Drivers of persistent high rates of undernutrition in the Sahel – a comprehensive contextualized research study

NRF Research Study Fiche

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NUTRITION RESEARCH FACILITY
Knowledge and Research for Nutrition

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The Knowledge and Research for Nutrition project of the European Commission (2020-2024) aims to provide improved knowledge and evidence for policy and programme design, management and monitoring & evaluation in order to reach better nutrition outcomes.

The project is implemented by Agrinatura - the European Alliance on Agricultural Knowledge for Development – which has established a Nutrition Research Facility, pooling expertise from European academia and having the ability to mobilise internationally renowned scientific networks and research organisations from partner countries.

The Nutrition Research Facility provides expert advice to the European Commission and to the European Union (EU) Member States and Partner Countries.

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List of Acronyms

Acronym	Description
AI	Artificial Intelligence
BMI	Body Mass Index
C4N	Capacity for Nutrition
CRIS	Common External Relations Information System
COVID-19	Coronavirus Disease 2019
EU	European Union
FNSSA	Food and Nutrition Security and Sustainable Agriculture
INTPA/D4	European Commission Directorate General for International Partnerships, Unit D4
INTPA/F3	European Commission Directorate General for International Partnerships, Unit F3
LMICs	Low- and Middle-Income Countries
ML	Machine Learning
NRF	Nutrition Research Facility
RS	Research Study
SDGs	Sustainable Development Goals
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organisation

Content

Glossary

Term	Description
Undernutrition	This term is used to describe wasting, stunting and deficiencies in vitamins and minerals (micronutrient deficiencies).
Immediate causes of undernutrition[1]	This term is used to refer to the inadequate dietary intake and infection.
Basic and underlying causes of undernutrition[1]	This term is used to refer to interacting causes of undernutrition such as: i) inadequate access to food and or/poor use of available food; ii) inadequate childcare practices; and iii) poor water and sanitation and inadequate health services. It encompasses causes related to political, economic, cultural and religious systems and to institutional governance structures.
Systemic/structural causes of undernutrition[2]	This term was described in the context of acute undernutrition and refers to an additional level of causes such as environment, seasonality, livelihoods and gender.
Artificial Intelligence (AI)[3]	This term is used to refer to the development of computational techniques that can perform tasks simulating human intelligence and behaviour to solve practical problems
Machine Learning (ML)[4]	This term is used to refer to one type of AI. Machine Learning algorithms allow machines to learn by example or experience from historical data to uncover patterns and/or predict trends. Machine Learning algorithms are categorised as supervised learning, unsupervised learning, and reinforcement learning.

[1] Firstly described in UNICEF, Nutrition in the Nineties (1992). UNICEF, New York.

[2] Young, Helen. Nutrition in Africa's drylands: A conceptual framework for addressing acute malnutrition. Boston: Feinstein International Center, Tufts University.

[3] Goodfellow I, Bengio Y, and Courville (2016). *Deep Learning*. Cambridge, MA, USA: MIT Press; Openshaw S and Openshaw C. (1997). Artificial Intelligence in Geography. 1st ed. USA: John Wiley & Sons, Inc.

[4] Graves A (2012). Sequence transduction with recurrent neural networks. arXiv:1211.3711; Sathya R and Abraham A (2013). Comparison of supervised and unsupervised learning algorithms for pattern classification. International Journal of Advanced Research in Artificial Intelligence 2: 34-38.

Rationale

This Research Study aims to produce evidence to assist decision-makers in addressing the problem of persistent undernutrition in several areas of Sahelian countries, despite the significant concentration of regular and sustained nutrition programming supported by national governments and international humanitarian agencies.

Persistent undernutrition such as wasting and stunting in children under-five, or anaemia in women of reproductive age, has been consistently observed in the Sahel, despite substantial and sustained concentration of investments[5] for intervention . North Burkina Faso and Niger[6], are examples of such areas where, despite all efforts, undernutrition continues to be highly prevalent (illustrative short desk review provided in Annex I).

Success in nutrition programming is highly contextual at both country and intra-country levels in the Sahelian region. Even within the same area it varies seasonally and accompanies social dynamics, introducing additional complexity in determining the effectiveness of a given intervention programme. Particularly relevant are: i) the divide between urban and rural and between coastal and landlocked areas; ii) demographic dynamics (e.g. population growth); iii) the specific social-ecological environment; and iv) climate, seasonality, livelihoods and gender(Young 2020).

There is no silver-bullet approach and most nutrition programming per se often fails to deliver clear-cut benefits on the occurrence of undernutrition, which may be an issue of poorly informed programme . Some of the most relevant explanatory variables found in the literature include child age, birth interval, mother's educational status, mother's nutritional status, maternal occupation, place of residence, household conditions (source of drinking water and type of toilet facility), family size, number of children living in the household, birth-weight, duration of breastfeeding and timing of complementary feeding initiation (Masibo 2013; Akombi et al. 2017).. The failure in reducing undernutrition in some locations also prompts, thus, the need to address drivers explaining effectiveness not only of nutrition-specific, but also of nutrition-sensitive interventions, bridging other sectors beyond health, such as agriculture, education, water, sanitation and hygiene, and social protection, for example. This has also to do with "design" of the interventions. Environmental (both natural and socioeconomic) exposures are thought to contribute to stunting, but evidence regarding specific exposures remains inconclusive, although attesting to individual setting or country specificities and to the multifaceted nature of the associated risk factors (Masibo 2013; Akombi et al. 2017; AAS 2021).

