims and objectives as part of their programme management cycle. However, unlike those that focus on the use of mapping to establish the current problem / issue / situation, those that aim to use mapping as part of their programme management cycle are few and they have only done so relatively recently. This demonstrates that the potential to use spatial mapping to inform on-going programme revision and improvement has not yet been fully realised. Comparing visual images representing a snapshot in time in the life of a programme is, however, a rapid, striking and very accessible way for all those involved to appreciate the evolution in performance.

Some examples of those who have done so are World Vision with their mHealth program on GIS health vulnerability mapping (World Vision International, 2014). In this program, GIS is used as a baseline assessment tool to capture the current problem / issue / situation. This information is then used to plan and implement projects and interventions accordingly. Collection of routine monitoring data includes location information that can be geo-referenced to allow presentation of monitoring results on a map. Finally, evaluation of the project / intervention includes spatial analysis of routine monitoring data and conduct of evaluation activities that allow for spatial analysis. Map 8 is an example of a mapping output produced by World Vision.

Map 8: Heat map of an indicator of interest produced by World Vision GIS team in support of their health vulnerability mapping



Note: Map is most likely produced based on spatial interpolation using Gaussian techniques (i.e. Kriging methods)
Source: http://www.wvi.org/health/mhealth-gis

A similar approach to the use of GIS and spatial mapping to support the programme management cycle is exemplified by USAID Nepal, who have GIS analysts on their team to create mapping products to aid their delivery of programmes (USAID Nepal, 2013).

1.3.2.4 Programme coordination maps

The fourth aim of coordination of programmes and interventions is usually the concern of organisations such as the UN Office for the Coordination of Humanitarian Affairs (UNOCHA), whose main role is the coordination of interventions during humanitarian emergencies. Mapping has been a central tool for these actors, and the methods they have used for mapping have evolved over time.
UNOCHA has used mapping approaches that do not necessarily fit the common conception of maps or mapping. This is what can be called 'tabular mapping or the matrix mapping approach', which is a quite

common tool used in organising information regarding programmes and interventions in a country. As its name implies, this type of map comes in the form of a table or a matrix that organises information regarding the different organisations working in a particular country or area, what types of interventions / programmes they implement, where they implement them, when they started (or are planning to start) and when they plan to stop, and to whom they are providing support. A good example of this type of map is the 3W or 4W (W stands for who, what, where when) used by OCHA and the clusters during emergencies to coordinate the humanitarian relief efforts. Map 9 is an example of the use of the matrix mapping by UNOCHA for the humanitarian response to Typhoon Haiyan in the Philippines.

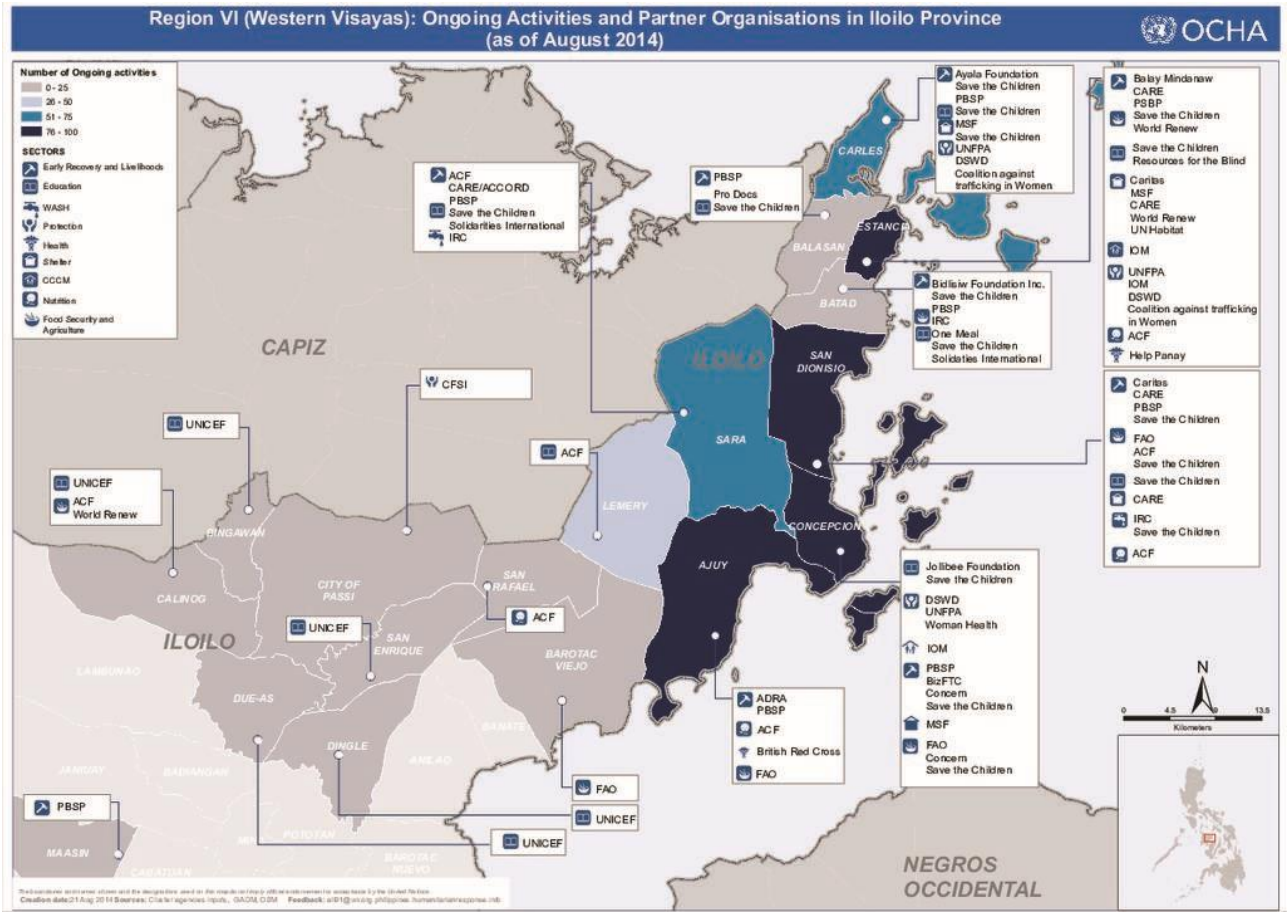
Figure 2: 3W matrix created by UNOCHA for the Typhoon Haiyan humanitarian response in the Philippines

