Assessing the Multi-Dimensional Risk of Stunting Amongst Children Under Five Years in Zimbabwe

An Application of Machine Learning and Advanced Econometrics Techniques on Population Survey Datasets in Zimbabwe

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Abstract

Background: Despite the commendable decline from a peak of 35% in 2005 (Zimstat 2005), child stunting in Zimbabwe remains high, at 23.5% (Zimstat/UNICEF 2019). The stunting prevalence nevertheless remains considerably lower than the sub-Saharan average of 34.1% in 2017 (WDI 2018). Despite the increasing knowledge on the patterns of stunting, a lot more is still to be established regarding the determinants of stunting in Zimbabwe. Global evidence and literature has provided a framework for understanding the determinants and pathways for child malnutrition.

The major causes of malnutrition include immediate causes that are anchored on the inadequate intake and utilisation of food that has the right nutrient content and is safe for human consumption; and the poor health status of individuals. Food insecurity, limited knowledge about diets, and sub-optimal child feeding and care practices contribute to the inadequacy of quality food intake and utilisation. Poor health status is largely driven by limited access to health care services that have an impact on nutrition and a range of environmental factors. Although this understanding provides a sound basis for policy formulation, the extent to which these policies are translated into sound strategic actions depends to a large extent on a robust understanding of the role of the sub-components of these domains of influence and their interactions within the Zimbabwe context. This study sought to identify the key predictors of child stunting, quantify the multi-dimensional risk exposure amongst children in Zimbabwe as well as explore the interplay of stunting predictors and poverty.

Methods: In order to achieve the above, the study used Machine Learning and Artificial Intelligence techniques as the core tools of analysis. Specifically, the analysis focused on three interrelated steps: i) feature selection using the Random Forest (RF) Model; ii) development of the Multi-dimensional Malnutrition Risk Index (MMRI) using selected features; and iii) decomposition of the MMRI and exploratory analysis (including spatial mapping). This entailed initially selecting the most important predictor variables (feature selection) using the RF and Boruta Models, followed by using the selected features to compute a risk index, MMRI, based on a child's concurrent deprivations against these features and subsequently using the computed index scores in exploratory analysis with poverty measures.

Findings: The study reveals that child stunting in Zimbabwe is influenced by an interplay of a complex web of factors that align to the domains of health (status, behaviour, family planning and utilisation), biological, socio-economic, demographic and environmental factors as well as direct factors such as feeding/caregiving practices. The extent to which children were exposed to the desired state for each of the selected predictor variables varies and the top most common areas of deprivations are related to breastfeeding practices, child care and maternal health care. In general, the analysis shows that the drivers of child malnutrition in Zimbabwe go beyond deficiencies in food consumption to include child care and feeding practices, health related behavioural practices, access to and utilisation of quality health care, socio-economic determinants and poverty induced inequities. The multiple concurrent exposure to deprivations with respect to the identified determinants (key predictors) is heterogenous in Zimbabwe.

1. Introduction

Key Messages

Child malnutrition in Zimbabwe is driven by a range of factors that go beyond deficiencies in food consumption to include health related behavioral practices, access to and utilisation of quality health care, socio-economic determinants and poverty induced inequities. Multiple concurrent exposures to deprivations across these determinants heighten the risk of stunting amongst children.

- The programmatic response to the malnutrition burden should prioritise the continued provision of high impact nutrition interventions that aim to improve access and uptake of services noted to reduce stunting in children.
- There is scope to strengthen the capacity of sub-regional structures and adopt a sequenced geographical targeting approach for nutrition focused financing/ investments and programme implementation recognising the potential for scale-up of interventions in line with the varying intensity of stunting risk across the country.
- The multi-dimensional nature of the risks of stunting including the association with poverty underpins the need for a multi-sectoral response and coordination.
- Improving investments in nutrition specific interventions and efficiently allocating these in line with local needs provides a huge opportunity to accelerate the reduction in stunting prevalence.
- Advancements in technology present a low-hanging strategic opportunity that may be leveraged for strengthening data-driven decision making, including for targeting and adaptive learning from implementation.

Country Context

Zimbabwe is land-locked country in Southern Africa bordering with Botswana, Mozambique, South Africa and Zambia. It covers 390,757 square kilometres and had a total population of 13,061,239 according to the 2012 National Census. This translates to a population density of 33 persons per square kilometre. Women and girls account for 52% of the population whilst slightly over two thirds (67%) reside in the rural areas. The total fertility rate is estimated at 4 children per woman, and the age-specific fertility rate for women aged 15-19 years is 110 births per 1,000 (Zimstat/UNFPA 2015). The population growth rate is estimated at 2.0% per year (ibid.). Youths represent over 50% of the population. While progress has been made in reducing malnutrition compared to other countries in the region, child stunting in Zimbabwe remains high at 23.5% (Zimstat/UNICEF 2019).

Figure 1: Geographical Location and Map of Zimbabwe

Nearly two decades of economic difficulties that started from the early 2000s and peaked in 2007/2008 left the country in a low-income food-deficit status and led to a decline in key human development indicators. Zimbabwe ranked 156th of 189 countries in the 2018 Human Development Index (HDI) and 107th of 119 countries in the 2018 Global Hunger Index. Life expectancy at birth is estimated at 61.7 years, the expected and average years of schooling at 10.3 and 8.1 years respectively as well as the estimate of the Gross National Income (GNI) per capita of $1,683 contributed to the HDI ranking. The 2019 Mini-PICES showed that in 2019 an estimated 57% of Zimbabweans were living below the poverty line, with 38% in extreme poverty. The latter marks an 8-percentage increase from the 2017 estimate of households living in extreme poverty. In rural areas, 51% of the population is extremely poor, and 72% is poor, compared with 28% poor in urban areas (Zimstat 2019). Although gender inequalities have decreased, they remain significant in some sectors; the 2018 Human Development Report gives a Gender Inequality Index of 0.534, placing Zimbabwe 128th of 189. Most sectors were severely weakened and have remained constrained as a result of the protracted economic crisis. The health sector, in particular, suffered from out-migration of skilled personnel and inadequate investments in pharmaceuticals and infrastructure, which led to a sharp decline in key health outcomes in the early years of the last decade.