Based on existing evidence, a high-level **Theory of Change of reducing persistence of malnutrition in the Sahel indicates that (see figure 1):**

- If contextual and structural drivers of malnutrition in specific contexts are known and addressed, and
- If association of such drivers with systemic, basic, underlying, and immediate causes of undernutrition is well understood, and
- If nutrition actions and investments are well designed, and

[5] The EU is one of the largest donors of humanitarian aid to countries of the Sahel and Lake Chad region to support their efforts to achieve peace, security and development. The European Union Emergency Trust Fund for stability and addressing root causes of irregular migration and displaced people in Africa (EUTF for Africa or EUTF) was launched in November 2015. Since then, and until September 2021, the EUTF has committed €2.21 billion to assist projects in the Sahel and Lake Chad region, in a total of 202 operational projects. Additional information available at: https://ec.europa.eu/trustfundforafrica/region/sahel-lake-chad_en

[6] These two settings were identified as highly relevant by policy makers during the consultation process (report on the consultation rounds for research questions formulation in year 1 – NRF Deliverable 1.6).

- If undermining effects of the contextual and structural drivers on implementation effectiveness of nutrition actions and investments are reduced,
- Then, national, and international programmes would be more effective in reducing persistence of malnutrition in the Sahelian context, and
- Then, reduced prevalence and incidence of malnutrition in the Sahel may materialize.

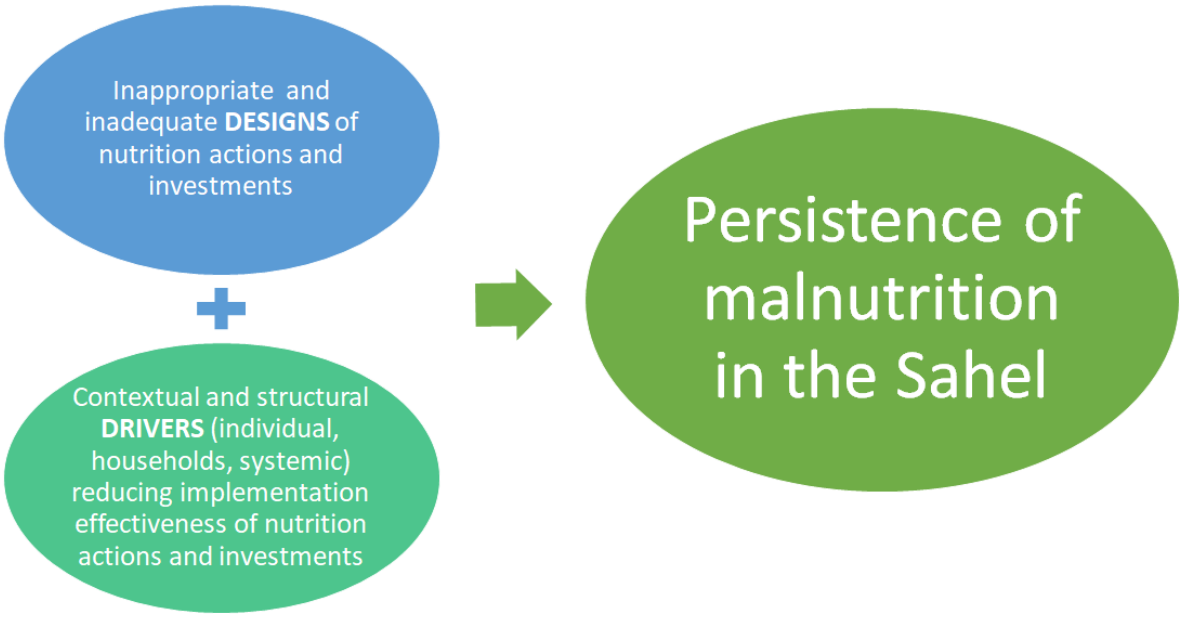


Figure 1. High level understanding of persistence of malnutrition in the Sahel[7]

The above proposition indicates the need for additional research that can generate evidence on both 'Designs' of nutrition actions and investments and 'Drivers' reducing the implementation effectiveness of actions and investments causing a persistence of malnutrition in the Sahel. Under this scenario, identifying contextual and structural/systemic drivers that affect the implementation effectiveness of nutritional programming is mandatory to complement the understanding of "a minimum package of essential nutrition actions" (as recognized since the 2008 Lancet series (Black et al. 2008)). To ensure the effectiveness of these actions, evidence on "what works, to what extent and why", is missing. The academic consensus illustrates that appropriate designs and effective implementation could be the key to reducing persistent undernutrition.

Therefore, this study will be complementary to the parallel NRF study: "*Assessing the design of nutrition interventions to better understand persistent malnutrition*", aimed at providing a contribution to understanding the design of such interventions and focusing specifically on the programme layout of intervention packages (including both nutrition-specific and -sensitive interventions). This synergy enables a connection of the "Why" and the "What" (this study) with the "How" of nutrition programming (the complementary study). In brief, with this Research Study, we aim at identifying the contextual drivers that may explain the effectiveness/efficiency of nutritional programming on reducing malnutrition, in order to gain insights on the structural circumstances under which interventions are set up and to determine their impact. The complementary study specifically addresses to what extent EU and non-EU programmes/project designs in the Sahel are offering a combined package of nutrition-sensitive and nutrition-specific interventions. Hence, the collective integration of the results from both studies has the potential to deliver

[7] Designs and Drivers are addressed in parallel, in two complementary NRF Research Studies.

evidence on the influence of contextual and structural drivers in the effectiveness of nutrition-related designs (the complementary study) and interventions (this study).