OCHA

		Aff. Pop	CCCM	Early Recovery & Livelihood	Education	Em. Shelter	Em,Telecom	Food Sec. and Agr.	Health	Nutrition	Protection	WASH	Grand Total	Completed	Ongoing	Planned
AKLAN	Altavas	23919	0	2	19	15	0	9	3	0	0	0	48	24	20	2
	Balete	27197	0	2	18	13	0	8	0	0	0	0	41	18	21	2
	Banga	38063	0	2	1	15	0	1	0	0	0	0	19	16	3	0
	Batan	30312	0	2	29	22	0	16	3	8	5	16	101	49	43	6
	Buruanga	16962	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ibajay	45279	0	0	0	0	0	1	0	0	0	0	1	0	1	0
	Kalibo	74611	34	0	0	1	0	16	2	0	6	0	59	52	2	3
	Lezo	14518	0	0	0	0	0	9	0	0	0	0	9	9	0	0
	Libacao	28005	0	2	10	10	0	0	10	0	0	0	32	8	15	2
	Madalag	18168	0	0	5	13	0	3	0	0	0	0	21	4	6	11
	Makato	25461	0	0	1	4	0	22	0	0	0	0	27	26	1	0
	Malay	45811	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Malinao	24108	0	0	0	22	0	12	0	0	0	0	34	23	0	11
	Nabas	31052	0	0	0	12	0	3	0	0	0	0	15	3	0	12
	New Washington	42112	0	0	8	12	0	27	0	0	0	0	47	39	6	2
	Numancia	29862	0	0	0	1	0	12	0	0	3	0	16	15	1	0
	Tangalan	20277	0	0	0	13	0	7	0	0	0	0	20	8	2	10
	not specified	n/a	0	0	0	1	0	0	0	1	1	0	3	0	1	2
ANTIQUE	Anini-y	5188	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Barbaza	21775	0	0	18	24	0	10	0	0	8	0	60	36	19	5
	Belison	7899	0	0	0		0	0	0	0	0	0	0	0	0	0
	Bugasong	32264	1	0	10	10	0	1	0	0	7	0	29	8	11	10
	Caluya	30046	0	0	15	16	0	0	0	0	0	1	32	17	15	0
	Culasi	39086	3	0	23	5	0	5	0	0	13	1	50	28	22	0
	Hamtic	8723	0	0	3	0	0	1	0	0	0	0	4	3	1	0
	Laua-an	25211	0	0	4	6	0	30	0	0	10	0	50	39	5	6
	Libertad	15669	0	0	3	0	0	1	0	0	0	3	7	0	4	3
	Pandan	32494	0	0	4	0	0	0	0	0	0	0	4	0	4	0
	Patnongon	35102	0	0	15	0	0	0	0	0	0	0	15	0	15	0
	San Jose	4657	0	0	0	0	0	1	0	0	0	0	1	0	1	0
	San Remegio	30446	0	0	3	0	0	0	0	0	0	0	3	0	3	0
	Sebaste	17270	0	0	6	3	0	1	0	0	0	0	10	4	6	0
	Sibalom	56677	2	0	1	0	0	1	0	0	0	0	4	2	2	0
	Tibiao	24513	0	0	20	21	0	4	3	0	14	0	62	39	20	0
	Tobias Fornier	3021	0	0	1	0	0	0	0	0	0	0	1	0	1	0
	Valderama	18442	0	0	7	0	0	1	0	0	0	0	8	0	8	0
	not specified	n/a	0	0	0	2	0	0	0	1	1	0	4	1	1	2
CAPIZ	Cuartero	25456	3		21	14	0	6	16	6	0	6	72	49	21	0
	Dao	31911	2	2	30	8	0	6	5	0	0	9	62	30	29	2
	Dumalag	29298	1		4	19	0	2		0	0	4	30	29	1	0
	Dumarao	43986	0	2	6	19	0	4	5	0	7	9	52	35	12	0
	Ivisan	26763	0	2	109	11	0	0	15	9	3	10	159	34	62	63
	Jamindan	35002	0	0	99	12	0	1	23	0	0	10	145	40	25	78
	Ma-ayon	36430	3	2	17	20	0	12	8	0	12	11	85	44	29	8
	Mambusao	37672	1	0	11	20	0	4	18	7	0	5	66	51	6	1
	Panay	43449	0	2	92	16	0	14	32	5	0	9	170	71	25	72
	Panitan	37895	0	2	27	9	0	3	9	0	6	8	64	22	34	6
	Pilar	41572	19	0	25	5	0	3	18	24	14	40	148	61	53	20
	Pontevedra	43523	14	2	18	14	0	11	17	46	29	38	189	88	79	16
	Pres.Roxas	28561	0	0	20	3	0	9	4	5	2	7	50	25	23	2
	Roxas City	156197	4	3	206	33	2	15	19	6	108	19	415	207	146	55
	Sapi-an	24779	0	2	8	6	0		2	1	0	6	25	20	4	1
	Sigma	29138	0	1	15	13	0	7	40	0	3	12	91	44	41	4
	Tapaz	48051	0	0	67	47	0	0	59	11	33	2	219	55	49	64
	not specified	n/a	0	0	0	2	0	0	0	1	8	0	11	0	1	10

The tabular or matrix type of mapping approach generally aims to illustrate visual overlaps between organisations with regard to the locations where they operate and to the type of interventions they provide. The overlaps can either show complementarity of efforts (i.e., two organisations in the same area but providing different but synergistic interventions, or two organisations in the same area with the same intervention but different target groups); or wastage of resources (i.e., two organisations in the same area providing the same intervention to the same groups, while only one organisation in another area providing the same intervention but to only a few of the target groups due to lack of resources). This is a low level type of map but is quite effective in what it does. More recently, UNOCHA has used this tabular map format of the 3W / 4W and then geo-referenced them to be able to put them on traditional map formats.
Map 9 is an example of the 3W matrix that has been put on a traditional map.

Map 9: 3W matrix presented in a map format, Typhoon Haiyan response, Philippines



Note: Choropleth maps using data from the table

Source: UNOCHA, 2014

1.4 Relevance of spatial mapping

To date, although a number of different mapping approaches have been used by different organisations with varying aims, the active application of spatial analysis is still in its infancy and its full potential remains untapped. For this reason there is currently limited information readily available on the spatial overlap of interventions funded by DFID and others to tackle undernutrition. Given that cross-sector actions are essential to achieve sustained reductions in undernutrition, understanding and mapping the extent of overlap between nutrition specific and nutrition sensitive programmes is important, because opportunities for synergy are likely to contribute significantly to impact. Spatial analysis offers the possibility to identify and highlight areas of overlap between interventions and, at the same time, evaluate the impact of these interventions by mapping multiple indicators. The analysis of spatial data will enable better targeting of existing interventions, and help inform coherent planning and programme expansion for nutrition specific or related sectors.

Current constraints on effective programme planning

Programmatic planning would benefit from the up to date, detailed and visual data provided by spatial mapping. Currently prevalence data for malnutrition is highly aggregated and often only available at national or regional level, making the effective allocation of resources problematic. This existing data cannot easily be disaggregated to produce statistically reliable results for geographical sub-locations. Although the increasing scale-up of nutrition programmes is often accompanied by funding at scale, overall figures representing a district or larger administrative unit mask variation. Spatial mapping is useful as it reveals detailed variation across a wide area. It improves the timeliness and accuracy of decision-making because it offers a visual overview of an entire programme area and also identifies and differentiates 'hot spots' at local level. This is useful, not only to target resources, but to target the necessary (and often limited) resources where they are genuinely needed.

In addition, although malnutrition is known to be multi-causal, accurately mapped data on determinants is rare. Again, spatial mapping may highlight differing geographical contributors to malnutrition, providing useful information to make decisions on the relevant type or combination of nutrition specific and nutrition sensitive interventions in the appropriate location.

The need for multi-sectoral input

Efficient programming needs input from different sectors. Spatial mapping allows for the collection of data on different indicators and for the results to be overlaid on the same programme area, thus allowing for cross-referencing. In Sudan, the recent spatial survey was designed to include, not just nutrition specific, but also nutrition sensitive health and WASH indicators, and to be implemented by nutritionists and personnel from other programmes. This enabled, not only the identification of areas with the greatest need by those directly involved, but helped afterwards to facilitate better integrated programming and determine the specific and complementary actions necessary by different interventions to ultimately reduce child mortality and stunting.

Similarly in a number of countries (such as in Sudan or Ethiopia), where a programme area can encompass a number of different agro-ecological or climatic zones, which impact in varying ways on the causes of malnutrition and on the nutrition strategies employed by sectors involved in say agriculture or resilience, all interventions and variations by zone can be mapped and nutrition specific programming adapted accordingly to ensure a cohesive approach.

1.5 Case Studies: Spatial Mapping in Sudan and Niger

Spatial mapping is undoubtedly a powerful tool but it may only provide part of the solution to improving programmatic planning and coherence between interventions. If the political will exists as well as the capacity of different services to act on the information provided, spatial mapping can make a vital difference and result in more effective and coherent programming. However, without the essential 'political buy-in', data alone, no matter how accurate or informative, may not be sufficient to prompt action to revise or improve programme delivery. The two case studies below of Sudan and Niger illustrate respectively where spatial mapping has proved successful, and where it has not been acted upon to address the problems revealed.

Box 1: Case Study 1

Sudan Simple Spatial Sampling Method (S3M) Survey

The Simple Spatial Sampling Method was used to conduct a survey in all 18 states of Sudan during June/July and November 2013. The methodology was specifically chosen in order to map results for basic health, WASH and nutrition indicators at small area (sub locality) level.