Despite improvements in most health outcomes following collective efforts and investments in select high impact interventions in the last five years, the progress has been slow and respective indicators continue to fare poorly with respect to progress against milestone targets. For example, the Multiple Indicator Cluster Survey (MICS) of 2019 estimated the maternal mortality ratio at 462 maternal deaths per 100,000 live births, which remains high relative to the 2015 target of 300 maternal deaths per 100,000. Under-5 mortality is currently at 69 deaths per 1,000 births and neonatal mortality has increased from 29 deaths per 1,000 live births in 2015 to 32 deaths per 1,000 live births in 2019 (Zimstat/UNICEF 2019). The table below provides a summary of key health outcomes in the past decade.

Table 1: Key Health Outcomes

Indicator	Measure and Source	ZDHS 2010-11	ZDHS 2015-16	MICS 2019 /Other
Maternal Mortality Ratio	Maternal Deaths per 100,000 Live Births	960	651	462
U5 Mortality	Deaths per 1,000 Live Births	84	69	65
Neonatal Mortality	Deaths per 1,000 Live Births	31	29	32
Stunting for Children U5	Prevalence (%)	32%	27%	23.5%
Adolescent Fertility Rate[1]	Live Births per 1,000 Adolescent Women	115	110	108
Teenage Pregnancy Rate[2]	Prevalence (%)	24%	22%	
Family Planning (FP) Coverage	Population Coverage (%)	59%	67%	68%
Unmet FP Needs	Prevalence (%)	13%	10%	8%
Adult HIV Prevalence	Prevalence (%)	15.2%	13.8%	12.7%
Malaria Incidence	Incidence Per 1,000 Population		29	19

Regional and Country Situation on Chronic Child Malnutrition (St ting

Malnutrition, in all its forms, includes undernutrition (wasting, stunting, and underweight), inadequate vitamins or minerals, overweight, obesity, resulting diet-related non-communicable diseases (NCDs). Globally 1.9 billion adults are estimated to be overweight or obese, while 462 million are underweight. Forty-seven million children under 5 years of age are wasted, 14.3 million are severely wasted and 144 million are stunted, while 38.3 million are overweight or obese. Around 45% of under-five mortality is linked to undernutrition, mostly occurring in low- and middle-income countries. The developmental, economic, social, and medical impacts of the global burden of malnutrition are serious and lasting, for individuals and their families, for communities and for countries.

Globally, in spite of the evidence of growing increase in knowledge on the patterns of stunting, the prevalence remains unacceptably high, with Low- and Middle-Income Countries (LMIC) continuing to be disproportionately affected, with rates of 30-50% (Reinhardt and Fanzo 2015). In Sub-Saharan Africa, stunting rates have stagnated even in countries where economic growth has been observed (SADC 2019, UNICEF/WHO/World Bank 2021). In 2019, nine of the SADC Member States had stunting prevalence rates of above 30%, which according to the WHO are classified as very high (SADC 2019). The body of evidence around the causes of stunting and its pervasive persistence are multiple and variable and have been widely understood using the UNICEF conceptual framework on undernutrition (UNICEF 2013, 2021). The framework outlines that undernutrition is the impact of three levels: the basic, underlying, and immediate causes.

According to this framework, basic causes of malnutrition are linked to systemic-level challenges that reflect the structural and political processes in each society. These include social, economic, environmental, and political issues that lead to the lack of or imbalanced distribution of natural (e.g. productive land), human, physical, social and financial resources. On underlying causes, the framework places emphasis on household food security, adequate care and feeding practices, access to health services, and residing in a healthy environment. The immediate causes emanate from the impact of the basic and underlying causes at the individual level through inadequate food quality intake and disease. This framework is also used to guide interventions from a multi-sectoral and multi- dimensional perspective, moving from macro to micro-levels of focus.

Box 1: Global Nutrition Targets

To address these global nutrition challenges and recognising that accelerated global action is needed to reduce the persistent and vicious problem of malnutrition, in 2012 the World Health Assembly Resolution 65.6 recommended a comprehensive implementation plan on maternal, infant and young child nutrition, which specified a set of six global nutrition targets that by, 2025, aim to:

- Achieve a 40% reduction in the number of children under-5 who are stunted;
- Achieve a 50% reduction of anaemia in women of reproductive age;
- Achieve a 30% reduction in low birth weight;

- Ensure that there is no increase in childhood overweight;
- Increase the rate of exclusive breastfeeding in the first 6 months up to at least 50%;
- Reduce and maintain childhood wasting to less than 5%.

To buttress the global efforts towards achieving Global Nutrition Targets by 2025 the United Nations (UN) General Assembly proclaimed 2016–2025 the United Nations Decade of Action on Nutrition. It sets a concrete timeline for implementation of the commitments to meet a set of global nutrition targets and diet-related NCD targets by 2025, as well as relevant targets in the Agenda for Sustainable Development **by 2030**, particularly Sustainable Development Goal (SDG) 2 (end hunger, achieve food security and improved nutrition and promote sustainable agriculture) and SDG 3 (ensure healthy lives and promote wellbeing for all at all ages).

Stunting continues to be a major public health and socio-economic problem in Zimbabwe affecting mostly children under the age of five years and women of child bearing age. Stunting prevalence amongst children under five years remains high despite a commendable decline from a peak of 35% in 2005 (Zimstat 2005) to 26% in 2018 (FNC 2018) and now 24% (Zimstat/UNICEF 2019). The rate of decline has however not been fast enough to meet the target regional and international thresholds. Malnutrition, in all its forms, includes undernutrition (wasting, stunting, and underweight), inadequate vitamins or minerals, overweight, obesity, and resulting diet-related non-communicable diseases (NCDs).