The studies should examine systemic/root causes of poor nutrition and health and illustrate the complex, multi-level causation of malnutrition in the Sahel building on the assumption that multidimensional, cross-sectoral interventions to sustain nutritional improvements over the long term are needed, together with increased political commitment and adequate funding. Several examples in Low- and Middle-Income Countries (LMICs) settings support this assumption (Annex II). Understanding the implementation effectiveness of nutrition interventions is even more challenging as these depend on political, economic, cultural, and religious systems, community ownership and institutional structures, which govern society, influence women's status, and control the availability of potential human, economic and organizational resources at the household level. Implementation effectiveness depends on interventions tackling both immediate and contextual and structural/systemic drivers, which represents the main focus of the proposed research.

Identifying the critical drivers explaining the persistence of undernutrition (or, in opposition, their decreased prevalence and incidence) is therefore essential for assessing the implementation effectiveness of interventions. There is consequently a large degree of uncertainty because the end-line conditions of the beneficiaries depend not only on the intervention, but on a myriad of external influences that are far beyond the scope of the programme and its managers' control (Coleman 1987). This dimension is even more important considering that the Development community faces new challenges of uncertain budgets and resource flows in the context of growing responsibility given to national actors, such as regional development banks and governments. The endurance of public interventions frequently depends on the political and ideological approaches of successive governments, exacerbating instability.

A comprehensive contextualized investigation of the drivers of malnutrition has been hard to promote, as research funding bodies frequently assume there is sufficient knowledge to design interventions that address the principal underlying causes of malnutrition, as illustrated by studies on acute malnutrition (Young 2020). Moreover, most of the existing studies employed generalized (mixed) linear models for statistical analysis. Despite being widely used for causal inference, these models present limitations such as the allowance of only a small number of covariates and the fact that they do not properly assess multicollinearity (Knol et al. 2008; Goldstein, Navar, and Carter 2017). Furthermore, many studies are limited to cross-sectional designs. To overcome some of these gaps, Machine Learning (ML) methods have recently been suggested to contribute informative data to the study of drivers of undernutrition at the country level and have been adopted, for example, in Ethiopia (Bitew, Sparks, and Nyarko 2021; Fenta, Zewotir, and Muluneh 2021) and Bangladesh(Mansur, Afiaz, and Hossain 2021). These approaches allow the use of a larger number of predictors/covariates, require fewer assumptions, incorporate "multi-dimensional correlations", and result in a more flexible relationship among the predictor and outcome variables (Knol et al. 2008; Goldstein, Navar, and Carter 2017; Adler et al. 2020). Nevertheless, so far, such studies are restricted to the intra-country or country-level scope, and mainly address stunting, overlooking other important indicators of child undernutrition such as wasting and micronutrient deficiencies.

The present Research Study aims at addressing these gaps, starting from a contextual broad analysis including literature and retrospective data (referring to several time-frames[8]) from countries in all Sub-Saharan regions to identify candidate explanatory drivers, being attentive to intra-regional variations and countries' experiences. Sensitivity analyses will be further conducted considering Sahel-specific data and literature. The use of ML methods will be of utmost relevance for providing a comprehensive longitudinal analysis of the drivers of undernutrition in the Sahel region, and allow comparison with other regions in SSA, with distinct social, economic, demographic and environmental characteristics. An additional innovation of

[8] Dependent on the quality of available data.

this study will be a focus on multiple undernutrition-related indicators as outcomes: stunting, wasting and micronutrient deficiencies. Selected main findings will be further explored and validated using case studies.

Scope

There are many different reasons behind the persistence of undernutrition, even in settings having received a concentration of support programmes for decades: programmes not well designed or implemented, not addressing the systemic, basic and underlying causes of undernutrition, dispersion of actions, series of external events (e.g. climate shocks or locust invasions), stunting not being the right nutrition outcome to target, etc. The problem has been analysed in multiple but fragmented streams, under traditional methods of statistical analysis. Linking these multiple standpoints into one comprehensive, contextualised and investigative approach will contribute to visualizing critical issues that may have been "falling into the cracks" of the segregated approaches. The aim of this research is to understand which drivers explain the lack of sustained effectiveness of nutrition programming. A focus will be made on the impact of the enabling socioecological and political environment on sustainability.

The underlying proposition is that nationally and development assistance supported policies and interventions related to tackling undernutrition, comprising not only initiatives targeting the health sector or the food system and agricultural sector, but all those which are implemented in a specific setting, have the potential to influence the nutritional status of the populations. The said influence depends on the specific socioecological context and enabling environment, including issues related to political commitment towards nutrition, financing mechanisms, accountability and alignment between national and development partners' priorities.

Research questions

This study will investigate the influence of contextual and structural/systemic drivers on reducing the "implementation effectiveness" of nutrition interventions in the Sahel. Specific questions are: Why does high prevalence and incidence of undernutrition (stunting, wasting, micronutrient deficiencies) persist in Sahelian countries, even when regularly supported by multiple nutrition programmes? What are the main drivers leading to this persistence of high prevalence and incidence? What are the contextual and structural/systemic drivers that are reducing the implementation effectiveness of nutrition interventions across the Sahel, explaining the abovementioned continued and high prevalence and incidence of undernutrition in that context?

Methodology

A stepwise methodological approach will be implemented to bridge the contextual political and socioeconomic characteristics and the natural environment of different settings in the Sahel, with long-term assistance regarding development and nutrition programming. In addition, it aims to explore critical drivers and why they might influence the impact achieved after the completion of development projects and programmes and the sustainability of the achieved results, i.e. implementation effectiveness. Two case-studies in the Sahelian region will be conducted for an in-depth confrontation of the hypothesis.

