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Benefit-Cost Analysis

Preventative Nutrition Interventions

COPENHAGEN CONSENSUS CENTER

Haïti Priorise
Un plan de **développement** alternatif

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Preventative Nutrition Interventions

Haïti Priorise

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Abbreviations:

BCR, benefit cost ratio; Copenhagen Consensus, CC; DALY, disability adjusted life year; DHS, Demographic and Health Survey; ECVMAS, L'Enquête sur les Conditions de Vie des Ménages Après Séism; FAPSBA, folic acid-preventable spina bifida and anencephaly; IDA, iron deficiency anemia; IDD, iodine deficiency disorder; MNP, micronutrient powder; PSC, pre-school age children; RR, relative risk; SAC, school-age children; WRA, women of reproductive age.

Academic Abstract

Anemia and micronutrient deficiencies affect a large proportion of the population in Haiti. Pregnant women and young children are most vulnerable to micronutrient malnutrition, due to their increased nutrient requirements, the small amounts of foods they consume, and the fact that deficiencies during this life stage can lead to life-long disabilities. Anemia in pregnancy is associated with an increased risk of infant mortality, preterm delivery, and low birth weight. Supplementation with multiple micronutrient capsules substantially reduces those risks. Further, women consuming diets low in calcium may be at greater risk of pre-eclampsia or eclampsia, which increases the risk of maternal mortality. The World Health Organization recommends calcium supplementation for women during pregnancy to mitigate that risk. Among children, micronutrient deficiencies can also lead to anemia, increased susceptibility to infection, and higher mortality risk. Provision of micronutrient powders has been found to significantly reduce the risks of anemia. For both pregnant women and young children, fortification of staple food products, such as wheat flour, with iron and folic acid may offer similar benefits with regard to anemia reduction while also reducing the risk of neural tube defects. In the present analysis, we have presented the evidence and rationale for considering each of these three intervention strategies: multiple micronutrients and calcium delivered to pregnant women, wheat flour fortification with iron and folic acid, and micronutrient powder delivery to children 6-23 months of age. We estimated costs to deliver and scale up the programs. We estimated benefits based on years of life saved (reductions in maternal mortality, deaths due to neural tube defects, low birth weight, and preterm birth), disability-adjusted life year losses averted (due to the current and future effects of anemia, low birth weight, and preterm birth), and future productivity gains due to the prevention of low birth weight. For all three of the interventions considered, benefit cost ratio estimates were well above 1. Specifically, assuming a 5% discount rate and valuation of DALYs at 3XGDP, the benefit cost ratios were: 10 for provision of multiple micronutrient and calcium supplementation to women, 24 for wheat flour fortification with iron and folic acid, and 8 for provision of micronutrient powders to young children. Sensitivity analyses suggested that benefit cost ratios would remain favorable under various assumptions related to costs and program delivery effectiveness (e.g., coverage). Limitations of the foregoing analysis are discussed, including the important caveat that the modeled program scenarios are not additive. We consider the quality of evidence suggesting that the selected interventions would have the predicted impact to be strong.

Policy Abstract

Overview and context

Anemia and micronutrient deficiencies affect a large proportion of the population in Haiti. Pregnant women and young children are most vulnerable to micronutrient malnutrition, due to their increased nutrient requirements and the fact that deficiencies during this life stage can lead to life-long disabilities. Anemia in pregnancy is associated with an increased risk of infant mortality, preterm delivery, and low birth weight. Supplementation with multiple micronutrient capsules substantially reduces those risks. Further, women consuming diets low in calcium may be at greater risk of pre-eclampsia or eclampsia, which increases the risk of maternal mortality. The World Health Organization recommends calcium supplementation for women during pregnancy to mitigate that risk. Among children, micronutrient deficiencies can also lead to anemia, increased susceptibility to infection, and higher mortality risk. Provision of micronutrient powders has been found to significantly reduce the risk of anemia. For both pregnant women and young children, fortification of staple food products, such as wheat flour, may offer similar benefits with regard to anemia reduction while also reducing the risk of neural tube defects by increasing folic acid intake in early pregnancy. In the present analysis, we have presented the evidence and rationale for considering each of these three intervention strategies: multiple micronutrient supplements and calcium supplements delivered to pregnant women, industrial fortification of wheat flour with iron and folic acid, and provision of multiple micronutrient powders to children 6-23 months of age.

Implementation considerations

We estimated initial costs for intervention planning and scale-up and recurring costs for intervention delivery thereafter. In these scenarios, multiple micronutrient capsules and calcium supplements are provided by health workers to pregnant women who attend antenatal care visits, with home visits to pregnant women in rural areas who receive less than the recommended number of antenatal care contacts. In these projections, micronutrient powders are provided to children 6-23 months of age (as per WHO guidelines) who attend health clinics or rally posts to receive vaccinations or other health services by health workers. Fortification of wheat flour with micronutrients is implemented by wheat millers and wheat flour importers, with external support for program planning, monitoring, and evaluation.