Child stunting is a key contributor to the Human Capital Index (HCI) – a measure of the amount of human capital that a child born today can expect to attain by age 18 given the risks of poor health and poor education that prevail in the country where s/he lives. Zimbabwe's Human Capital Index was 0.44 in 2017, placing it in a moderate position relative to other countries in Africa. Zimbabwe is a signatory to the international and regional agreements on the fight against malnutrition, therefore it is also tracking its performance towards the 2025 Global Nutrition Targets. The Zimbabwe Constitution recognises the right to adequate food and nutrition coupled with access to basic health care and social services

Figure 1. Nutrition Trends - Zimbabwe

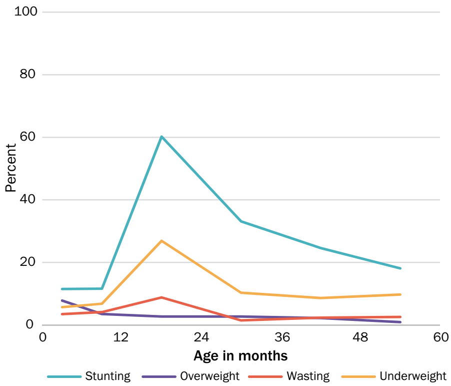
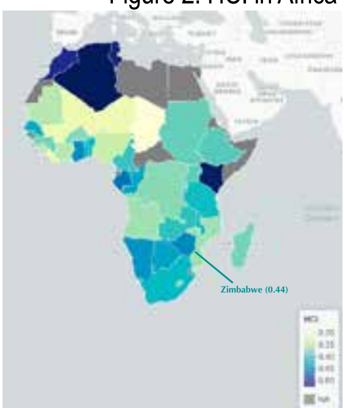


Figure 2. HCI in Africa



Source: MICS2019 Source: Author Using WB HCI Report Data

Previous analysis of survey data in Zimbabwe has shown some demographic and geographic variations in the country over years. Stunting is higher in rural areas (26.5%) than in urban areas (22.7%) and varies by Province with Manicaland having the highest (31.2%) whilst Matabeleland South had the lowest (24.2%) (FNC 2018). Boys are more undernourished than girls, largely because boys are weaned at an earlier age; children in rural areas are significantly more malnourished than children in urban areas.

Evidence drawn from the malnutrition framework has often been mirrored to shape the narrative of the determinants and pathways for child malnutrition without sufficient adaptation to local settings. In that regard, interventions have been broadly fashioned to address the major causes of malnutrition as per the malnutrition framework (UNICEF 2019, Black et al. 2020). Unfortunately, interventions that have been loosely developed based on this framework fall short on the specifics of what needs to be done in the current context, and how to do it, due to a lack of robust understanding of the role of the sub-components of the frameworks' domains of influence and their local interactions. Current responses have had small and often poorly targeted (outside of the 1,000 days window) investments in nutrition programmes, and this has consistently resulted in very slow and marginal improvements with stunting prevalence improving by 3% between 2015 and 2019 (Zimstat/UNICEF 2019).

Additional knowledge of the determinants of stunting in the local context, therefore, remains a key priority for refining efforts to accelerate progress against the backdrop of constrained resources. A comprehensive understanding of the determinants of stunting, including the inter-relationships across these factors at the local level, is essential in crafting the appropriate response package and delivery in a targeted manner. Although the understanding of the broader malnutrition framework provides a sound basis for policy formulation, the extent to which these policies are translated into sound strategic actions depends to a large extent on a robust local understanding of the role of the sub-components of these domains of influence and their interactions. Prior evidence has generally adopted a singular approach in validating associations or predictors of malnutrition based on the framework and other literature (Black et al. 2020). This is partly due to limitations in some standard analytic approaches that may not sufficiently address the architecture of big data and the likely correlations across multiple variables.

Zimbabwe has made good progress in establishing the appropriate policy environment to facilitate a national response to malnutrition in the country. Various legislation, policies and guidelines are in place to promote and safeguard access to services, safe products and sound practices that ensure good nutrition for the population. These have been supported by relevant structures that include a Food and Nutrition Council that is mandated to promote a cohesive national response to prevailing food and nutrition insecurity through co-ordinated multi-sectoral action, and the Ministry of Health and Child Care that leads the implementation of nutrition specific interventions, collaboratively with other line ministries and development partners in a multi-sectoral approach. A number of inhibitors to the response have been noted and these include the recent climatic and pandemic shocks that have compounded the already vulnerable health service delivery system owing to the protracted macro-economic challenges. This has further heightened the call to enhance the effectiveness and efficiency of the response to child malnutrition in order to accelerate the decline in prevalence against the backdrop of limited fiscal space in the country.

Study Focus and Policy Question

The study aimed to identify the key predictors of child stunting and quantify the multi-dimensional risk exposure amongst children in Zimbabwe. The analysis sought to answer the following policy questions:

1. What is the nature and extent of interplay between demographic, environmental, social, economic and health related factors that predispose households to the increased risks of child stunting in Zimbabwe?
2. What are the priority target interventions to be considered in constituting a package of responses to address inequities in child stunting in Zimbabwe?
3. What is the extent of alignment of the geographical distribution of current development investments focused on mitigating child stunting to the hotspots of the risk of child stunting in Zimbabwe?

In line with the above focus, this paper has been structured to provide an overview of findings and key policy considerations drawn from the analysis of determinants of stunting in Zimbabwe. The findings of the artificial intelligence (AI) enabled analysis of household survey data have provided additional insights into the key predictors of child stunting, the scope, scale and spread of multi-dimensional stunting risk exposure as well as the interplay between these determinants and poverty in driving stunting.