Following a pilot survey in two states in 2012, preparations started several months in advance of the national survey, with participation of senior staff across several departments at the Federal Ministry of Health and the local UNICEF office. The Khartoum State Research Directorate provided support with data management throughout, and Valid International and Brixton Health ensured in-country and remote technical support. Regional and state supervisors took responsibility for training their own state team of enumerators, who were mostly made up of nutritionists, but also included Expanded Programme on Immunisation (EPI) and Integrated Management of Childhood Illness (IMCI) staff thus promoting inter-sectoral coordination. Issues and concerns were addressed or at least acknowledged painstakingly at every stage of the planning, implementation and analysis process with the actors involved.

Results, presented in matrix form (for core indicators) and also as visual maps at national, state and locality level, clearly showed geographical areas with the highest need for each indicator (64 in total).

The long-term commitment and involvement of politicians and health practitioners enhanced learning from, and engagement with, the results. The breadth and depth of information provided by the maps on services, health and nutrition related issues prompted discussion on extension from national to locality level and generated actions to improve poorly serviced areas. The government pledged to address the SAM "hotspots" identified across the country. At national, state and locality levels the maps are now actively used as a tool to assist with coherent 3-5 year planning by the programmes involved.

Box 2: Case Study 2

Niger CMAM Coverage Survey using S3M

Five regions of Niger were surveyed using the Simple Spatial Sampling Method to assess SAM coverage for the CMAM programme and IYCF practices from October 2011 to February 2012.

A design document was shared with local partners in advance but practical preparations and detailed discussions were not held until the arrival in-country of the support team from Valid International at the start of the survey. A technical committee, responsible for the planning, implementation, and supervision of the survey, was quickly formed comprising nutritionists from the National Ministry of Health, statisticians from the National Institute of Statistics (INS) and staff from UNICEF. Regional and district health and administrative authorities were notified of the survey shortly before its passage and visited on the arrival of the survey team in their area, but were not directly implicated. Enumerators were mostly experienced surveyors, rather than health staff, recruited to work for the duration of the survey across all 5 regions.

The survey was implemented effectively and high resolution maps were produced depicting spatial variation in the results, but overall a very low level of coverage across all regions.

The short nature of the planning phase and the minimal involvement of high ranking personnel impacted on the political and practical engagement with the results and all the more so given their disappointing nature. The unexpectedly poor results gave rise to questions about the validity of the methodology and the findings. To date it is not thought that the maps have been shared with other related departments or used to inform programme planning or to take specific action necessary to improve coverage.

1.6 Key Lessons

Overall, the key lessons that the literature review highlights are:

- Spatial mapping in its many forms and approaches is generally possible for nutrition and nutrition-related or nutrition-sensitive programmes. It can produce detailed maps that can locate interventions and measure their impact. However, depending on the aim and objectives as discussed in the previous section, the approaches used can differ in terms of data requirements and complexity.

- Use of already existing datasets seem to be the most common source of data for spatial mapping, particularly for achieving the objective of mapping the problem, situation or condition at a large-scale (i.e., worldwide, national or sub-national). Specific collection of spatially-orientated data that can be geo-referenced, or direct collection of geographic location data using global positioning satellite (GPS) locators tend to be done at smaller-scale (regional or district level within a country) with some exceptions, and tend to be used for the purpose of achieving programme cycle objectives and also for evaluation. Use of hybrid primary and secondary data is also made but not as commonly. More and more, institutions that collect large-scale datasets have been including geo-location into their data collection as the utility of accurate spatial data is recognised, not just for locating a problem, but also for its visual explanatory value.

- Health and nutrition are multi-dimensional, and spatial mapping of health and nutrition tends to involve multi-indicators and multi-sectors that are relevant. Therefore, data requirements for health and nutrition tend to be wide, covering various indicators.
  This means that assembling a spatially orientated database at a national level requires a lot of coordination and buy-in from many partners and agencies within the countries. The example of Sudan shows this is possible and indicates the potential benefits of concerted multi-sectoral programme planning and geo-specific actions to tackle undernutrition.

- Higher spatial resolution is always better but is not always the most useful. The literature review has highlighted how more and more groups and spatial mapping proponents are aiming for as high resolution maps as possible. This is always ideal and the new approaches that have been developed to increase mapping resolution have greatly advanced this field of study. However, high-resolution maps do not necessarily translate into changes in programming or changes in policy or both, especially at national and global levels of governance.
  This is most likely due to two key reasons: The first is that the highly-resolved maps can be deemed intimidating by the people who the maps are meant to inform or influence. Hence, they tend to default back to “headline” figures or aggregated results that they are most accustomed to. The second reason is that highly resolved maps tend to not follow administrative boundaries that national policy and governance are organised around. Taking action on information from these maps may not be as straightforward, because budgets and planning tend to fall within the bounds of the governance structure of the country. Again, long term investment with partners is necessary to ensure the results provided by spatial data are accessible, fully understood and actionable through multi-sector and cross boundary coordination and planning.

- Availability of maps on prevalence or coverage does not necessarily equate to action. Most spatial mapping work that is currently done revolves around documenting the current problem or situation. The assumption (either explicit or implicit) is that if those concerned see the maps then they will take the necessary action to address the problem or correct the situation. Unfortunately, this is not the case for the most part. Existing structures and mechanisms of monitoring and evaluation do not as yet place value on the geographic component of programming. This means that mapping is perceived as just a novelty or a something that is nice to have in a report but not necessarily something that should generate action. Engagement of those responsible for monitoring and evaluation and coordination with planning departments and funding organisations with a view to demonstrate the actionable and dynamic nature of spatial data and its place in the programme cycle will be vital at the outset to ensure that identified problems are tackled and that the benefits of concerted action are clearly discerned (partly through the use of spatial mapping as an on-going monitoring tool).

Chapter 2: Data Review

Spatial mapping requires a specific set of data in order to be implemented. In general, additional data that provides the specific geographic location from where the data has been collected is the most important. Other ancillary data required is determined by the mapping method to be used and the type of indicator to be measured.

This chapter reviews the various mapping methods that have been applied (in the recent past and currently) to nutrition and nutrition-sensitive programming. This then informs the data review conducted for each of the four focus countries selected for this project in terms of what specific data to look for.

2.1 Methods of the Data Review

Figure 3 shows the data review algorithm used.

Figure 3: Data review algorithm

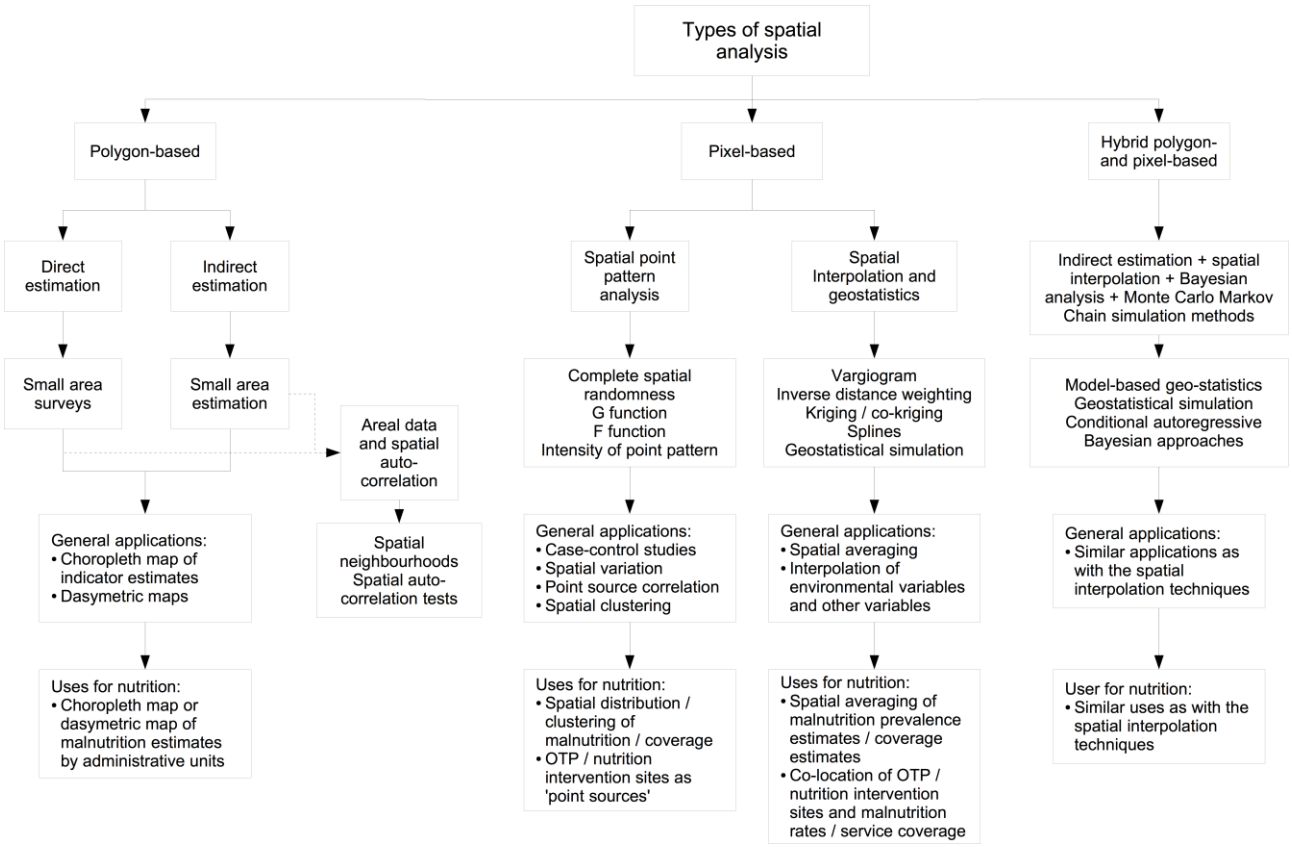
Based on information from the literature review, particularly the first stage that assessed the various methods used in spatial mapping related to health and nutrition, a matrix has been constructed that identifies the different types of data required. The matrix is organised by the broad categories of methods currently used in spatial mapping that will address the objectives of Phase 2 of this project. This matrix has been used to inform DFID HQ in the selection of up to 4 countries that have the relative highest probability of having most of the data required for the specific methods identified.