Study 1

Conduct a systematic literature review for assessing contextual and structural/systemic drivers that facilitate or hinder the "implementation effectiveness" of nutrition programming (targeting both immediate and contextual and structural/systemic drivers) in the Sahel, such as specific sociodemographic, economic, infrastructure, resources, political, cultural and social norms, characteristics and environments. Both scientific and grey literature will be analysed.

This study will take into account the "UNICEF conceptual framework of undernutrition" (first developed in 1990 and regularly updated (UNICEF 1990; 2020)) and adopted by the WHO (WHO 2008). Our review will be attentive to enhancing the framework dimensions with the systemic factors identified by (Young 2020) in the context of acute malnutrition – climate, seasonality, livelihoods and gender -, but also relevant to this study. All activities will be conducted by the NRF team. Upon completion of the literature review, the study will focus specifically on the nutrition programming of Sahelian countries.

Study 2

Identify drivers of effectiveness/efficiency in reducing undernutrition by looking at contextual indicators, **using non-linear methods based on Artificial Intelligence (AI) and ML**. Metadata summarizing the time-series and the scope of nutrition programming implemented at the country level will be used to categorise findings on the explanatory drivers.

Despite its relevance, understanding if and why projects and programmes contribute to broader development goals is often neglected due to limited validation of correlations between programme indicators and developmental indicators in a specific context. Evaluating the long-term impact and effectiveness of implementation of development projects is not straightforward. While achieving the planned outcomes, it may be challenging to achieve them in a way that ensures they remain sustainable beyond the end of the project, and even more complex to ensure articulation with co-existing initiatives. For this, understanding the social and natural context and drivers of change is mandatory.

Specifically, this study aims at delivering a set of potential explanatory drivers of the persistence of undernutrition, by analysing the contextual and structural conditions in which nutrition-related development projects take place in Sub-Saharan vulnerable settings[9], ultimately to understand their implementation effectiveness.

Machine learning training processes will be used to process quantitative and spatial data obtained through database research, raw metadata from INTPA/F3 databases, and programme portfolios from publicly available sources. Analyses of relevant linear and non-linear correlations between the selected variables and parameters will follow, aiming at identifying clusters of settings according to their profile and the behaviour of a set of interdependent variables. Considering examples from recent literature (Fenta, Zewotir, and Muluneh 2021; Bitew, Sparks, and Nyarko 2021), the analysis should encompass a variety of ML algorithms/models[10], and appropriate indicators should be used for evaluating them (*e.g.,* model performance, covariate selection and ranking covariate) and selecting one which best fits the study purposes. Data will include contextual indicators (demographic[11], social, political, economic, natural resources…), and relevant elements of nutrition-related programmes funded by the EU and other donors, namely the topic it aims at addressing and the regions and years covered[12]. Of particular relevance will be the addition of land cover and environmental data captured through satellite images[13], also allowing interpretation of seasonal dynamics.

[9] For this study it is mandatory to include data from a high number of Sub-Saharan Africa countries - expanding Sahelian countries - to identify patterns/clusters of non-linear relations that enable us to establish possible explanatory drivers of efficiency in development programming, including those specifically related to nutrition.

[10] Such as natural language processing/unsupervised neural networks and supervised neural networks.

[11] Population growth, for example, will be an essential demographic indicator. In contrast to the steady rates observed globally in Sub-Saharan Africa, countries in the Sahel (e.g Burkina Faso and Niger) have been facing rapid population growth in recent decades (available at: https://data.worldbank.org/indicator/SP.POP.GROW?locations=BF-NE-ZF). The analysis in this study will, on one hand, account for the different cross-country demographic patterns and, on the other, allow the interpretation of findings on the prevalence of undernutrition while adjusting for the effects of this driver in the denominator (total population).

[12] Narrative analyses will be conducted in the parallel study on "Design". Here, dedicated databases will be constructed using binary matrices (0 for absence and 1 for presence) to retrieve the scope of nutrition programming supported by the EC under implementation, along years and locations.

[13] Available through Copernicus services (available online at: https://www.copernicus.eu/en)

Data must be collected from multiple sources and integrated into a common geodatabase. Potential drivers will consist of indicators selected from three analytical frameworks (Organisation for Economic Co-operation and Development (OECD) 1996), (Scoones 1998) and (HLPE 2017), following the SDGs outline, the Food Systems Dashboard (Fanzo et al. 2020), (Abreu e Mesias 2020), (Bryden 2002) and the (Kageyama 2004) proposals. The main data sources in recent country-level ML-based approaches to study drivers of undernutrition with regards to both predictor and outcome variables, have been Demographic and Health Surveys[14], which will also constitute a main data source for this study. Additional data sources that may be used to retrieve information on specific drivers/predictors include, for example, the World Bank[15], FAOSTAT[16], WHO data collections[17], UNICEF data on "The State of the World's Children 2021"[18], the Global Nutrition Report[19], and/or data from nationally-representative surveys.

Due to the spatial data science expertise required for the activities of this study, which is outside the scope of the NRF team, Study 2 will be entirely subcontracted (see Project Management section).

Study 3

Use Case Study approaches to conduct qualitative longitudinal analyses based on interviews with actors which have the institutional memory of interventions that have been implemented, as well as with beneficiaries of these interventions at the community level in a pair of particular settings in the Sahelian region with persistent undernutrition (candidate case studies: North Burkina Faso and Niger[20]). Attention will be given to community participation in implementation as a factor for increasing the effectiveness of interventions in improving nutritional status, rather than solely assessments of cost-effectiveness. Use of the Actor-Network Theory and the Social-Ecological Model integrating individual and environmental factors, causal pathways, and potential mixed effects to target intervention strategies based on the environment, could be appropriate. However, since this study will be informed by findings delivered in Studies 1 and 2 (see "Project Management" section), the specific methodology will be reviewed at the beginning of the study.