Methodology

Data Sources

This study is based on the 2018 National Nutrition Survey (FNC 2018) data and the Poverty Income and Consumption Expenditure Survey (2017). The Zimbabwe National Statistics Agency, in partnership with the Food and Nutrition Council of Zimbabwe and Ministry of Health and Child Care, conducted the survey with funding and technical support from development partners in health, food security and nutrition.

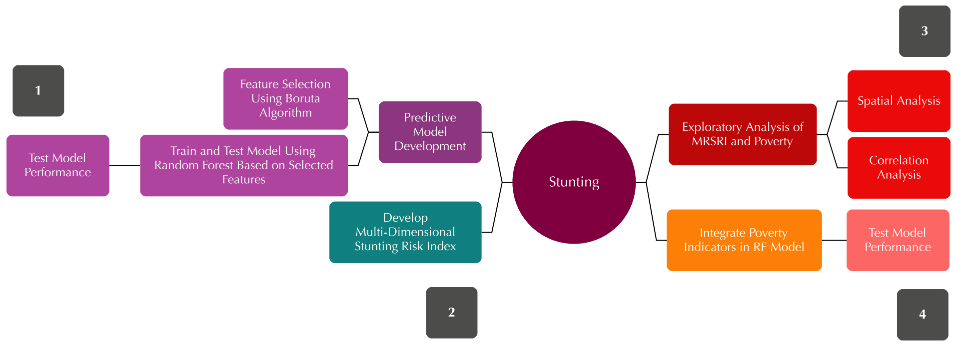
The NNS is a nationally representative survey that covers the entire population and is based on a two-stage stratified sampling framework. Stratification was based on the separation of urban and rural areas in each of the 10 provinces. The sample design was such that key food and nutrition indicators, particularly stunting prevalence, could be reported at domain level (60 rural and 4 urban) with at least 95% confidence. Stunting prevalence as the chosen key indicator for the survey informed the sample design as well as the sample size. The 2012 Zimstat master sampling frame was used to draw 30 enumeration areas (EAs) for each domain using the Probability Proportional to Population Size (PPS) method. A total of 30 households to be enumerated were selected using systematic random sampling from a randomly selected village within the sampled EAs. Households with children under the age of 5 years were the sampling units. All children under 5 years in the households were considered for anthropometric measurements as well as key child nutrition and health indicators.

The NNS 2018 successfully held interviews for a total of 28,464 households and 34,714 children aged 6-59 months were measured. Of these children, the study used 31,704 for whom complete, credible anthropometric and age data were non-missing. The standard WHO definition for stunting based on the Height-for-Age, which is regarded as a measure of linear growth retardation and cumulative growth deficits was adopted and used for the study. All children whose height-for-age Z-score (HAZ) is below minus two standard deviations (-2 SD) from the median of the reference population are considered short for their age (stunted), or chronically undernourished.

Analysis Approach

The analysis focused on three interrelated steps: i) feature selection using the Random Forest Model; ii) development of the Multi-dimensional Malnutrition Risk Index (MMRI) using selected features; and iii) decomposition of the MMRI and exploratory analysis (including spatial mapping). Figure 3 outlines the sequencing of the analysis, which entailed initially selecting the most important predictor variables (feature selection) using the RF and Boruta Models, followed by using the selected features to compute the MMRI and subsequently in exploratory analysis with poverty measures. The section below provides a detailed description of each of the methods and how they were integrated in the analysis pipeline.

Figure 3. Steps in Analysis



a) Feature Selection Using the Boruta and Random Forest Algorithms

The identification of determinants was based on ML algorithms – Boruta and Random Forest Model (RF) applied on the NNS 2018 data. The RF algorithm was developed by Breiman (2001) to classify data using a set of decision trees. A multitude (k) of trees is built from an initial sample that corresponds to N records with F studied features, represented by a matrix of size (N, F). For each tree node f features are then randomly pulled among the F features (f is equal to rounded square root of F). A key property of the RF is that it enables the assessment of the importance of each feature through the computation of the OOB (Out of Bag) error (%).

The analysis process entailed partitioning data into 70% training dataset and 30% test dataset. Modelling is done on the training dataset to construct the predictive classifier whilst the test dataset is applied to evaluate performance of the classifier. The importance of variables (features) is then evaluated by measuring the decrease in prediction performance, which is reported as either accuracy or the Gini index. In order to improve the performance of the RF, we used the Boruta Algorithm, which is a wrapper algorithm based on the Random Forest that has greater strength in feature selection as it creates a classification model based on shadow and original attributes to assess importance. The Boruta is able to confirm those attributes regarded as important and reject others. In this analysis, the RF was then used as a second step as it was applied on only those features that Boruta had identified as important. The process was aimed at improving precision in the feature selection.

The use of the machine learning approach in this analysis was deemed appropriate and robust due to its ability to handle many features, capture nonlinear pattern relationships and provide more robust discriminant power compared to classical statistics when analysing a huge number of variables. A total of **230 independent variables/features** that ranged from demographics, socio-economic, environmental, geographic, health utilisation and other factors fitting in the framework for determinants of malnutrition were included in the modelling. The RF model has shown good performance in variable selection (Genuer et al. 2010) and demonstrates the ability to handle the problem of multi-collinearity that would arise when using other methods such as the classical Ordinary Least Squares (OLS) regression technique.

b) Computation of the Multi-dimensional Malnutrition Risk Index (MMRI)

The set of the selected variables were then transformed into binary variables coded as 1 representing a deprivation in a particular variable and 0 for non-deprivation. The classification of deprivation was based on evidence and policy. For example, the global recommendation for breastfeeding is to have exclusive breastfeeding for at least six months, and in that regard every child who was not exclusively breastfed for six months was considered as deprived and therefore awarded a code=1. Coding for every selected indicator and against every child allowed for the application of the Alkire-Foster (AF) Headcount approach in determining a Multi-dimensional Malnutrition Risk Index.