Once focus countries were selected, a per-country data checklist was created to support the per-country data review. This checklist was then provided to country contacts, including DFID country office representatives, who facilitated contact with other relevant partners and data holders in country. Data were retrieved and assessed to see whether they provide the basic information that will allow the data to be mapped as well as the data that will allow the measurement of nutrition and nutrition-sensitive indicators.

2.2 Results

Table 4 shows results of Stage 1 of the literature review summarising the various spatial mapping methods that can potentially be used for Phase 2 of the project.

Figure 4: Summary of spatial analysis methods



Based on the methods review, we generally classify the different spatial mapping methods found into three broad categories: polygon-based, pixel-based and hybrid polygon- and pixel-based approaches. These categories are based on the spatial unit by which results are reported for the mapping techniques, which determines the spatial resolution of the maps produced. The general rule is that the smaller spatial unit to which results are reported, the higher the spatial resolution.

2.2.1 Polygon-based Methods

Of the three methods, the polygon-based method is probably the most common and widely used. Most researchers and programme managers have at one point created or utilised a polygon-based map to report their findings or their programme outputs. The name itself describes what this category of spatial mapping is about. It primarily reports results to a polygon – that is a shape created by a close chain of line segments – which is either coloured or shaded to represent the value of the result attributable to that polygon. This polygon can be the boundaries of the administrative units of a country or a region or of the world. It can also be functional or categorical boundaries within or across a country such as zip code areas, livelihood zones and other similar categorisations.

The most common type of polygon-based maps are called choropleth maps (Eicher & Brewer, 2001), which are basically thematic maps with each boundary unit (either administrative or categorical) coloured or shaded according to the values of the indicator attributable to that unit. This is the most common type of map in this category (and also across all other types of maps), because it is quite straightforward to do, and because it can be done using data from a standard survey that has results disaggregated by different boundary units. The main issue with polygon-based maps is their spatial resolution, which depends on the level of disaggregation of the survey providing the data. In general, standard nationally representative surveys such as the DHS and the MICS are only representative down to the first administrative unit (typically the region or province) of a country, and therefore, can only generate a low spatial resolution map.

Meanwhile, there has been successful implementation of small area estimation techniques (Rao, 2003; Ghosh & Rao, 1994; Elbers, Lanjouw & Lanjouw, 2003; Hentschel, Lanjouw, Lanjouw, *et al.*, 1998) initially with poverty and income data that enabled the mapping of data to much lower administrative units of a country (from second level, i.e. district, even down to census enumeration area levels). For nutrition, an example is Simler's mapping of underweight and stunting in Tanzania shown in Map 1 (Simler, 2006). In cases where different nutrition specific and nutrition sensitive interventions are determined by administrative units, the polygon approach could be useful in mapping their location and overlap.

2.2.2 Pixel-based Methods

The other broad category of spatial mapping methods is that of pixel-based approaches. Again, the name itself describes what the method is about. The term 'pixels' is familiar to most of us as the resolution of our computer monitors, television or digital cameras. Pixels are basically the small square grids that an area (i.e., computer monitor, television or a country) is divided into. Hence, the smaller the area size of square grids, the more pixels within an area; and the more pixels the higher the resolution.

Pixel-based mapping utilises these square grids across a whole area as the spatial units to which results are reported. To be able to do this, techniques such as small area estimation, spatial interpolation (Bivand, Pebesma & Gómez-Rubio, 2008; Elliot, Wakefield, Best, *et al.*, 2000; Isaaks & Srivastava, 1989) or model-based geostatistics (Tatem, Gething, Pezzulo, *et al.*, 2013; Tatem, Campbell, Guerra-Arias, *et al.*, 2014; Gething, Atkinson, Noor, *et al.*, 2007; Noor, Amin, Gething, *et al.*, 2006) are used. Pixel-based is not as common as polygon-based methods, but it is being used more due to advances in computing technology that allow more advanced and computer-intensive mapping and statistical techniques. This approach would be useful to map the spatial variation of indicators in more detail across a programme area.

2.2.3 Hybrid Methods

The last category of methods is a combination of polygon- and pixel-based approaches to mapping. Again, as the name implies, this is a mixed approach utilising polygon- and pixel-based techniques into an overall model-based geo-statistical mapping approach (Gething, Noor, Gikandi, *et al.*, 2008; Gething, Johnson, Frempong-Ainguah, *et al.*, 2012; Tatem, Campbell, Guerra-Arias, *et al.*, 2014). The advantages of the mixed approach is that the model can utilise mixed sources of data that are either representative of a polygon or of a pixel or point within an area. Because a wider set of pre-existing data can be utilised, the precision of results

is greatly improved, refining the mapping that is produced. Where more specific targeting of an intervention is required, this type of precision mapping would be a useful tool.[4]

2.3 Data Requirements by Method

Based on the methods review, a table of data requirements by spatial analysis type was created and can be found in Table 2.

Of the three methods, the polygon-based approach using small area estimation seems the most accessible given that it generally requires data that is most likely already available, such as a nationally representative survey and a corresponding census survey. Most countries will have such data.

Pixel-based and hybrid mapping methods on the other hand require numerous other ancillary geospatial data that may or may not be readily available. These include topographic maps of the country, land use and land cover maps, road network maps, and other similar or related type of data.

Table 2 was used to inform the selection of an initial list of 15 countries that would be likely to have most of these data available. This list was then shortened to a list of 4 countries namely Zambia, Tanzania, Ghana and Yemen.

[4] The level of effort required for the application of spatial mapping methods varies according to the method chosen, area size, data availability, and staff and computational capacity. Apart from the data requirement by method analysis presented in Table 2 and the data availability analysis for Ghana, Tanzania and Yemen presented in Table 3, 4, and 5, respectively, it is beyond the scope of this report to provide an in depth analysis of the resources needed to implement spatial mapping. It should, however, be noted that once the code for a map is scripted, it can be applied to wide range of contexts, provided that data is structured in a suitable format.