Study 3 will benefit from both experienced knowledge of the specific conditions through networks of actors operating in situ, and promptness of accessing information from local/regional organisations and stakeholders. It will therefore be subcontracted (see "Project Management" section).

Stakeholder involvement

Stakeholder engagement is critical for obtaining quality and [near]-complete data and for validating findings with a contextualised perspective (Table 1). Of particular importance will also be access to specific data on EU nutrition programming, namely CRIS, the Nutrition Tracking Tool, the INTPA/F3 database on FNSSA and the annual results reports.

Local engagement will be mandatory to complete Study 3 (Case-Studies), including interviews, focus groups, or Actor-Network Theory. Engagement of all relevant stakeholders with a role in nutrition (*lato sensu*, to

[14] Available online at: https://dhsprogram.com/

[15] Available online at: https://data.worldbank.org/

[16] Available online at: https://www.fao.org/faostat/en/#home

[17] Available online at: https://www.who.int/data

[18] Available online at: https://data.unicef.org/resources/resource-type/datasets/

[19] Available online at: https://globalnutritionreport.org/resources/nutrition-profiles/

[20] These two settings were identified as highly relevant by decision-makers during the consultation process (report on the consultation rounds for research questions formulation in year 1 – NRF Deliverable 1.6). According to the project feasibility and human and financial efforts required, the number of case studies could be enhanced to include a comparative analysis of two groups of settings receiving high and regular nutrition support from national and international programmes - one with substantial nutrition improvement and another with a persisting high prevalence of malnutrition.

include all typologies of the framework policy) regarding policy, programming, monitoring and research is needed to achieve a comprehensive map of each context.

Table 1. Stakeholder involvement in the Research Study

Type of Stakeholder	Name of organisation	Strategic objective	Method of stakeholder involvement
International and national level stakeholders	Donors, international governmental and non-governmental organizations operating in selected countries	Study 3	Active provision of contextual data and nutrition programming related information through interviews, focus groups and elements from consultative meetings
International and national level stakeholders	EU Delegations in the selected countries	Studies 1 and 3	Active provision of contextual data and nutrition programming related information through interviews and elements from consultative meetings
International level stakeholders and donors	INTPA/F3	Studies 1 and 2	Active provision of data at nutrition programming level through database consultations and elements from consultative meetings
International level stakeholders	INTPA/D4	Studies 1 and 2	Active provision of data from thematic indicators through database consultations
International level stakeholders	C4N	Studies 1 and 3	Active provision of data at nutrition programming level and results discussion further to consultative meetings
International level stakeholders	NIPN and other NRF "sister" networks	Studies 1 and 3	Active provision of data at nutrition programming level and results discussion further to consultative meetings
Implementers of research	Nutrition experts and researchers	Study 3	Interviews, focus groups and roundtable discussions: quality assessment of progress and recommendations
Target groups of research	Beneficiaries and professionals involved in the implementation of nutrition programming interventions; policy makers	Study 3	Active participants in interviews, focus groups and roundtables

Communication strategy to maximize impact

A regular dialogue will be maintained with EU Delegations and regional and national actors and stakeholders to co-create useful knowledge and maximise adoption of the findings. The NRF will also interact closely with INTPA/F3 and C4N to share and discuss findings in a timely manner. The communication strategy foreseen is not based on a conventional "results transfer" principle but on co-research and co-dissemination.

Representatives of the relevant actors and stakeholders (at national, regional and global level) are expected to be involved in the co-development of evidence, thus increasing awareness in relevant organisations and ensuring ownership of the findings. The co-research activities will engage stakeholders and actors in data collection and by their participation in local workshops and a roundtable (involving the respective EU Delegations) to discuss the main findings and reinforce communication and dissemination amongst them. The research results will be communicated in suitable forms (e.g. Policy Briefs) for informed discussions with decision makers and other relevant actors participating in these events and for policy up-scaling. Further dissemination and deep scaling will include the publication of scientific papers and the organization of a webinar. On a regular basis, research results will be disseminated through the NRF webpage by direct communication, social media and participation in congresses and seminars, etc.

The overall dissemination approach will be:

- Publication of a comprehensive study report as a project deliverable
- Organization of a workshop with relevant partners and stakeholders to discuss the study results
- Publication of an article in a scientific journal based on the study report, if relevant
- Publication of a brief for decision-makers based on the study report, posted on the NRF document repository and advertised through relevant newsletters, emailing and social networks
- Participation in relevant events/conferences to share the results of the study

Project Management

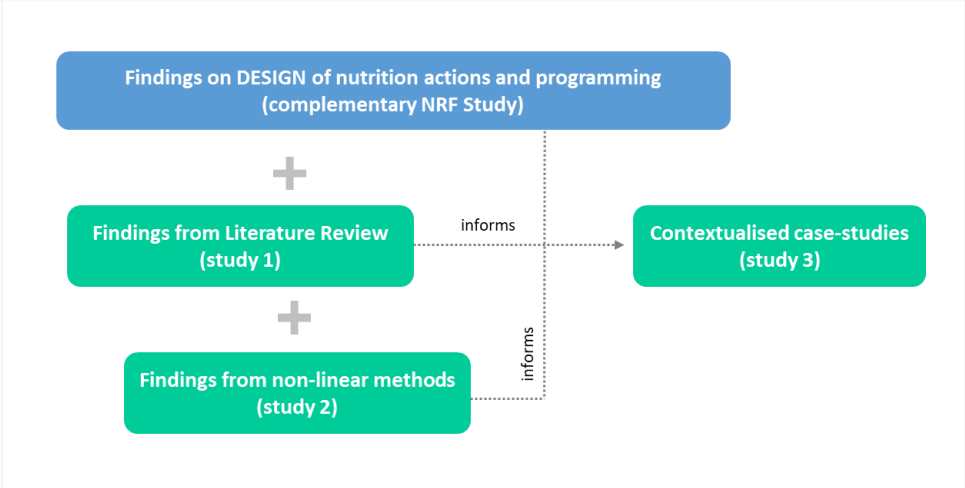
Organisation of work and time frame

The research study is expected to commence in March 2022 for a duration of 18 months. Details on the duration of Tasks/Activities and expected outputs are presented in the Gantt chart. All activities related to Study 1 will be conducted by the NRF team, and Studies 2 and 3 will be subcontracted, following a public procurement/call for proposals.