The AF method is typically used to measure the Multi-dimensional Poverty Index (MPI), an index designed to measure acute poverty. The MPI was used to measure children experiencing multiple deprivations, children who, for example, are not breastfed and do not have clean drinking water, adequate sanitation or electricity. The MPI combines two key pieces of information in its measure: the incidence of the negative outcome, e.g. stunting, or the proportion of people (within a given population) who experience multiple deprivations, in this case the incidence of multiple exposure to malnutrition risk, and the intensity of their deprivation – the average proportion of (weighted) deprivations they experience. The two measures are relevant and valuable as they can easily be interpreted and comparisons across regions and other sub-populations can be determined. Using insights from the exploratory data analysis with a focus on the mean deprivations, a cut-off k=0.5 was applied, implying the analysis provides information on the incidence of 18 or more concurrent exposures to malnutrition risks (Ho - Incidence) and the intensity (MMRI).

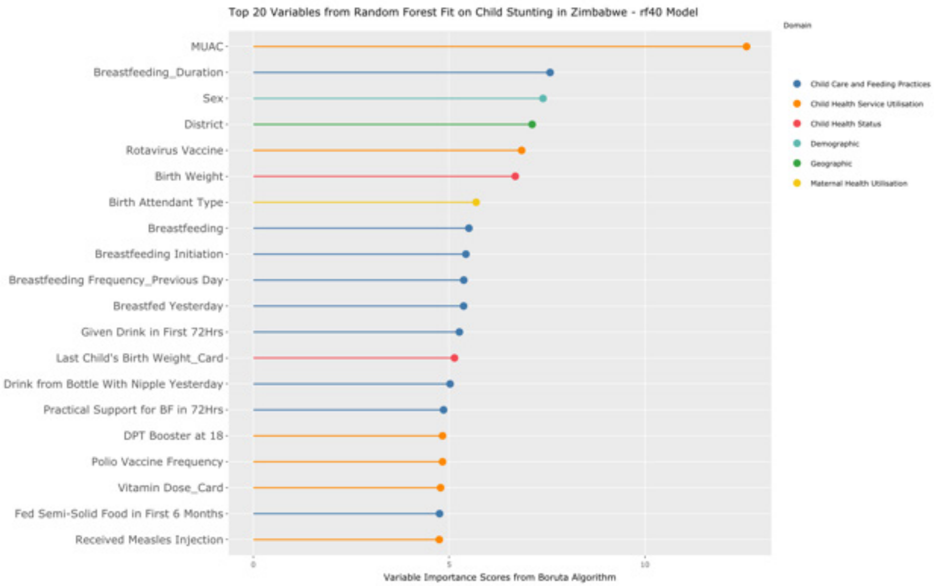
c) Exploratory Analysis of the Multi-dimensional Malnutrition Risk Index (MMRI)

Based on the computed MMRI and the incidence of multi-dimensional nutrition risk exposure, we conducted exploratory data visualisations to assess the decomposition of the index and determine contributions of the domains. Furthermore, spatial analysis was conducted using district level estimates of the stunting and MMRI derived from the NNS 2018 data as well as poverty estimates (proportion of poor and extremely poor households) drawn from the Poverty Income Consumption and Expenditure Survey (PICES).

Findings - Determinants of Stunting

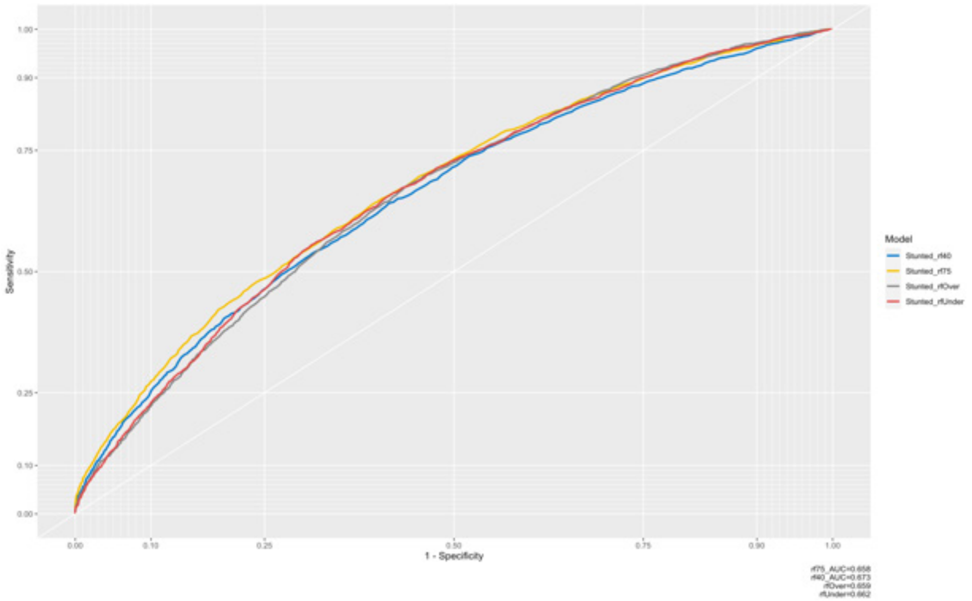
Child stunting in Zimbabwe is influenced by a complex web of factors that align to the domains of health (status, behaviour, family planning and utilisation), biological, socio-economic, demographic and environmental factors, as well as direct factors such as feeding/caregiving practices. The analysis showed that stunting could be accurately predicted by a modelled combination of children's and household characteristics. A total of 95 variables or features from the 320 in the NNS 2018 dataset were confirmed as important predictor variables for stunting. Two predictive models, the rf75 and rf40, with 75 and 40 variables respectively were successfully trained to predict stunting. These variables belong to several domains that confirm the multi-dimensional nature of stunting determinants and validate the strong alignment with the UNICEF Malnutrition Framework. Figure 4 provides a summary of the top predictors of stunting based on Boruta and Random Forest Model, and shows Mid-Upper Arm Circumference as the top predictor, which is not surprising but remains critical given the role of growth monitoring in the nutrition response.