Table 2: Reportable indicators and data requirements by spatial analysis technique

Method type	**Analytical technique**	**Indicator/s**	**Data requirements**
Polygon-based	Indirect estimation using small area estimation by census enumeration areas (choropleth mapping)	Undernutrition prevalence Stunting prevalence Wasting prevalence Underweight prevalence Undernutrition co-variates WASH indicators EPI coverage indicators IYCF indicators Maternal nutrition Health-seeking behaviour indicators	Household surveys with anthropometric data and co-variates locatable geographically by census enumeration areas Population data by census enumeration areas Vector data of boundaries by enumeration areas
	Indirect estimation using small area estimation by land-use zones, agro-ecological zones, livelihood zones (dasymetric mapping)	Undernutrition prevalence Stunting prevalence Wasting prevalence Underweight prevalence Undernutrition co-variates WASH indicators EPI coverage indicators IYCF indicators Maternal nutrition Health-seeking behaviour indicators	Household surveys with anthropometric data and co-variates locatable geographically by identified zones (e.g., land-use, agro-ecological, livelihood zones) Vector or raster data of identified zones
	Direct estimation using results of small area surveys by small administrative units at level 3 or 4 (choropleth mapping)	Undernutrition prevalence Stunting prevalence Wasting prevalence Underweight prevalence Undernutrition co-variates WASH indicators EPI coverage indicators IYCF indicators Maternal nutrition Health-seeking behaviour indicators	Small-scale household surveys with anthropometric and co-variates data locatable geographically by smaller administrative sub-units (level 3 or 4) Vector or raster data of administrative level 3 or 4

Method type	Analytical technique	Indicator/s	Data requirements
Pixel-based	Spatial point pattern analysis by small area or wide area	Undernutrition prevalence Stunting prevalence Wasting prevalence Underweight prevalence Undernutrition co-variates WASH indicators EPI coverage indicators IYCF indicators Maternal nutrition Health-seeking behaviour indicators Notes: Analysis of spatial variation / distribution / clustering of undernutrition prevalence 'Point-source' analysis of undernutrition prevalence distribution by co-variates	Household surveys with anthropometric data and co-variates locatable geographically by longitude and latitude coordinates Nutrition intervention / services / clinics data with information on type of services provided and locatable geographically by longitude and latitude coordinates Vector or raster data of boundaries of administrative units
	Spatial interpolation	Undernutrition prevalence Stunting prevalence Wasting prevalence Underweight prevalence Undernutrition co-variates WASH indicators EPI coverage indicators IYCF indicators Maternal nutrition Health-seeking behaviour indicators Notes: Undernutrition prevalence surface analysis Co-variates surface analysis Co-location of services and indicators surface analysis	Household surveys with anthropometric data and co-variates locatable geographically by longitude and latitude coordinates Nutrition intervention / services / clinics data with information on type of services provided and locatable geographically by longitude and latitude coordinates Vector or raster data of boundaries of administrative units

Method type	Analytical technique	Indicator/s	Data requirements
Hybrid polygon- and pixel-based	Spatiotemporal modelling	Undernutrition prevalence Stunting prevalence Wasting prevalence Underweight prevalence Undernutrition co-variates WASH indicators EPI coverage indicators IYCF indicators Maternal nutrition Health-seeking behaviour indicators Socio-economic co-variates Poverty measures Socio-economic indicators to proxy travel mode and travel times Notes: Analysis of access to nutrition intervention centres / clinics / sites by travel time Analysis of health service use Analysis of co-location of services and indicators surface	Household surveys with anthropometric data and co-variates locatable geographically by longitude and latitude coordinates Nutrition intervention / services / clinics data with information on type of services provided and locatable geographically by longitude and latitude coordinates Population data by grids Vector or raster data of boundaries of administrative units Vector or raster data of cost-surfaces Vector or raster data of topography (i.e., roads, rivers, elevation)

2.4 Available datasets for Phase 2 selected countries

With the focus countries decided, a specific search for secondary data for each selected country was performed. Table 3, Table 4, Table 5 and Table 6 present the data available for Ghana, Tanzania, Yemen and Zambia respectively based on the in-country data review.

In general, the yield of available data for spatial mapping was quite comprehensive. Survey data from nationally representative surveys was readily available for all countries except for Yemen. However, in Yemen a DHS survey has just finished and GPS coordinates are potentially available. Acquiring this data will only be a matter of confirming access with current survey stakeholders in the country. This is in process.
Census data is also available for all countries except for Yemen as feedback / response from the census office is still pending.

As for boundary data, all countries have available boundary vector files for their different administrative units. All countries (except Yemen) have boundary files that are related to their most recent census. From this most basic set of data, we are confident that a polygon-based, small area estimation approach, similar to approaches used by Simler in Tanzania ((Simler, 2006) for undernutrition indicators and by Pullan and colleagues (Pullan, Freeman, Gething, *et al.*, 2014) for WASH indicators, can be used to map IYCF and feeding behaviour indicators as well as other health and health-related indicators (e.g., EPI coverage, prevalence of illnesses).

In terms of data on location of programmes and interventions, the approach used for the data review was to gather ancillary data that will allow us to geo-reference any data that can be made available. These ancillary data include a list of all (or almost all) villages and towns in a country with their GPS locations. We were able to obtain this data for all four focus countries. This list will allow us to geo-locate down to the level of the villages and towns the different projects or interventions that organisations have provided in the country. This is a backup approach should there be no currently existing data or list that provides such information, or if a list is found that only specifies areas by name but not by specific coordinates on a map. At present, no lists that specify interventions by the area where they have been delivered have been identified.

There is current “mapping” work similar to the 3W / 4W mapping of OCHA being conducted by UN REACH in Tanzania and Ghana. We have contacted them to explore the possibility of obtaining access to the results of this mapping once completed. An alternative approach is to ask DFID country offices to provide rough lists, reports or databases of projects they have supported over time, and, if necessary, manually collect the information on locations of interventions and geo-reference them. The DFID country office in Kenya has indicated a possibility that their existing database of projects can be queried to provide this list automatically. These options can be explored.

There is also an existing online database on aid called AidData (http://aiddata.org) supported by various funders such as the World Bank. This database currently holds geo-referenced data on the location of interventions and programmes funded by the World Bank. They also maintain a much larger database that contains all the projects supported by the various funders in almost all countries; however, this data is not geo-referenced and most of the locations are only up to the country level, which will not be useful for this exercise.

As for the other mapping methods, we will most likely be able to try the model-based approaches to mapping as the ancillary data that will help produce these maps are readily available for all countries. This will enable a direct comparison of the utility of the different mapping methods and their relative precision. We have begun to programme the analytic scripts for this model-based approach using approaches found in our methods review {Gething:2007kg, Gething:2008dy, Gething:2004jx, Gething:2012dm, Patil:2011cr}. Pending that Phase 2 of this project will go forward, we will trial these with one country data. This model-based approach will most likely be important for the prevalence of severe acute malnutrition map as we expect relatively small levels of SAM in the countries selected.

Table 3: Available datasets for Ghana

Data requirements	Data sources	Notes	Obtained?
Household surveys with anthropometric data and co-variates locatable geographically by longitude and latitude coordinates	Demographic and Health Surveys (DHS) datasets including GPS datasets (for some rounds) https://dhsprogram.com	DHS datasets for the year 1988, 1993, 1998, 2003, 2007 and 2008 available from DHS website Corresponding GPS datasets for some of the years	YES
	International Food Policy Research Institute (IFPRI) Household Panel Survey	IFPRI Household Panel Survey 2001 and 2004 Datasets can be geo-referenced	YES
	Multiple Indicators Cluster Survey (MICS) http://data.unicef.org	MICS datasets for the year 2006 and 2011 Datasets can be potentially geo-referenced	YES
	World Health Survey http://www.who.int/healthinfo/survey/en/	WHS dataset for 2003 Dataset has longitude and latitude coordinates	YES
Population data	2010 Population and Housing Census Ghana Statistical Service (GSS) http://www.statsghana.gov.gh	The 2010 Population and Housing Census from the GSS is available on request Requested and will be received soon	TBC
	WorldPop http://www.worldpop.org.uk	Provides estimates of numbers of people per grid square (of 100m from equator spatial resolution) Provides 2010 estimates of number of live births per grid square (of 100m from equator spatial resolution) Provides 2010 estimates of number of pregnancies per grid square (of 100m from equator spatial resolution) 2010 estimates of proportion of people per grid square living in poverty, as defined by the Multidimensional Poverty Index (http://www.ophi.org.uk/policy/multidimensional-poverty-index/), and $1.25 a day and $2 a day thresholds (of 1km from equator spatial resolution)	YES