Rationale for Intervention

For delivery of micronutrients to pregnant women, we estimated benefits based on years of life saved due to reductions in maternal mortality and reductions in infant mortality due to low birth weight and preterm birth, and disability-adjusted life year losses averted were estimated for current effects of maternal anemia, and future effects of low birth weight and preterm birth, and future productivity gains due to the prevention of low birth weight. For large-scale fortification of wheat flour, we estimated benefits in terms of years of life saved due to reduction in neural tube defects following folic acid fortification, and disability-adjusted life year losses averted due to reductions in iron-deficiency anemia prevalence among women of reproductive age, school-age children, and preschool children. Finally, we estimated disability-adjusted life year losses averted due to reduction in anemia prevalence among children 6-23 months of age who receive micronutrient powders.

For all three of the interventions considered, benefit cost ratio estimates were well above 1. Specifically, assuming a 5% discount rate and valuation of DALYs at 3XGDP, the benefit cost ratios were: 10 for provision of multiple micronutrient and calcium supplementation to women, 24 for wheat flour fortification with iron and folic acid, and 8 for provision of micronutrient powders to young children. Sensitivity analyses suggested that benefit cost ratios would remain favorable under various assumptions related to costs and program delivery effectiveness (e.g., coverage). Limitations of the foregoing analysis are discussed, including the caveat that the modeled program scenarios are not additive. We consider the quality of evidence suggesting that the selected interventions would have the predicted impact to be strong.

Summary Table

Interventions	Benefit (in gourdes)	Cost (in gourdes)	BCR	Quality of Evidence
Multiple micronutrient and calcium supplements to pregnant women	79,844,981,881	7,637,956,645	10	Strong
Wheat flour fortification with iron and folic acid	7,938,064,315	331,312,834	24	Strong
Multiple micronutrient powders to children 6-23 months of age	1,200,675,600	157,324,005	8	Strong

Notes: All figures assume that DALYs are valued at 3XGDP and a 5% discount rate is applied.

1. Introduction

Micronutrient deficiencies affect billions of people globally and contribute to increased morbidity and mortality, particularly among vulnerable groups such as young children (Black et al., 2013). Our objective was to estimate the costs and benefits of implementing selected preventive nutrition interventions in the context of Haiti.

We first review evidence on the burden of micronutrient deficiencies and related health outcomes in Haiti. Next, we consider the interventions available to reduce the burden of micronutrient deficiencies and, specifically, the evidence for effectiveness of the micronutrient interventions addressed in this analysis (provision of multiple micronutrient and calcium supplements to pregnant women; wheat flour fortification with multiple micronutrients; and provision of micronutrient powders to children 6-23 mo). We also review, but do not include benefit cost ratio (BCR) calculations for addition of iodine to salt (salt iodization). In Section 3 we describe the methods and assumptions used to calculate the benefits and costs of these interventions in the context of Haiti. We conclude by summarizing the benefits and costs for the interventions, with consideration for results of sensitivity analyses and quality of the evidence.

2. Literature Review

Health outcomes and prevalence of micronutrient deficiencies in Haiti

Pregnancy is a critical time for infant development, and maternal nutrition during pregnancy can have immediate and long-term effects on child nutrition and health. Adverse birth outcomes, such as preterm birth and small-for-gestational age or low birth weight increase the risk of child mortality and have other long-term consequences (GBD 2015 DALYs and HALE collaborators, 2016). An estimated 21% of children born in the last 3 years in Haiti had low birth weight (<2500 g; although birth weight was reported in only 26% of births (Cayemittes et al., 2013) and the estimated preterm birth rate was 14.1% in 2010 (Blencowe et al., 2012).

According to the most recent DHS survey in Haiti, 49% of women of reproductive age and 65% of preschool children were anemic (Cayemittes et al., 2013). Anemia among pregnancy has been linked to adverse birth outcomes (Rahman et al., 2016). Anemia can be caused by many conditions, including certain infectious diseases (malaria, hookworm, HIV), nutritional deficiencies (iron, folate, vitamin B12), and other causes (e.g., blood loss), but iron deficiency is considered the primary cause of anemia across many settings (Kassebaum et al., 2010). Iron deficiency anemia is associated with reduced work capacity among adults and poor cognitive development among children (Balarajan et al., 2011).

Although nationally representative micronutrient surveys (i.e., those collecting information on specific indicators of micronutrient status from a representative population) have not been conducted recently in Haiti, available evidence suggests that some micronutrient deficiencies are common. For example, an earlier study estimated that the prevalence of vitamin A deficiency among young children in Haiti was 32% in 2005 (MSPP/UNICEF, 2005).

The high prevalence of anemia, together with the results of smaller studies in Haiti, suggests that iron deficiency is common. The Global Burden of Disease 2015 study estimated that iron-deficiency anemia was the leading cause of years lived with disability in Haiti (GBD 2015). For example, a 1998 study of 305 urban Haitian children (2-5 y of age) of low socioeconomic status found that 45% had iron deficiency, defined as ferritin concentrations <12 µg/L (Nicklas et al., 1998). In a randomized controlled trial among children 9-24 mo. old in rural Haiti (n=469), daily consumption of micronutrient powders containing 12.5 mg iron, 5 mg zinc, 400 µg vitamin A, 160 µg folic acid, and 30 mg vitamin C reduced anemia (anemia prevalence in the treatment vs control group was 24% vs 43%, respectively, after 2 months of intervention), indicating that one or more of these nutrients (likely iron) was limiting adequate hemoglobin synthesis (Menon et al., 2007).