Figure 4: Variable Importance Plot Showing Top 20 Predictor Variables



The performance of the two models showed similar accuracy therefore justifying the use of the trimmed-up model with less variables. The rf75 and rf40 have accuracy of 72% and 71% and precision of 61% and 56% respectively. The precision estimates for the two models show that both models performed well in predicting the true negatives (Specificity) but poorly for the positives (Sensitivity). This was observed to have arisen from a 'class imbalance problem' because the outcome of interest, stunting, is found in only a quarter of the children in the dataset. Some adjustments to the imbalance were made to the model through the use of an adjustment algorithm, the Random Over-Sampling Examples (ROSE), and this improved the Sensitivity from 15% to 62%. The Area Under Curve (AUC) estimates for the different models, including those obtained by adjusting through over-sampling (rfOver) and under-sampling (rfUnder), were similar at 66% implying that the adjustments that led to better Sensitivity did not negatively affect overall model performance (see Figure 6). Given that the focus of the Boruta and RF analysis in this study was predominantly for feature selection and not development of a stand-alone prediction model, focus was placed on identifying the list of priority predictors of stunting for use in subsequent steps.

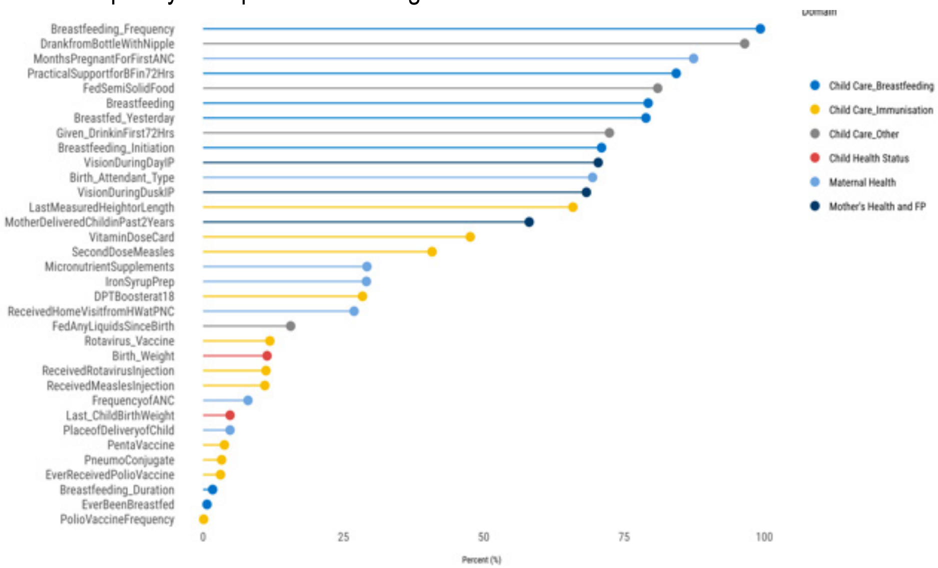
Figure 5: Receiver Operator Curve Characteristic (ROC) Curve Showing Model Area Under Curves



Dominant features in driving stunting in Zimbabwe reflect the need to prioritise child care feeding practices, utilisation of child care services including immunisation, and strengthening maternal health services including the health of the mother. The analysis shows that access to immunisation is highly predictive of stunting status, e.g. receiving Vitamin A supplementation is associated with children's growth and suggests that Vitamin A supplementation may be protective against stunting. Missing vaccination doses is observed as a less likely predictor of stunting in children, contrary to other literature. Vitamin A deficiency in pregnancy is a predictor of stunting. The health status of children (including at birth) and that of mothers contributes to the nutrition status of children. Children who had early initiation of breastfeeding, whose mother received support with 72 hours, and were breastfed frequently are less likely to be stunted. Mothers who book early and receive skilled birth attendance at delivery are less likely to have stunted children. The occurrence of geographic features such as districts and provinces amongst the list of important predicters affirms the heterogeneity in stunting prevalence in the country, with the spatial patterns of severity reflecting some moderate consistency between the current status (NNS 2018) and previously in 2015.

The assessment of the extent to which children were exposed to the desired state for each of the selected determinants[1] shows that the top most common areas of deprivations are related to breastfeeding practices, child care and maternal health care utilisation. The ranked list shows inadequate breastfeeding frequency (99%), non-use of bottle with nipple (97%), delayed attendance of first antenatal care checkup for mother (87%), inadequate practical support for breastfeeding in the first 72 hours (84%) and non-exclusive breastfeeding (79%) as the top areas of deprivations. Although immunisation related variables were identified amongst the key predictors of stunting, the frequency of deprivations amongst these was observed to be relatively lower for most of the variables with the exception of Vitamin A doses (less than 6 monthly) and growth monitoring (last measured more than three months), which had 66% and 48% deprivations respectively.

Figure 6: Frequency of Deprivations Amongst Children

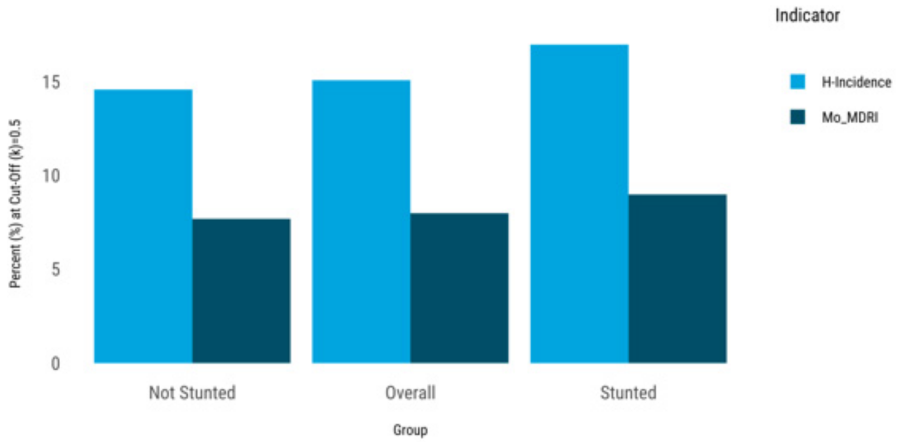


The concurrent occurrence of deprivations (having multiple deprivations at the same time for each child) is higher amongst children who are stunted. The incidence of multi-dimensional deprivation (child with deprivations in 50%+ of the set of top 34[4] predictor variables) was observed to be higher amongst children who are stunted (17%) than those not stunted (14.6%) and the overall group (15.1%) – Figure 7. Similarly, the Multi-Dimensional Stunting Risk Index is higher for stunted children (9%) though with only a