Data requirements	Data sources	Notes	Obtained?
	WorldPop http://www.worldpop.org.uk	Provides raster files for each of the WorldPop population products described above (with population data geo-referenced accordingly)	YES
Boundary files (vector or raster files)	Global Administrative Areas (GADM) http://www.gadm.org	Vector files for Ghana boundaries available for download at GADM site Available boundary data files are dated and does not reflect recent changes at district level	YES
	Centre for Remote Sensing and Geographic Information Services (CERSGIS) – University of Ghana http://cersgis.org/home.html	Most updated vector files for Ghana up to district level most likely available from CERSGIS Request made and files to be received soon	TBC
Road networks	Global Roads Open Access Data Set (gROADS), v1 (1980–2010) http://sedac.ciesin.columbia.edu/data/set/groads-global-roads-open-access-v1	Global data set of roads between settlements using a consistent data model (UNSDI-T v.2) which is, to the extent possible, topologically integrated.	YES
	Digital Chart of the World (available at DIVA-GIS http://www.diva-gis.org)	Roads / road networks of Ghana	YES
	CERSGIS in collaboration with Ghana Ministry of Roads and Transport and funded by DFID	DFID supported Ghana Ministry of Roads and Transport and CERSGIS to map the feeder road network of Ghana Request made and files to be received soon	TBC
Inland water networks	Digital Chart of the World (available at DIVA-GIS http://www.diva-gis.org)	Rivers, canals, and lakes	YES
	CERSGIS http://cersgis.org/home.html	CERSGIS has been central in a detailed national programme of land surveillance carried out by the Water Research Institute, Department of Feeder Roads, Ghana Survey Department and the Forestry Commission of Ghana between 1995 and 2005 Requested and files to be received soon	TBC

Data requirements	Data sources	Notes	Obtained?
Topographic data – elevation	CGIAR Consortium for Spatial Information http://srtm.csi.cgiar.org	Shuttle Radar Topography Mission (SRTM) data to 250m resolutions for the entire globe (updated from previous NASA version)	YES
Topographic data – land cover	Global Land Cover 2000 http://bioval.jrc.ec.europa.eu/products/glc2000/legend.php	Land cover, original data resampled onto a 30 seconds grid	YES
Location of health clinics / health posts	Ministry of Health http://www.moh-ghana.org	Ministry of Health has a database of containing records of 2,021 health facilities of all type nationwide that include description of services offered and region, district and town which each facility was located.	YES
	Ministry of Health Ghana Health Service http://www.moh-ghana.org http://ghanahealthservice.org/healthstats.php	Ministry of Health also has a listing of health facilities by district available from their website Data downloaded and verified; have been geo-referenced already	YES
	CERSGIS	CERSGIS has a list of geo-referenced facilities that contain 1,915 facilities nationwide	YES
Location of nutrition interventions	Ministry of Health Ghana Health Service http://ghanahealthservice.org/index.php	Need to check with Ministry of Health and / or Ghana Health Service whether they have a listing / database of nutrition interventions with their locations throughout the country If this is not available, need to coordinate with Ministry of Health and / or Ghana Health Service in cross-checking the list on health clinics / health facilities above to verify if they include nutrition interventions / activities	ACTION
	UNICEF / NGOs / other nutrition and health stakeholders in Ghana	Need to check if an inventory of nutrition interventions (and their locations) is available or can be put together	ACTION

Table 4: Available data for Tanzania

Data requirements	Data sources	Notes	Obtained?
Household surveys with anthropometric data and co-variates locatable geographically by longitude and latitude coordinates	Demographic and Health Surveys (DHS) datasets including GPS datasets (for some rounds) https://dhsprogram.com	DHS datasets for the year 1999, 2003, 2004, 2007, 2010 and 2011 available from DHS website Corresponding GPS datasets for some of the years	YES
	Living Standards Measurements Survey (LSMS)	LSMS National Panel Survey for 2008 and 2010 from IFPRI website Datasets can be geo-referenced	YES
Population data	Population and Housing Census (PHC) of 2012 from the National Bureau of Statistics (NBS) http://www.nbs.go.tz	The PHC 2012 from the NBS provides population data down to the enumeration area level and is available from the NBS website	YES
	WorldPop http://www.worldpop.org.uk	Provides estimates of numbers of people per grid square (of 100m from equator spatial resolution) Provides 2010 estimates of number of live births per grid square (of 100m from equator spatial resolution) Provides 2010 estimates of number of pregnancies per grid square (of 100m from equator spatial resolution) 2010 estimates of proportion of people per grid square living in poverty, as defined by the Multidimensional Poverty Index (http://www.ophi.org.uk/policy/multidimensional-poverty-index/), and $1.25 a day and $2 a day thresholds (of 1km from equator spatial resolution)	YES
Boundary files (vector or raster files)	Population and Housing Census of 2012 from the National Bureau of Statistics (NBS) http://www.nbs.go.tz	The PHC 2012 utilised vector shape files down to enumeration area level (with population data geo-referenced accordingly)	YES
	WorldPop http://www.worldpop.org.uk	Provides raster files for each of the population products described above (with population data geo-referenced accordingly)	YES

Data requirements	Data sources	Notes	Obtained?
Road networks	Global Roads Open Access Data Set (gROADS), v1 (1980–2010) http://sedac.ciesin.columbia.edu/data/set/groads-global-roads-open-access-v1	Global data set of roads between settlements using a consistent data model (UNSDI-T v.2) which is, to the extent possible, topologically integrated.	YES
	Digital Chart of the World (available at DIVA-GIS http://www.diva-gis.org)	Roads / road networks of Tanzania	YES
	Tanzania National Roads Agency (TANROADS) http://www.tanroads.org	Listing of road networks in Tanzania available online and PDF versions of maps Requested from TANROADS vector or raster files for road networks and files received	YES
Inland water networks	Digital Chart of the World (available at DIVA-GIS http://www.diva-gis.org)	Rivers, canals, and lakes	YES
Topographic data – elevation	CGIAR Consortium for Spatial Information http://srtm.csi.cgiar.org	SRTM data to 250m resolutions for the entire globe (updated from previous NASA version)	YES
Topographic data – land cover	Global Land Cover 2000 http://bioval.jrc.ec.europa.eu/products/glc2000/legend.php	Land cover, original data resampled onto a 30 seconds grid	YES
Location of nutrition interventions	Tanzania Food and Nutrition Centre (TFNC) REACH	TFNC and REACH currently mapping nutrition interventions in Tanzania using a spreadsheet that collects location information that can be geo-referenced (potentially) Communication with TFNC and REACH made; coordination of data to be operationalised	TBC
Location of health clinics / health posts	Ministry of Health and Social Welfare (http://www.moh.go.tz) – online health facility registry at http://ehealth.go.tz/mfl	Registry contains type of health facility, services offered and location List with GPS coordinates obtained	YES
	Ministry of Health and Social Welfare eHealth and / or Health Management Information System (HMIS)	List accessed and data will be available for Phase 2	YES

Table 5: Available data for Yemen

Data requirements	Data sources	Notes	Obtained?
Household surveys with anthropometric data and co-variates locatable geographically by longitude and latitude coordinates	Demographic and Health Surveys (DHS) datasets https://dhsprogram.com	DHS datasets for the year 1991-92 available from DHS website but with no corresponding GPS datasets 1997 DHS dataset restricted 2013 DHS dataset not yet available but preliminary report available (unknown whether GPS dataset also taken)	TBC
	Multiple Indicator Cluster Survey (MICS) http://data.unicef.org	MICS dataset for 2006 available from website Can be geo-referenced	YES
Population data	Central Statistics Office (CSO) http://www.cso-yemen.org	Latest census 2003 (??) Need to contact CSO for population dataset	ACTION
	WorldPop http://www.worldpop.org.uk	Provides estimates of numbers of people per grid square (of 100m from equator spatial resolution) Provides 2010 estimates of number of live births per grid square (of 100m from equator spatial resolution) Provides 2010 estimates of number of pregnancies per grid square (of 100m from equator spatial resolution) 2010 estimates of proportion of people per grid square living in poverty, as defined by the Multidimensional Poverty Index (http://www.ophi.org.uk/policy/multidimensional-poverty-index/), and $1.25 a day and $2 a day thresholds (of 1km from equator spatial resolution)	YES