To assure the feasibility of Study 2, our ambition is to identify a comprehensive set of candidate explanatory drivers (Study 2 deliverable 6) and then select a subset of drivers (by integrating the results with relevant findings from Study 1 and from the complementary NRF Research Study on “Design”) to be further explored in detailed contextualised studies (Study 3). Study 2 is expected to begin while Study 1 is under implementation, given that no relevant information from the first study will be needed. Since Study 3 will be informed by findings from Study 1 and Study 2, it will start upon their completion. Relevant insights from the NRF “Design” Research Study will also be integrated (see Figure 2)and will be useful to refine certain methodological aspects.

Adjustments may include, for example, the selection and characteristics of participants to be interviewed and the structure and scope of the questions to address.

Figure 2. Representation of interlinkages between studies.



Study 2 will be subcontracted to a successful tenderer following public procurement or a call for proposals due to the spatial data science expertise required for the activities, which is outside the scope of the NRF team. The successful tenderer must demonstrate technical and professional capacity with demonstrated relevant professional experience, including a team of senior and junior level researchers/experts. The following essential skills and qualifications are needed:

i) Experience in conducting research projects targeting African countries
ii) Spatial data modeling and analysis;
iii) Building spatial databases;
iv) Machine learning and deep learning techniques;
v) Land cover change and satellite image classification;
vi) Skills in programming (preferably Python and R).

The proposed team leader is expected to have more than 10 years' professional experience related to the Study 2 methodology. Relevant team experience in linking data science with public policies and strategies is also required. The tenderer must hold team level proficiency in English and demonstrated experience in participating in international research. Applications from both global north and global south research institutes are welcomed.

Study 3 will be also subcontracted to institutions with demonstrated field experience in the selected countries, taking advantage of the NRF's partner network. The successful tenderer must demonstrate technical and professional capacity, notably concerning:

i) team expertise in a field related to food systems, nutrition, epidemiology, statistics as well as design and evaluation of public policies and strategies in development contexts, with demonstrated relevant professional experience, preferably in Sahelian countries;
ii) team expertise in qualitative/social science methods (e.g. interviews, focus groups, etc.);
iii) experience of collaboration with networks of partners in Sahelian countries;
iv) skills in local languages would be an advantage. Members of the NRF will participate in the roundtables and relevant discussions.

According to the NRF subcontracting mechanism[21], the NRF will follow a global price approach to subcontract the respective research study. The tendering process will be based on the subcontracting mechanism. The outcomes of the process, an evaluation report and decision upon the selected tenderer, along with the technical and financial proposals of any tenderers, will be submitted to INPTA/F3 for prior approval. Technical capacities will be further elaborated (if needed) in the procurement notice for the relevant subcontracting. The methods/ methodology considered in this fiche are not prescriptive on the process of developing the relevant proposal. The tenderers may consider further refining of the methodology, adequately explaining their approach in their application.

Table 1. Experts to be involved

Role in the study	Expert profile	Expected input	Resources
Research study coordinator (Principal investigator)	Senior – Luis Goulão	54.5	NRF core team
Research assistant (co-PI)	Junior – Gabriela Albuquerque	106	NRF core team
Stakeholder engagement	Senior – Arlene Alpha	9.5	NRF core team
Communication	Senior – Melanie Broin	6.5	NRF core team

Activity monitoring & Quality assurance

The research study coordinator is responsible for monitoring the overall activity as defined in the workplan and also for quality assurance of the expected deliverables. The team of experts together with the NRF management team will convene on a bi-monthly basis to review the progress of activity implementation and study deliverables. A short activity report will be provided by the RS coordinator to the NRF management team no later than 5 days before the team meeting (structured template to be provided).

All expected study deliverables will be reviewed by the RS coordinator and NRF Team Leader – Paolo Sarfatti. An external expert (with relevant experience in the field/topic) will be mobilised to review the preliminary findings of the study (in presentation format) and the draft final study report. The draft final version of study deliverables must be submitted to the NRF management team for review and recommendations (if needed) no later than 15 days before submission of the final version.

List of deliverables

The following table presents the expected deliverables for the present research study.

Table 2. Expected deliverables

No.	Deliverables	Short description	Month
1	Inception report	Short report on the approach, work plan and finalisation of the methodology	1
2	Manuscript for scientific journal publication (study 1)	Contextualised systematic literature review based on Study 1	7
3	Policy brief (study 1)	Summary of the research results and presentation of any key recommendations for decision makers	7
4	Geodatabase (Study 2)	Standardised geodatabase	7

[21] Submitted in the NRF Inception & 1st Progress report as Annex 7, and approved by INPTA/F3 as per the approval of the Inception & 1st Progress report.