The effect of folic acid supplementation or appropriate fortification around the time of conception on neural tube defects and subsequent infant mortality has been well documented (Blencowe et al., 2010; Arth et al., 2016; Atta et al., 2016), although differences exist in the methods used to predict the magnitude of the effect. Very little information is available on folate status of women in Haiti, but the estimated incidence of neural tube defects is 18 per 10,000 births (Food Fortification Initiative, 2017), which is three times higher than the estimated incidence of 5 per 10,000 births which is considered the 'underlying' incidence of neural tube defects in the presence of appropriate folic acid interventions (Arth et al., 2015).

Iodine is an essential nutrient that plays a key role in growth and development. Iodine deficiency in pregnancy and among infants and young children can lead to hypothyroidism, congenital abnormalities and impaired cognitive development (Delong, 1994). Iodine deficiency tends to be prevalent where soil iodine is low, particularly in mountainous areas (which cover ~75% of Haiti). Several previous surveys reported very low urinary iodine content (<50 µg/L) (Iodine Global Network, UNICEF, USAID, 2016). In addition, in 2004-2005, a national iodine survey revealed a median urinary iodine concentration (84 µg/L) that was low relative to the minimum threshold of 100 µg/L, and historically iodized salt represented a small proportion of available salt in Haiti (MSPP/UNICEF, 2005; Ngnie-Teta et al., 2012). Since then, it is possible that changes in available sources of dietary iodine (namely, increasing consumption of bouillon cubes containing iodized salt), may have contributed to increased iodine intake (Marhone et al., 2016). In 2015, in a small survey of preschool children 9-72 months of age in 3 geographic sites, median urinary iodine concentration was 128 µg/L, although median UIC was still low in the mountainous site (89 µg/L) (von Oettingen et al., 2016). However, this survey was only done in selected communities, so the national prevalence and distribution of iodine deficiency disorders is not known. Plans are underway to conduct a new survey of IDD levels in 2017/2018 (Omar Dary, personal communication).

Micronutrient intervention programs

The classes of interventions available to address micronutrient deficiencies typically include supplementation, fortification (large-scale industrial fortification of staples or condiments, or home fortification, such as with micronutrient powders), dietary diversification (increasing consumption of nutrient-dense foods, including breast milk), and "nutrition-sensitive" approaches, which include efforts such as agricultural programs, sanitation and hygiene interventions, and poverty reduction efforts. The latter of which are usually not designed specifically to address nutrition problems, but may nevertheless impact nutritional status through various pathways.

Dietary diversification and "nutrition-sensitive" interventions are theoretically preferable to supplementation and fortification, because they offer the opportunity to address multiple facets of inadequate dietary intake and/or nutritional status (compared to a focus on single nutrients). However, the amount and quality of the evidence for the efficacy, effectiveness, and cost-effectiveness of these interventions on nutritional status and other health outcomes has historically been limited, in part due to the complexity of these interventions. Thus, with consideration for the size and quality of the body of evidence, we focus on micronutrient supplementation and fortification interventions in this analysis, with the understanding that these interventions can be modified or even curtailed as poverty-reduction and other efforts succeed in raising incomes and improving diets. Specifically, we review the literature on 1) effectiveness of multiple micronutrient supplements delivered to pregnant women and risk of maternal anemia and adverse birth outcomes, 2) calcium supplementation of pregnant women and risk of maternal mortality (due to preeclampsia) and preterm birth, 3) wheat flour fortification with folic acid and preventable neural tube defects among newborns, 4) wheat flour fortification with iron and risk of iron deficiency anemia among multiple population groups, 5) multiple micronutrient powders and risk of anemia among children 6-23 mo., and 6) salt iodization and risk of iodine deficiency disorders.

Effectiveness of selected interventions on health outcomes

Multiple micronutrient supplements and calcium supplements delivered to pregnant women.

A recent meta-analysis examined randomized controlled trails of daily iron supplementation to pregnant women and a variety of outcomes, including iron deficiency anemia (Peña-Rosas et al., 2015). The pooled risk ratio from 3 trials of maternal iron and folic acid supplementation on maternal anemia at 37 weeks gestational age was 0.34 (95% CI: 0.21, 0.54). In addition, the authors identified a single study that reported iron deficiency anemia as the outcome, which reported a risk ratio of 0.43 (95% CI: 0.17, 1.09). Six trials compared the effects of daily iron supplementation versus the same supplements without iron or no treatment/placebo on iron deficiency anemia at term; the overall risk ratio was 0.33 (95% CI: 0.16, 0.69). Among the 5 trials that examined the effects of supplementation among women who were anemic at the start of supplementation, the pooled risk ratio was 0.39 (95% CI: 0.20, 0.74). Estimates have also suggested that iron supplements could reduce the risk of low birth weight by a marginally significant 16% (RR=0.84, 95% CI: 0.69, 1.03).