Data requirements	Data sources	Notes	Obtained?
Boundary files (vector or raster files)	Ministry of Planning and International Cooperation (MOPIC) and Yemen Food Security Committee and IFPRI on the digital atlas of food security in Yemen http://www.ifpri.org/publication/digital-food-security-atlas-yemen	MOPIC and Yemen Food Security Committee in partnership with IFPRI created a digital atlas of food security in Yemen which would have involved using boundary files for the maps IFPRI contacted and request made for boundary files (and other relevant data) Boundary files obtained	YES
	WorldPop http://www.worldpop.org.uk	Provides raster files for each of the population products described above (with population data geo-referenced accordingly)	YES
Road networks	Global Roads Open Access Data Set (gROADS), v1 (1980–2010) http://sedac.ciesin.columbia.edu/data/set/groads-global-roads-open-access-v1	Global data set of roads between settlements using a consistent data model (UNSDI-T v.2) which is, to the extent possible, topologically integrated.	YES
	Digital Chart of the World (available at DIVA-GIS http://www.diva-gis.org)	Roads / road networks of Yemen	YES
Inland water networks	Digital Chart of the World (available at DIVA-GIS http://www.diva-gis.org)	Rivers, canals, and lakes	YES
Topographic data – elevation	CGIAR Consortium for Spatial Information http://srtm.csi.cgiar.org	SRTM data to 250m resolutions for the entire globe (updated from previous NASA version)	YES
Topographic data – land cover	Global Land Cover 2000 http://bioval.jrc.ec.europa.eu/products/glc2000/legend.php	Land cover, original data resampled onto a 30 seconds grid	YES
Location of nutrition interventions	??	Need to find best contact organisation to locate data on nutrition interventions	ACTION

Data requirements	Data sources	Notes	Obtained?
Location of health clinics / health posts	Ministry of Public Health and Population (MOPP) Health Facility Survey http://www.mophp-ye.org/english/survey_healthfacility.html	The 2004-2005 Health Facility Survey is the first survey of all health facilities in the five USAID-supported governorates - Amran, Al Jawf, Marib, Sadah and Shabwah - since the Yemen Health Facility Survey was conducted in 1998. The survey, supported by USAID/Yemen through the Partners for Health Reformplus Project, inventoried all private and public health facilities in each district and included the use of handheld global positioning system (GPS) units to pinpoint the exact geographic locations of villages and health facilities. Data available online and retrieved	YES

Table 6: Available data for Zambia

Data requirements	Data sources	Notes	Obtained?
Household surveys with anthropometric data and co-variates locatable geographically by longitude and latitude coordinates	Demographic and Health Surveys (DHS) datasets including GPS datasets (for some rounds) https://dhsprogram.com	DHS datasets for the year 1992, 1996, 2001-2002, 2005 and 2007 available from DHS website Corresponding GPS datasets only for DHS 2007	YES
	Multiple Indicators Cluster Survey (MICS) http://data.unicef.org	MICS datasets for the year 2000 Datasets can be potentially geo-referenced	YES
	World Health Survey http://www.who.int/healthinfo/survey/en/	WHS dataset for 2003 Dataset has longitude and latitude coordinates	YES
Population data	2010 Population and Housing Census Central Statistics Office http://www.zamstats.gov.zm/nada/index.php/catalog/63	The 2010 Population and Housing Census from the CSO is available from website	YES
	WorldPop http://www.worldpop.org.uk	Provides estimates of numbers of people per grid square (of 100m from equator spatial resolution) Provides 2010 estimates of number of live births per grid square (of 100m from equator spatial resolution) Provides 2010 estimates of number of pregnancies per grid square (of 100m from equator spatial resolution) 2010 estimates of proportion of people per grid square living in poverty, as defined by the Multidimensional Poverty Index (http://www.ophi.org.uk/policy/multidimensional-poverty-index/), and $1.25 a day and $2 a day thresholds (of 1km from equator spatial resolution)	YES

Data requirements	Data sources	Notes	Obtained?
Boundary files (vector or raster files)	Global Administrative Areas (GADM) http://www.gadm.org	Vector files for Zambia boundaries available for download at GADM site Available boundary data files are dated and does not reflect recent changes at district level	YES
	WorldPop http://www.worldpop.org.uk	Provides raster files for each of the population products described above (with population data geo-referenced accordingly)	YES
Road networks	Global Roads Open Access Data Set (gROADS), v1 (1980 – 2010) http://sedac.ciesin.columbia.edu/data/set/groads-global-roads-open-access-v1	Global data set of roads between settlements using a consistent data model (UNSDI-T v.2) which is, to the extent possible, topologically integrated.	YES
	Digital Chart of the World (available at DIVA-GIS http://www.diva-gis.org)	Roads / road networks of Zambia	YES
Inland water networks	Digital Chart of the World (available at DIVA-GIS http://www.diva-gis.org)	Rivers, canals, and lakes	YES
Topographic data – elevation	CGIAR Consortium for Spatial Information http://srtm.csi.cgiar.org	SRTM data to 250m resolutions for the entire globe (updated from previous NASA version)	YES
Topographic data – land cover	Global Land Cover 2000 http://bioval.jrc.ec.europa.eu/products/glc2000/legend.php	Land cover, original data resampled onto a 30 seconds grid	YES
Location of health clinics / health posts	Ministry of Health http://www.moh-ghana.org	Ministry of Health has a list of health facilities by district available online http://www.moh.gov.zm/docs/facilities.pdf	YES
Location of nutrition interventions	Ministry of Health	List obtained from MoH	YES
	UNICEF / NGOs / other nutrition and health stakeholders in Zambia	There is an existing list available. However it does not have enough information to geo-reference at much finer resolution (i.e., district level)	ACTION

Chapter 3: Synthesis and Recommendations

This review has highlighted how the work on spatial mapping on health and nutrition in particular has been an on-going process for a significantly long period of time. Recent advances in mapping-related technologies have greatly spurred this work and have given it prominence and also generated much greater interest. More and more institutions and organisations are adopting spatially orientated approaches to programme planning and implementation and to data collection that informs their programme monitoring and evaluation. This growth will most likely continue and contribute to a considerable amount of useful data that can be presented as maps, thus serving to generate and promote coherent geographical and programmatic actions between actors planning and implementing nutrition specific and nutrition sensitive strategies.

However, despite this long history and the current rate of uptake, it is interesting how the dominance of the highly aggregated results from traditional nationally representative surveys still persists and continues to be the bedrock of planning and resource allocation for health and nutrition and related programmes. This is made evident by the high-profile attention given to the attainment of the Millennium Development Goals (MDGs), which monitor progress at country level and compares inter-country achievements, but without any clear or direct language that talks about within-country variation or disparities and any related achievement regarding this (i.e., equal or even spatial distribution of success of MDGs within country). The same can be said about the Scaling Up Nutrition (SUN) movement, where the focus and importance is given at country level, without clearly stated goals regarding within-country spatial variances and disparities.

Preoccupation with aggregated results is likely to be the single most important reason why, despite the growth of interest and capacity in spatial mapping, it has remained a peripheral or side issue. To some extent it also explains why spatial mapping is regarded merely as a topic of interest or curiosity rather than a useful tool for assessing country achievements on health and nutrition equity within the country. The technological shift that is happening in terms of mapping needs to be matched by a corresponding paradigm shift in the assessment of health and nutrition achievements within a country that gives as much importance to spatial homogeneity of results as to national aggregates. If such a paradigm shift does not materialise and is not actively advocated by leading development actors, it is very likely that spatial mapping will continue to be considered a novelty method rather than a standard part of routine programme planning and implementation and routine monitoring and evaluation.