5	Preliminary results (Study 2)	First snapshot of the spatial data analysis and a preliminary proposal of a set of explanatory drivers	8
6	Study 2 report	Evidence based final report with identification of the main drivers	10
7	Policy brief (study 2)	Summary of the research results and presentation of any key recommendations for decision makers	11
8	Report on the context-specific data analysis	Report summarising the findings of the analysis of reports from local and regional organizations as part of the case studies	14
9	Report on interviews conducted with local stakeholders	Report including transcripts translated into English from the interviews; focus groups with stakeholders and actors; narrative synthesis of harmonised data collected from the interviews/focus groups	15
10	Report on the roundtable with local stakeholders and actors	Report summarising the roundtable discussions with local stakeholders	16
11	Study 3 report	Synthesis and critical analysis of results, main findings and interpretation	17
12	Research dissemination workshop	Targeted event with key policy and programme participation in focus countries	17
13	Policy brief	Summary of the research study results and presentation of any key recommendations for decision makers	18
14	Final comprehensive research study report	Final report on the research study findings and key recommendations for stakeholders (synthesis of results from different case studies/ countries)	18

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Annexes

Annex I – Desk review: Burden of undernutrition in Sub-Saharan Africa and global drivers of undernutrition

The burden of undernutrition in Sub-Saharan Africa

Notwithstanding the global decline observed in the burden of undernutrition in the last two decades (namely stunting, with a decreased prevalence from 33.1% in 2000 to 22.0% in 2020), the progress has been unequal across regions. Africa is one of the world regions where the progress was slower, being home to 41% of all stunted under-five children, and 22% of all children suffering from severe wasting. Stunting in the region is still increasing (from 54.4 million to 61.4 million of under-5 stunted children from 2000 to 2020), particularly in Eastern and Southern Africa, where the rise was from 23.6 million to 26.8 million in the same period (World Health Organization 2020). Associated reasons include slow rates of stunting reduction and a quickly expanding child population(World Health Organization 2020).

Specifically, in countries located in the Sahelian region, such as Niger and Burkina Faso, the prevalence of stunting and wasting among under-five children was higher than the regional average (Africa: 30.7% of stunting and 6.0% of wasting; Niger: 23.8% of stunting and 8.1% of wasting; Burkina Faso: 23.8% of stunting and 8.1% of wasting). The prevalence of anaemia among women of reproductive age presented a similar trend in both countries (Africa: 40.4%; Niger: 49.5%; Burkina Faso: 52.5%) (2021 Global Nutrition Report 2021b; 2021a), illustrating a high burden of micronutrient deficiencies. At the global level, maternal and child undernutrition and child mortality are expected to be exacerbated in LMICs due to economic crises and food and health system disruptions related to the COVID-19 pandemic (Osendarp et al. 2021).

Stunting and wasting are negative results of poor nutrition in-utero and early childhood. Stunting at early stages in life leads to an intergenerational cycle of poor growth and development (including the cognitive potential), in which women who were stunted in childhood remain stunted as adults and tend to have stunted offspring (Black et al. 2013). Children suffering from wasting have weakened immunity, are susceptible to long-term developmental delays and face an increased risk of death, particularly when wasting is severe (World Health Organization 2020). Undernutrition produces conditions of poverty by reducing the economic potential of the population and likewise, poverty reinforces malnutrition by increasing the risk of food insecurity. Stunting more pervasively hinders the developmental potential and human capital of entire societies due to its longer-term impact on cognitive function and adult economic productivity. Hence, this two-way link between malnutrition and poverty creates a vicious cycle.

Drivers of undernutrition

Addressing the basic structures of social hierarchy that drive livelihood conditions is mandatory to successfully strengthening health, including nutrition. A conceptual framework was developed by UNICEF (UNICEF 1990) to guide the work of the WHO Commission on Social Determinants of Health and illustrate the drivers of undernutrition (WHO 2008). Basic drivers include the nature and degree of social stratification and disparities in power in the society, underpinned by biases, norms and values related to gender, education, ethnicity/race and income. They also include the global and national macroeconomic, social and health policy and the global, national, and local processes of democratic governance. This assumption was recently confirmed by (Argaw et al. 2019), using data from 14 LMICs where stunting is highly prevalent, which observed that a decreased Gini coefficient and increased urbanization and participation of women in decision-making were significantly correlated to a lower risk of stunting. Immediate drivers of undernutrition are those connecting food consumption/nutrient intake with health/infection and operate at the individual level (WHO 2008). This framework was recently reviewed to bring in systemic drivers, with a new focus on the importance of climate, seasonality and environment in influencing livelihood systems, resilience and adaptation (Young 2020).

Recognizing that interventions tackling immediate drivers alone cannot change the underlying conditions that contribute to child undernutrition (Dewey and Adu-Afarwuah 2008), it has been argued that their implementation should not exclude investing in the effective interventions tackling contextual and structural/systemic drivers that can offer sustained nutritional gains over time. Hence, it is essential to understand the "implementation effectiveness", i.e., which and why contextual and structural drivers compromise the implementation, addressing collectively factors such as climate, conflicts, political instability, infrastructure, markets, education level or women empowerment.

All countries implement policies and programme frameworks aimed at improving food security and nutrition. These endeavours show similarities in terms of both the main interventions (such as nutrition education, school-based interventions and behaviour change communication) and the topics addressed (the most frequent being nutrition advisory, health care support, agriculture/food security, school health/feeding, and Infant and Young Children Feeding). These interventions are often combined with initiatives aimed at rural poverty reduction (e.g. empowering subsistence smallholders to give them access to markets by improving access to credit and inputs, land tenure, incorporating technology into production systems, or reducing inequality in all levels of the society).