Multiple micronutrient supplements have been compared to iron or iron and folic acid supplements in a total of nineteen trials, of which 17 were included in a recent systematic review representing data from 137,791 women (Haider and Bhutta, 2015). This analysis concluded that multiple micronutrient supplementation was associated with a statistically significant reduction in low birth weight of 12% (RR=0.88; 95% CI: 0.85-0.90) and small for gestational age of 9% (RR=0.91; 95% CI: 0.84-0.99). On the other hand, multiple micronutrient supplements were no better than iron or iron and folic acid supplements in reducing the risk of maternal anemia.

High blood pressure during pregnancy can increase the risk of maternal and perinatal morbidity and mortality. Hypertensive disorders are a significant risk factor for preterm birth, which is the leading cause of neonatal and infant mortality in low and middle income countries (GBD 2015 DALYs and HALE collaborators, 2016). Calcium supplementation during pregnancy offers a potential intervention to reduce hypertension, thereby reducing the risk of preeclampsia and eclampsia, preterm birth, and maternal and infant mortality. The most recent meta-analysis on the topic included a total of 13 high-quality trials that enrolled 15,730 women (Hofmeyr et al., 2014). Pooled estimates suggested that this intervention has the potential to reduce the risk of pre-eclampsia (RR=0.45; 95% CI: 0.31, 0.65) and preterm birth (RR=0.76; 95% CI: 0.60, 0.97). The risk of maternal mortality and serious morbidity and found that supplementation was associated with a 20% reduction in risk of this composite outcome (RR=0.80; 95% CI: 0.65, 0.97). In general, effect sizes were larger in populations with low calcium diets and in studies of women at elevated risk of preeclampsia.

A major limitation for the present literature, however, is the lack of available data from research trials in Haiti. While there have been some randomized controlled trials of micronutrient interventions in preschool and school-aged children in Haiti, our search did not uncover any studies of maternal supplementation.

Wheat flour fortification with multiple micronutrients

Wheat flour can be fortified with a number of vitamins and minerals. Haiti currently has legislation for mandatory wheat flour fortification with iron, niacin, riboflavin, and thiamin, although the chemical form of iron is not clear. Forms of iron differ in their cost, likelihood of reacting with the food matrix, and in their bioavailability (absorption). Fortification with inappropriate iron compounds will hinder program effectiveness (Hurrell et al., 2010); guidelines are available to inform program design (Allen et al., 2006). In this analysis, we model the impact of fortification with an appropriate iron compound, such as ferrous fumarate, and addition of folic acid to the premix to reduce the incidence of neural tube defects.

Numerous studies have documented the efficacy and effectiveness of fortification with iron for reducing iron deficiency, anemia, and iron deficiency anemia among diverse population groups (Das et al., 2013). In a meta-analysis of 15 studies of preschool and school-aged children (n=3,096 participants), the combined RR for fortification with iron on anemia was 0.55 (95% CI: 0.42, 0.72) (Das et al., 2013). Among these studies, the effect for processed commercial foods (weaning foods, dairy products, and noodles) on anemia was RR=0.46 (95% CI: 0.28, 0.76; 10 studies), and the effect for staple foods was RR=0.81 (95% CI: 0.60, 1.10; 5 studies); both types of products significantly increased hemoglobin concentrations.

Among women, Das et al. reported a combined RR of 0.68 (95% CI: 0.49, 0.93) for 3 studies (n=1,180) on the effect of iron fortification on anemia among women (staple foods: RR=0.67 (95% CI: 0.39, 1.17) from 2 studies). The authors rated the quality of the body of evidence on iron fortification as “moderate” based on the WHO GRADE criteria (Guyatt et al., 2008), possibly reflecting the mixture of randomized and non-randomized studies. These results were generally consistent with those of an earlier meta-analysis which reported a significant increase in hemoglobin and reduced risk of anemia (RR = 0.59, 95% CI: 0.48, 0.71) and iron deficiency (RR = 0.48, 95% CI: 0.38, 0.62) in 60 randomized controlled trials of iron fortification or biofortification of various foods among different population groups (Gera et al., 2012).

A recent systematic review summarized the results of 13 studies of 26 subgroups of women and children exposed to government-supported, large-scale fortification programs (with pre- and post-fortification comparisons) (Pachón et al., 2015). The results of these studies were mixed (reduced prevalence of anemia in 4 of 13 subgroups of children and 4 of 12 subgroups of women), possibly due to variation in program compliance by industries (low or not reported in some studies) and/or flour consumption in the different study populations.