Spatial analysis can effectively cut across the discrete boundaries of different interventions and indicate overlap and need over the geographical area of a whole programme. It also enables the mapping of multiple indicators relevant to nutrition programming influenced by nutrition sensitive as well as nutrition specific strategies. Used effectively, and with the proactive engagement of politicians and practitioners, it provides a tool to facilitate cross-sector planning, implementation and monitoring of actions to tackle undernutrition on a wide scale, also at the local level, indicating where and how interventions are truly needed. There is therefore a critical role for this project to emphasise the value and the need to use spatial mapping in the programme management cycle, and to give examples of how this can be achieved using the outputs of the mapping exercise that Phase 2 can provide.

3.1 Recommendations

Based on the results of the literature and data review, we make the following conclusions and recommendations:

Ensure coordination on mapping work with already existing mapping initiatives in each of the focus countries

Existing mapping initiatives in the focus countries include REACH work in Tanzania and Ghana; information portals on mapping of nutrition and nutrition-sensitive indicators in Yemen (ArabSpatial – http://arabspatial.org) and Ghana (mapping portal on agriculture and mapping of health services); and global efforts by AidData to map aid. Centres like the KEMRI-Wellcome Trust in Kenya, which is conducting spatial mapping of nutrition, are strong partners that should be considered for further support under DFID's efforts on spatial mapping (either within this project or for future engagements). The interest and the capacity seem to be readily available, and having multiple actors across different countries able to focus on spatial mapping efforts contributes to pushing forward the spatial mapping agenda.

Moving forward with Phase 2 of this project is feasible and recommended; however, Phase 2 must take into account existing spatial mapping efforts

There is enough data available for each of the four countries selected to proceed with Phase 2.
The minimum mapping products that can be expected if Phase 2 proceeds are prevalence and coverage maps of nutrition and nutrition-sensitive programming that use small area estimation techniques and are able to map results down to possibly the 3rd administrative level of each of the countries. Model-based mapping methods will most likely be producible as well. Whilst there is still data that needs to be collected to enable spatial mapping to show co-location of interventions, this can be facilitated by a similar survey approach to that undertaken by REACH, using a template matrix for organisations within the country to fill in the required information. This can be done in the first few weeks of Phase 2 while the analytic scripts for the mapping process are being developed, and while existing data are being cleaned and prepared for mapping.

However, the decision on how to proceed with Phase 2 may be influenced by DFID's estimation of already existing mapping capacities within each focus country, i.e. if resources will be better used if invested in groups that are already in the midst of spatial mapping work rather than in the initiation of new spatial mapping projects. In Ghana for example, DFID has already provided considerable support to the country's mapping capabilities over the years through CERSGIS; and at the same time, other funders (i.e. USAID) and organisations are pushing for spatial mapping. In the other focus countries, however, the implementation of Phase 2 as envisioned in the current project proposal, will most likely be beneficial to illustrate to stakeholders the feasibility of spatial mapping and the different types of products it can generate to be used to guide planning and programme implementation.

Data collection for routine programme monitoring and for surveys should be required to include or specify location names (such as village or town names)

Given the wealth of geo-location data currently available, being able to geo-reference regular monitoring data or routine surveys at local level is not that difficult to implement. For programmes, it would always be advisable that catchment areas are clearly specified with respect to the villages covered, and reporting should identify the specifics of outputs and outcomes at this level. This information can then easily be geo-referenced using a master list of villages that have coordinate locations on a map. Such a mechanism will not require GPS devices to be used, but will ensure a spatial orientation by programme managers as they are being asked to "locate" their work in their data collection and reporting. The gender disaggregation efforts of the past years have demonstrated that generating such programmatic change may not be a simple task. However, if consistently pursued over time and advocated, particularly by funding agencies such as DFID, we will be able to secure a database of information that has the potential to be mapped and will prove invaluable for committed actors to ensure effective and coherent nutrition programming.

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Annex 1: ToR: Spatial Mapping of Nutrition Programing

Terms of Reference:
Spatial Mapping of Nutrition Programming

Objectives and scope of work

The overall objective of this piece of work is to help DFID (and others) to better understand if and how spatial analysis can help to coordinate and co-locate nutrition relevant programmes.

The assignment involves working with DFID country offices and SUN donor convenors in 2-4 countries or areas within countries, to conduct spatial analysis of nutrition relevant programming (including both nutrition specific and nutrition sensitive interventions), developing 'heat maps' to show variations in programme intensity which can then be overlaid against available spatial data on malnutrition.

Key research questions:

1. Background:

- What examples (in published or 'grey' literature exist) of where spatial mapping techniques have been applied to nutrition programme planning or evaluation (eg Valid Nutrition S3M work)? What was the aim of these initiatives? What are the key lessons from the experience of applying these techniques to nutrition to date? What other approaches have been used to deliberately support geographical coherence of nutrition programming?

2. Data availability:

- To what extent is spatial data on nutrition specific and nutrition sensitive **programming** available in the areas selected? With what level of granularity is this information available?
- To what extent is spatial data on undernutrition (stunting and wasting) prevalence available?
- What relevant spatial data sets are available which map immediate or underlying determinants of undernutrition?

3. Spatial analysis:

- To what extent do (i) DFID supported, (ii) other donor supported, and (iii) non-donor supported nutrition specific and nutrition sensitive programmes overlap:
    a. With each other?
    b. With available data on immediate or underlying determinants of undernutrition?
    c. With measured undernutrition prevalence?

4. 'So what?' – policy relevance

- What opportunities do the above suggest for DFID and other development partners to better support reductions in undernutrition? To include:
    a. Where co-location occurs, what has supported or facilitated this happening?
    b. Where programmes are not co-located, what has made this less likely?
    c. What data gaps limit the value of these sorts of analyses? What data standards could be adopted by key stakeholders to allow more effective cross-programme coordination and colocation?

Background

Sustained reductions in undernutrition require cross-sector action. We currently have limited data on how DFID and others' investments in tackling undernutrition overlap spatially, yet the extent of such overlap is likely to be a major determinant of impact, as synergies are likely between programmes. In addition, malnutrition prevalence data is often only available at regional or district levels of specificity. Similarly, data on causes of malnutrition is rarely accurately mapped.

This work is divided into phases, starting with an initial feasibility analysis and assessment of data availability. If sufficient data are available, more detailed analyses and development of 'heat maps' of intervention intensity and accuracy of programme targeting will be developed, and implications drawn.

It is envisaged that the work will be developed in partnership with a number of DFID country offices, who will be responsible for helping with introductions to data holders/implementing partners, and with DFID Policy Division nutrition team who will coordinate the overall consultancy.

Anticipated methods / phases of work

The project will be divided into discrete phases; work on subsequent phases will only commence after review of the previous phase.

Phase 1: Feasibility analysis and assessment of data availability

- Inception meeting with consultants to clarify assignment + deliverables
- Short literature review to answer research question 1 above.
- DFID HQ to identify 3-4 countries where the DFID office is keen to support the project + to introduce them to consultants
- Consultants to liaise with country office contacts regarding sources of spatial data for DFID funded programmes and holders of (open access) spatial data on malnutrition prevalence and determinants
- Consultants to produce a report with recommendations including:
    a. Whether subsequent phases of work can be completed given the data available for each country,
    b. If not, what actions/future data needs to be collected at country level within programmes?
    c. An updated budget/plan for completion of the next phase of work.

NB: it is envisaged that this phase of work will be completed without travel to the countries identified, and will be rely on email/phone/VC communication.

Phase 2: Detailed country level analysis + synthesis

- Data collection and spatial analysis for each country to be conducted, focusing on the research questions above.
- Synthesis report to be developed, identifying lessons between and across countries examined.
- Above to be presented initially to DFID HQ, potentially with country focused presentations in addition.

Target Audience(s)

The key target audiences are initially DFID HQ and DFID country offices.

Timeline

Activity	Date
Contracting/appointment of team	On or about mid-June 2014
Phase 1	By end July 2014
Decision by DFID whether to continue	By end July/early September 2014

Completion of Phase 2	By end September/early October 2014
Presentation of results to DFID	October 2014

Reporting

The team will report to Rob Hughes in the DFID Policy Division Nutrition team.

Anticipated team/skills required

It is presumed that the work will be completed by a team with the following skills/experience:

- Expertise and familiarity with evidence-based multi-sectoral strategies for addressing **undernutrition**
- **GIS mapping and spatial analysis,** ideally with experience mapping malnutrition prevalence and determinants of undernutrition