Annex II – Illustrative examples[22] of evidence that persistent undernutrition can be attributed to contextual and structural/systemic drivers in LMICs

In Ghana, results from a longitudinal assessment of diet and growth of children engaged in nutrition rehabilitation programmes showed that nutrition education was not sufficient to improve children's diets at home due to factors such as lack of knowledge (both education and inequalities among household members) or money, or habits and preferences for ready-to-eat foods (Colecraft et al. 2004). In Bangladesh, the effects of prenatal food and early food and multi-micronutrient supplementation on infant development produced a slight impact in infants of low BMI but no impact in children of high BMI mothers, as disclosed in a large randomised controlled trial (Tofail et al. 2008). Conversely, in Bolivia, a regression model of pathways linking maternal education and child nutritional status was developed based on a large national sample of more than 5,000 children. It indicated socioeconomic factors, namely the impact of education on knowledge and attitudes about health care, to be the most important pathways (Frost, Forste, and Haas 2005). The findings emphasize that maternal education can influence child nutritional status, provided they have access to sufficient resources. They position maternal education as the single most important factor in explaining differentials in child health outcomes. Likewise, in Brazil, economic policies were complemented by policies to support major investments in direct nutrition inputs (food programmes) and by social sector spending on water and sanitation, health services, and education (FAO 2016). In India, massive economic growth in the country has not resulted in a reduction in child undernutrition, showing that although hunger is strongly linked to poverty, it is only weakly linked to economic growth (Pridmore and Carr-Hill 2009)and strongly depends on equity in resource distribution at national, regional and household levels. A cross-country analysis conducted by the IFPRI using data collected in 63 LMICs between 1970 and 1995, aimed at explaining contribution of underlying causes of undernutrition to the observed 15% reduction of prevalence of underweight and disclosed that: 43% came from improvements in childcare, represented by women's education measured by female enrolment at school; 26% came from increases in per capita food availability; 19% came from improvements in the health environment measured by access to safe water; and 12% came from improvements in women's status. Regarding the basic causes, the study reports that increases in per capita national income had accounted for half of the total reduction in undernutrition, suggesting that actions in sectors that have not been the traditional focus of nutrition interventions can result in significant achievements towards reducing undernutrition (Smith and Haddad 2000). In Bangladesh, a high prevalence of micronutrient deficiencies has been identified and monitored for some decades but, despite the downward trend, a significant proportion of preschool-aged children and women of reproductive age still live with micronutrient deficiencies and present anaemia. Multiple approaches and interventions have been implemented and supported (e.g., biofortification, supplementation, improving child feeding practices, promotion of dietary diversity) resulting in considerable success. There are, however, many inequities to overcome, in coverage, quality and compliance. Food insecurity, suboptimal diets, poor hygiene, infection and infestation, as well as low education and lack of awareness about the benefit of supplements, for example, are among the key contributing factors to the high prevalence of micronutrient deficiencies (Ahmed, Prendiville, and Narayan 2017).

[22] Not exhaustive. A comprehensive systematic literature review will be conducted as per "Study 1" of this research proposal.

Annex III – RS Work plan

Study Title: Drivers of persistent high rates of undernutrition in the Sahel – a comprehensive contextualized research

Tasks and Activities		M1		M2		M3		M4		M5		M6		M7		M8		M9		M10		M11		M12		M13		M14		M15		M16		M17		M18	
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Task 1	**Inception**																																				
Act 1.1	Kick off with NRF team, researchers and F3, C4N																																				
Act 1.2	Fine-tuning the approach methodology		D1																																		
Task 2	**Data collection & Systematic Literature Review (Study 1)**																																				
Act 2.1	Data needs assessment and collection from the EC																																				
Act 2.2	Systematic search for scientific papers in public databases																																				
Act 2.3	Search for grey literature in the internet																																				
Act 2.4	Selection of literature, data extraction and quality assessment																																				
Act 2.5	Data synthesis and critical interpretation of the results														D2																						
Task 3	**Map explanatory drivers using non-supervised, non-linear methods (Study 2)**																																				
Act 3.1	Collection and systematic organization of data and big data														D4																						
Act 3.2	Preliminary mapping of the explanatory drivers																D5																				
Act 3.3	Critical analysis of results, main findings and interpretation																				D6																
Task 4	**Qualitative longitudinal analyses through in-depth case-study approaches (Study 3)**																																				
Act. 4.1	Preparation and approval of the research ethical protocol and refinement of the research protocol																																				
Act. 4.2	Stakeholder engagement - Collection of context-specific data and relevant reports from local and regional organizations																												D8								
Act. 4.3	Stakeholder engagement - Conduct interviews and focus groups discussion with local actors																														D9						
Act. 4.4	Organization of a roundtable with local stakeholders and actors, engaging the respective EU Delegations to present and discuss results																																D10				
Act. 4.5	Synthesis and critical analysis of results, main findings and interpretation																																		D11		
Task 5	**Dissemination and Communication**																																				
Act 5.1	Research dissemination workshop																																		D12		
Act 5.2	Dissemination of research outputs through different channels, including the NRF webpage, direct communications, social media															D3						D7															D13
Act 5.3	Final comprehensive research study report																																				D14

Deliverables

D1: Inception report
D2: Manuscript for scientific journal publication (study 1)
D3: Policy brief (study 1)
D4: Geodatabase (Study 2)
D5: Preliminary results (Study 2)
D6: Study 2 report
D7: Policy brief (study 2)
D8: Report on the context-specific data analysis
D9: Report on interviews conducted with local stakeholders
D10: Report on the roundtable with local stakeholders and actors
D11: Study 3 report
D12: Research dissemination workshop
D13: Policy brief
D14: Final comprehensive research study report