Blencowe et al. reviewed studies on the effects of periconceptual folic acid supplementation or fortification on the incidence of neural tube defects (Blencowe et al., 2010). In this paper, a meta-analysis of 8 studies of folic acid fortification indicated an overall 46% reduction in neural tube defects (RR=0.54, 95% CI: 0.46, 0.63); for comparison, a meta-analysis of one controlled trial and three observational studies that controlled for confounding reported a reduction of 62% (RR=0.38, 95% CI: 0.29, 0.51). Because the percent reduction in neural tube defects following folic acid fortification may depend on the initial birth prevalence in the population, an alternative model for estimating the effect of fortification has been proposed by Arth et al. This method posits that there is a consistent underlying rate of neural tube defects which will not respond to folic acid fortification. This rate is estimated to be 5 per 10,000 births and is drawn from the rates in populations considered 'fully covered' by folic acid fortification. The number of cases of NTDs that could be prevented by folic acid fortification ("folic acid preventable spina bifida and anencephaly") is then estimated by subtracting this underlying rate from the observed NTD rate prior to fortification.

Micronutrient powders

Micronutrient powders consist of small sachets (~1 gram) containing a powdered micronutrient mixture. This strategy is referred to as "home fortification" or "point-of-use fortification" because caregivers of young children are instructed to mix the sachet contents with the child's food immediately prior to feeding the child. Different formulations are available, with the number of micronutrients ranging from 3 to 16 (Salam et al., 2013); different dosing schemes have also been employed (different age groups, and frequency and duration of consumption). The suggested scheme put forth in the WHO guideline is to provide one sachet per day (containing at least iron, vitamin A, and zinc) for a minimum of 2 months to infants and children 6-23 months of age in populations where the prevalence of anemia is 20% or higher (WHO, 2011).

In preparing evidence to formulate the WHO guideline on MNP, the advisory committee considered the critical endpoints to be anemia and hemoglobin, iron status and growth (WHO, 2011; De-Regil et al., 2011). In this review of 8 trials, there were no apparent effects of MNP on child growth (weight-for-age, height-for-age, or weight-for-length Z-scores), but significant reductions in anemia and iron deficiency prevalence were observed for MNP compared to placebo or no intervention. Specifically, among 6 randomized controlled trials, the average relative risk (RR) for anemia was 0.69 (95% confidence interval: 0.60, 0.78), i.e., a 31% reduction in anemia among children who received MNP (WHO, 2011). In addition, iron deficiency was reduced among infants and young children in 4 trials (RR: 0.49, 95% CI: 0.35, 0.67). Quality of the evidence was considered to be moderate for anemia and high for iron deficiency by the authors of this review.

An effectiveness trial evaluating the effects of MNP consumption on anemia among children was conducted in Haiti (Menon et al., 2007). Children 9 to 24 months of age were randomly assigned to receive MNP and fortified wheat-soy blend, or the fortified wheat-soy blend only. After 2 months, the prevalence of anemia decreased from 54% to 24% in the MNP group, and rose slightly from 39% to 43% in the comparison group (wheat-soy blend only). At a final assessment ~6-7 months after the supplementation period ended, 92% of children in the MNP arm who were non-anemic after the 2-month supplementation period remained non-anemic. This study indicates that a treatment regimen of providing a 2-month supply of MNP every 6 months could be effective in achieving a sustained reduction in anemia prevalence among children in the Haitian context, given a constant supply of the product and adequate compliance by the children's caregivers.

Because the MNP sachets include multiple micronutrients, several potential benefits might be expected in addition to reductions in iron deficiency anemia. A systematic review of 17 randomized, controlled trials published reported the effects of MNP on anemia, iron deficiency, vitamin A deficiency, zinc deficiency, anthropometric outcomes, and selected morbidity outcomes (Salam et al., 2013). As in the previous review, the authors reported that MNP significantly reduced the prevalence of anemia and iron deficiency anemia (with reductions of similar magnitude to the

2011 review by De-Regil et al.), but had no impact on anthropometric outcomes, including stunting. Additionally, this review reported no impacts on serum zinc (as a marker of zinc deficiency), and a slight increase in diarrhea among children who received MNP (RR: 1.04, 95% CI: 1.01, 1.06).

There was, however, a moderate reduction in prevalence of low serum retinol (a marker of vitamin A deficiency): RR: 0.79, 95% CI: 0.64, 0.98 based on 3 studies with durations of 6-12 months (Salam et al., 2013). A subsequent study also reported reduction in vitamin A deficiency prevalence among children who received MNP for 2-3 months compared to controls, although group allocation was not randomized (Silva et al., 2016). Among 5 trials in which indicators of vitamin A status were measured following provision of MNP to children, 2 trials showed no effect (Jack et al., 2012; Varma et al., 2007); the remaining 3 provided MNP for 8-12 months (Kumar and Rajagopalan, 2007; Suchdev et al., 2012; Osei et al., 2010), although in one of these trials consumption was infrequent, ~0.9 sachet/wk. (Suchdev et al., 2012). Thus, there is evidence that MNP reduces vitamin A deficiency, but direct evidence for a sustained (6 month) impact of the 2-month dosing period followed by 3-4 months without MNP, as suggested by the WHO guideline on MNP, is lacking.

Salt iodization

Introduction of iodized salt is considered a public health success in many parts of the world, where reductions in iodine deficiency disorders have been observed (UNICEF, 2008); a meta-analysis that included various study designs (randomized controlled trials, non-randomized controlled trials, quasi-experimental studies, cohort studies, and multiple cross-sectional studies) reported reductions in goiter, cretinism, and low intelligence in response to iodized salt (Aburto et al., 2014). Hence, this program is recommended to reduce consequences of iodine deficiency (WHO, 2014).