1. Note that variables such as Sex and District are predictors but not necessarily regarded as drivers or determinants as they only foretell the state but do not determine it.

percentage point difference relative to the other reference groups. Deprivations are more frequent for initiation and frequency of breastfeeding, utilisation of maternal health services (early ANC booking and frequency of ANC etc.), mother's health during pregnancy (e.g. vision challenges) and other child care practices.

Figure 7: Incidence of Deprivations and Multi-dimensional Malnutrition Risk Index



Food consumption and dietary diversity are important considerations in understanding the prevalence of stunting in Zimbabwe. Though relatively lower in the ranking of predictor importance, food security and dietary intake related variables remained amongst the list of important predictor features in the rf75 predictor model. Zimbabwe's food and nutrition situation is classified as 'serious' in the 2018 Global Hunger Index (Score - 32.9). The country failed to reach Goal One of the 2015 Millennium Development Goals (MDGs) – halving extreme poverty and hunger by 2015.

The interplay between poverty, food security and the multi-dimensional risk of deprivation to the stunting determinants also provides useful insights regarding its importance as a contributor to stunting. The heterogenous nature of poverty in Zimbabwe is well documented, e.g. through the Zimbabwe Poverty Atlas and PICES Reports. Specific districts and regions show much higher proportions of poor households. The pattern is however not distinctively correlated to the stunting risk or prevalence at the district level, as illustrated by the spatial maps (Fig 8) and the scatter plot (Fig 9) below. However, though moderate, inequities in stunting are widened when stunting risk (as measured by the MDRI) is combined with poverty. Figure 10 shows that the Concentration Index for the weighted MDRI is 0.07, which is positive, and given the distribution scale it means that children who are exposed to more poverty and higher stunting risk scores are more likely to be stunted than their counterparts. Furthermore, a visual inspection of the spatial pattern of the combined Poverty Prevalence and MDRI (Map 3) reflects some moderate alignment to the distribution of stunting in Zimbabwe.