However, the magnitude and timing of expected benefits of salt iodization depends in large part of the structure of the edible salt industry in Haiti, which currently consists of thousands of small-scale salt producers and a single processor. According to a report of a 2016 technical interagency visit on the Haiti Iodine Deficiency Disorders Prevent Program, 62% of edible salt available in Haiti is discretionary (i.e., used as salt applied to foods at household level) (Iodine Global Network, UNICEF, USAID, 2016). Most of this salt comes from small-scale salt producers who produce coarse salt, which is not suitable for iodization. Thus, in the absence of appropriate processing capacity, very little salt is food-grade, much less iodized. In the most recent Demographic and Health Survey in Haiti, among salt samples collected from households, 26.1% were iodized in urban areas and 12.6% were iodized in rural areas (Cayemittes et al., 2014).

Program efforts to increase production of food-grade salt and introduce salt iodization by small-scale producers (such as creating cooperatives) have been implemented in other countries, but in general these do not appear to have led to sustained production of high-quality, iodized salt by a large majority of small-scale salt producers. If these projects serve as a guide for a Haitian intervention, very large investments and a long time frame would likely be necessary to achieve results with this approach in Haiti, and the benefit: cost ratio would be low.

Through a partnership between the University of Notre Dame Haiti Program (UNDHP) and the Haitian government, there are now 2 facilities that produce good-quality fortified salt, together supplying about 12% of national edible salt (~3,600 MT) availability at the time of the report (Iodine Global Network, UNICEF, USAID, 2016). The program capacity is currently being doubled and will be closer to 25% by the end of the expansion. This group focuses on distribution to retail, food service, and food processing segments; thus iodized salt is made available in food products such as bread.

An estimated 29% of salt availability in Haiti (~8,800 MT) is supplied by bouillon cubes (composed of 48-60% salt), which are imported or produced locally using imported iodized salt (Iodine Global Network, UNICEF, USAID, 2016). The iodine content of this salt is high, at 60 mg/kg. This source of iodized edible salt may be expected to grow as bouillon cube consumption increases, which reduces the overall benefits that a national salt iodization program would be expected to deliver. Our analysis of household survey data from the L'Enquête sur les Conditions de Vie des Ménages Après Séism (ECVMAS) indicated that both bouillon cubes (Maggi) and salt were consumed by more than 90% of urban and rural households in the previous week (**Table 1**). Thus, bouillon cubes produced with iodized salt represent a source of dietary iodine that is already available and widely consumed.

An additional consideration is that total estimated salt consumption in Haiti (7.5-7.7 g/d) is quite high in relation to the recommended limit of 2 grams sodium per day (5 grams salt per day). WHO has suggested that sodium (and salt) intake should be reduced to avoid health consequences such as high blood pressure and risk of cardiovascular disease (WHO, 2012). These efforts would be compatible with continued promotion of iodization of salt in processed foods and, if feasible, table salt. Regular monitoring of population iodine status would be necessary to recognize if and when adjustments to the amount of iodine added to salt should be made.

Given the estimates provided by the interagency report, it is possible that the UNDHP and bouillon cube salt alone could supply sufficient iodine for the population on average. This information suggests that costly efforts to ensure universal salt iodization may not be needed if sufficient iodine is provided through other sources (bouillon cube, and bread and other processed foods). Thus, the report suggests a shift in framework from universal salt iodization, salt producer efforts, and retail consumer education to IDD-prevention, salt processing efforts, and food-processing education. If alternative sources of iodized salt (rather than table salt) do indeed provide the bulk of the benefits associated with reducing iodine deficiencies in Haiti, the benefit: cost ratio of a new program focused on universal salt iodization might be low. Therefore, detailed calculations of the costs and benefits of universal salt iodization were not conducted for this report. Because recent data on markers of iodine consumption are not available, questions remain regarding to extent to which the ‘food pathways’ (bread, bouillon cube, etc.) could deliver sufficient iodine to resolve deficiencies, so the need for complementary programs such as salt iodization is uncertain. A detailed study of iodine status and sodium consumption is currently underway in Haiti (Omar Dary, personal communication). The situation should be reviewed following results of the current survey to confirm whether iodine deficiency is still widespread despite the current food supply.

Table 1. Proportion of households reported consuming salt or Maggi (bouillon cube) in the past 7 days, by urban or rural residence

	Total metro and urban (%)	Rural (%)
Salt	96	97
Maggi	94	96

Source: Authors' calculations from ECVMAS data. Note that Maggi is a brand of bouillon cube; anecdotally, the term "Maggi" is used to refer to all bouillon cubes, but it is not clear whether the ECVMAS data reflect on the brand Maggi, or all bouillon cube.

3. Calculation of Costs and Benefits

We used an "ingredients" approach to estimate the costs of scaling up 1) delivery of multiple micronutrient and calcium supplements to pregnant women, 2) wheat flour fortification with multiple micronutrients, including iron and folic acid, and 3) delivery of micronutrient powders to young children. Resources and unit costs were estimated from published values, where available, and personal communications from local contacts and topic experts. Benefits were estimated by estimating the size of the target population and calculating the years of life lost (YLL) and disability-adjusted life years (DALYs) averted through deployment of these interventions at assumed levels of target population coverage. Benefits are valued as multiples of GDP per capita. We computed average costs and benefits over a 12-year time frame, to allow sufficient time for scaling up each of the programs.

Intervention 1: Delivery of multiple micronutrient and calcium supplements to pregnant women.

Costs

Costs have been divided into three categories: 1) costs for supplement procurement, transport, and storage; 2) costs for health care time to manage the additional supplement distribution efforts; and 3) training, coordination and supervision.

Supplement costs: Costs assume that an 8-mo supply of MN+Ca is purchased for each woman reached. WHO recommends daily supplementation with 1 tablet of MN plus consumption of 1.5-2.0 g of oral elemental calcium. The latter equates to roughly 6 tablets of Ca, based on typical tablet dosages of 250 mg. We have assumed a cost of $0.0575/tablet for MN and $0.015/tablet for Ca based on the International Drug Price Indicator Guide. To estimate transport and storage costs, we have assumed a weight of approximately 2 g per tablet, including packaging. We have assumed a transport cost of $0.33 per metric ton of supplements per kilometer and an average transport distance of 250 km. We have estimated that storage costs based on an estimate of 200 cases of supplements (10,000 tablets /case) per storage room and $6000 per room annually. All costs have been summed and converted from USD into Gourdes.

Health worker costs: We have assumed that supplements will be delivered through the health care system during antenatal care (ANC) visits. According to recent estimates, ANC coverage is relatively high with approximately 74% of urban women and 60% of rural women attending the recommended minimum of 4 visits during their pregnancy (DHS, 2012). While health workers have many responsibilities and this will be only one of many, we have estimated the added burden for this activity and the additional staff that would need to be hired to manage this effort on top of existing workloads. To estimate the time burden on health workers, we assumed four antenatal care (ANC) visits per pregnant woman and two months supplies of supplements provided to women at each visit (assuming that the first visit takes places soon after the first month of pregnancy). Communication with women about the supplements and providing new supplies will require at least 10 minutes per ANC visit.

Rural areas can be more difficult to reach and more difficult for women to travel from their home to the health facility. We have therefore included an additional push to increase ANC coverage in rural areas by including costs for home visits for women who attend less than the recommended visits. We have assumed that home visit ANC workers could only visit a maximum of 3 women per day due to travel time.

We have assumed the annual salary for health workers is 4830 Gourdes / month. To manage the additional workforce requirements, we have assumed that one supervisor will be required per 20 additional full time equivalent health care workers and that supervisors' salaries exceed that of their staff by 30%.

Training and scaling up: We have assumed that existing and additional ANC staff will need training on this new activity in the first year of implementation. Two days of training focused on micronutrients during pregnancy, supplement distribution guidelines, and methods of behavior change communication promoting supplement adherence would be required during the first year plus an additional 1 day every 6 months for refresher trainings. In subsequent years, we have assumed a staff turnover rate of 10%. Costs to develop the training curriculum, prepare for the training, and to cover the costs of the trainers were estimated at a fixed rate of $50,000 in the first year and an additional $5000 each subsequent year plus a daily salary estimate per training day per health worker. We have also assumed a fixed cost for printing pamphlets, posters, and other printed behavior change promotional materials.

With the additional investment to improve ANC services, we have assumed an upward shift in ANC attendance by 5 percentage points per year for women in urban areas and 2.5 percentage points per year for women in rural areas. We have assumed this slower rate of increase in rural areas, acknowledging the difficulties in providing services in these more remote parts of the country, even with additional investments. With this assumption, we have projected that 90% of women would have the targeted supplement distribution within four years.

Benefits

We defined intervention coverage as the proportion of optimal visits achieved, with optimal defined as 4 antenatal care visits per pregnancy with supplements delivered. Benefits were applied proportional to the ANC coverage rates.

Program benefits were estimated as the sum of DALYs averted due to 1) reduction in maternal anemia and 2) child deaths avoided due to improved birth outcomes (reduction in stillbirths), and 3) years of disability avoided due to reduction in low birth weight, each attributable to maternal supplementation with multiple micronutrients; and 4) maternal deaths avoided due to reduction in pre-eclampsia, 5) child deaths avoided due to reduction in preterm birth, and 6) years of life with disability avoided due to reduction in preterm birth, each attributable to maternal supplementation with calcium. We additionally estimated potential productivity gains due to cases of low birth weight averted using estimates from Alderman and Behrman (2006). DALYs were calculated according to Fox-Rusby and Hanson (2001) without age weights, and using discount rates of 3%, 5% or 12%. We applied disability weights from the Global Burden of Disease, 2015.