Figure 8: Spatial Patterns of Poverty, MDRI, Stunting and Poverty-Weighted MDRI

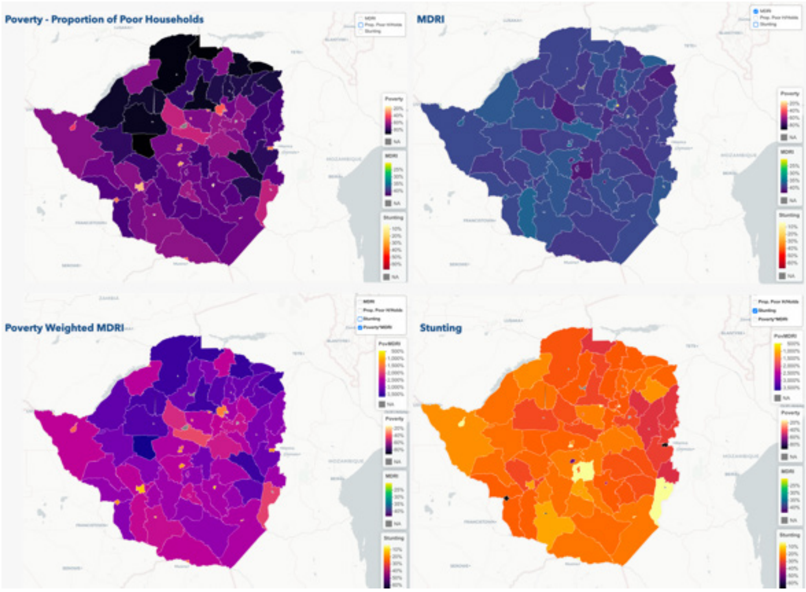


Figure 9: Scatter Plot of District Level Poverty and Stunting Prevalence

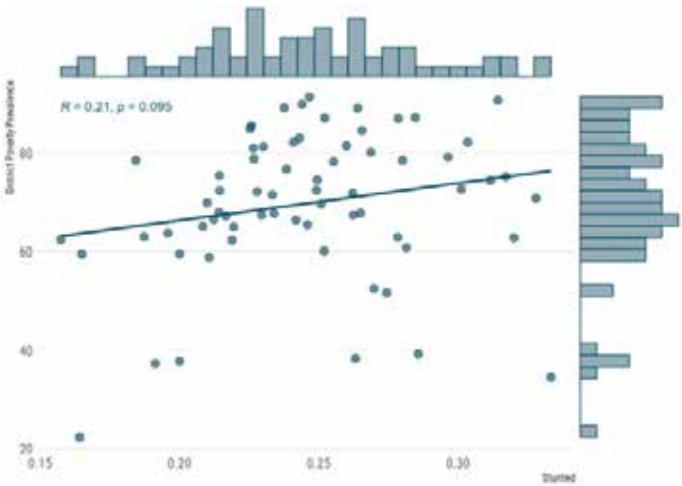
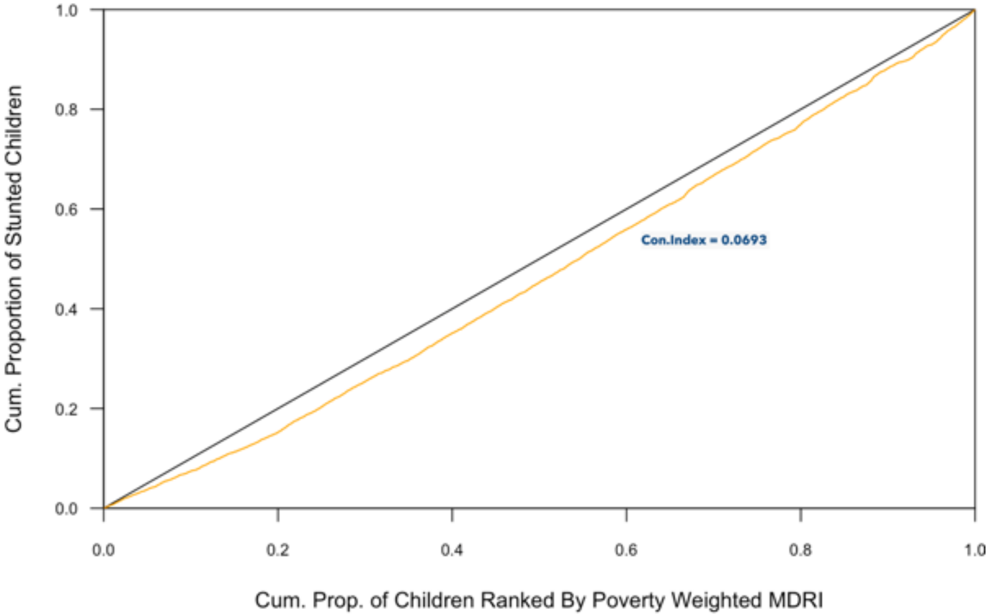


Figure 10: Concentration Curve Showing Poverty Weighted MDRI and Stunting Amongst Children



The findings show that child malnutrition in Zimbabwe is driven by a range of factors that go beyond deficiencies in food consumption to include health related behavioral practices, access to and utilisation of quality health care, socio-economic determinants and poverty induced inequities. Multiple exposures to these determinants further compound the risk of stunting in children. An effective national response to the stunting burden calls for a multi-sectoral approach and targeted interventions that aim to reduce exposure and break the complex linkages across these factors.

Policy and Strategic Considerations Going orward

The following key considerations are proffered in view of the evidence on the determinants of stunting and recognising the operational and policy related bottlenecks in the response.

The programmatic response to the malnutrition burden should prioritise the continued provision of high impact nutrition interventions that aim to improve access and uptake of services noted to reduce stunting in children. There are opportunities to leverage already existing programmes such as the Results Based Financing (RBF) and Community Based Management of Acute Malnutrition (CBMAM) in terms of structure, systems and lessons learnt to accelerate:

- Improvements in access to Vitamin-A Supplementation (VAS) for U5s
- Introduction and adoption of adolescent micronutrient supplementation

- Uptake of early ANC booking and further reducing home deliveries
- Improvements in Infant and Young Child Feeding support structures from health facilities to the community

Given the potential disruptions in the provision of health services arising from the COVID-19 pandemic, it is important that Reproductive, Maternal, Newborn, Child and Adolescent Health (RMNCAH) services are prioritised as essential services requiring measures to safeguard their continuity in service provision.

The evidence supports adopting a sequenced geographical targeting approach for nutrition focused financing/investments and programme implementation that recognises the current stunting burden with potential for scale-up in line with the varying intensity of stunting risk across the country. The heterogenous representation of stunting prevalence in the country justifies the need for a targeted approach in the national response. However, the composite multi-dimensional risk (as shown by the MDRI) is not distinctively varied across the country, implying that districts with low stunting prevalence may still also have moderate to high risks and would still require some relative exposure to interventions that minimise stunting. The heterogeneity reflected at the level of the MDRI domains (decomposed index) gives credence to the need for localised adaptation of national response frameworks to meet the priority needs specific to sub-regional levels (wards, districts and provinces). There is therefore scope to strengthen the capacity of sub-regional structures in priority setting based on a review of local level performance status against drivers of stunting and adaptation of national guidelines/frameworks to craft a customised response.

The multi-dimensional nature of the risks of stunting, including the association with poverty, underpins the need for a multi-sectoral response. The potential compounding effect of poverty on the risk of stunting provides additional pathways to addressing the underlying determinants of stunting by tackling the structural drivers of poverty. The involvement of all stakeholders in a collective response would therefore serve to address all potential bottlenecks across the pathways of change.

Improving investments in nutrition specific interventions and efficiently allocating these in line with local needs provides a huge opportunity to accelerate the decline in stunting prevalence. Increasing the allocation of resources to the nutrition response with strategic allocation to both programmatic needs and towards the country's national multi-sectorial response (including for the coordination, planning, monitoring and evaluation) would re-position the country to be on course to achieving the 2025 Global Nutrition Target on stunting.

It will be strategic for Government and stakeholders to consider leveraging advancements in technology to strengthen data driven targeting and adaptive learning from implementation to enhance effectiveness and efficiencies in the response. Building on this study's use of machine learning, there are opportunities to use technology to scale the reach in health and nutrition promotion (e.g. awareness about early breastfeeding initiation, duration and frequency), and apply AI and machine learning models to facilitate:

- Households' self-assessments/screening of child stunting risk and uptake of correction action. For example, using the models developed in this study, Mobile Apps or Chatbots can be developed that allow for self-assessment and based on obtained scores guidance be provided for triaging and advice on courses of action for immunisation, care practices, ANC, etc.
- Vulnerability assessments and household targeting for national programmes.

In order to facilitate the realisation of the optimal use of data for decision making in the national response, it will be important to invest appropriately in relevant Information Systems as well as policies for data access, privacy and utilisation.

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