Reduction in maternal anemia

Based on a meta-analysis of randomized, controlled supplementation trials which examined the effects of daily iron + folic acid supplementation on anemia among pregnant woman (Peña-Rosas et al., 2015), we applied a 66% reduction in anemia (Risk Ratio = 0.34). We applied this effect to all women estimated to have anemia who were covered by the program. We estimated DALYs for anemia reduction using separate disability weights for mild, moderate, and severe anemia (using proportions estimated from DHS 2012, and assuming the same percent reduction for each category of anemia).

Reduction in stillbirths

The stillbirth rate was estimated to be 15 per 1,000 births, according to WHO estimates (http://www.who.int/maternal_child_adolescent/epidemiology/profiles/neonatal_child/hti.pdf). We applied a risk ratio of 0.92 (i.e., 8% reduction) for reduction of stillbirths, based on a Cochrane review of trials among women supplemented with multiple micronutrients compared to iron and folic acid only (Haider and Bhutta, 2015).

Years of disability avoided due to low birthweight reduction

Incidence of low birth weight was taken from the most recent Haiti DHS data (2012). Studies comparing multiple micronutrient supplements to placebo are not available, so we combined pooled risk ratios (assuming an additive effect) of studies of iron+ folic acid vs placebo (Pena-Rosas et al., 2015) and multiple micronutrient supplements vs iron+folic acid (Haider and Bhutta, 2015).

Productivity losses avoided due to low birthweight reduction

Alderman and Behrman (2006) have estimated that low birth weight can account for an approximate 7.5% loss in potential productivity. Applying this to the population mean salary estimate (from assumptions provided by the Copenhagen Consensus group), we calculated the net present value of the lifetime earnings at 3%, 5%, and 12% discount rates.

Reduction in maternal deaths due to pre-eclampsia

We applied a risk ratio of 0.80 (20% reduction) for reduction in maternal deaths due to calcium supplementation, among women covered by the intervention, based on a recent Cochrane review (Hofmeyr et al., 2010). DALYs were calculated using an assumed age of death of 25 years.

Death and disability avoided due to reduction in preterm birth

We applied estimates of deaths due to complications from preterm birth from UNICEF (http://www.who.int/pmnch/media/news/2012/preterm_birth_report/en/index5.html) and applied a risk ratio of 0.76 for reduction in preterm birth from maternal calcium supplementation (Hofmeyr et al., 2010). Preterm birth is associated with a number of long-term impairments, including retinopathy, motor impairments, and cognitive impairments, the severity of which is dependent upon the degree of prematurity. We had no data upon which we could draw the current situation of gestational age of birth among survivors of preterm birth in Haiti. We have therefore assumed that most of the survivors would have been near-term births (32-36 weeks gestation) and we have estimated long-term disability from preterm birth based on mild-moderate motor and cognitive impairment. Thus, the estimated DALYs for preterm birth may be underestimated.

Benefit-Cost Analyses

With DALYs valued at 1XGDP, the benefit: cost ratio ranges from 6 (3% discount rate) to 2 (12% discount rate)(**Table 2**).

Table 2. Benefits, Costs, and Benefit-Cost Ratios at different discount rates

Intervention	Discount	Benefit (in gourdes) (DALY value = 1xGDP)	Cost (in gourdes)	BCR
Multiple micronutrients and calcium in pregnancy	3%	52,556,371,712	8,608,059,239	6
	5%	30,425,572,341	7,637,956,645	4
	12%	8,350,723,777	5,277,011,789	2

Sensitivity analyses

Ensuring that pregnant women are reached by antenatal care services is challenge in low-income settings. We conducted a sensitivity analysis to determine the benefit-cost ratios of maternal supplementation at different levels of achieved coverage. We examine the benefit-cost ratios at coverage rates of 30% and 60% (assuming that both benefits and selected costs (supplement procurement, health worker time) are proportional to program reach). DHS 2012 data indicate that 30% of women took 90+ iron supplements during the course of pregnancy; thus, we adopt this as a minimum estimate for the number of women who would take a full regiment of micronutrient supplements. Under this scenario, we have assumed that ANC visit frequency remained constant with the current rates and program promotional costs remained high, but supplement usage was low. This is therefore a lower bound of an estimated benefit cost calculation. It suggests that a minimum coverage of 60% would be needed under the conservative 12% discount rate in order for the benefits to exceed the costs (**Table 3**). In DHS 2012, data indicate that 90% of women attended at least one antenatal care visit, suggesting that with adequate behavior change communication, program reach could likely exceed this minimum threshold.

Table 3. Benefits, Costs, and Benefit-Cost Ratios at different levels of program coverage

Coverage (% of optimal ANC visits in which supplements were delivered)	Discount Rate	Present value of total benefits (DALYs valued at 1XGDP)	Present value of total costs	Benefit-Cost Ratio
30% (all years)	3%	17,217,939,947	8,459,347,074	2
	5%	10,003,179,345	7,509,653,832	1
	12%	2,779,708,892	5,197,080,318	1
60% (all years)	3%	34,435,879,895	8,459,347,074	4
	5%	20,006,358,690	7,509,653,832	3
	12%	5,559,417,784	5,197,080,318	1

Notes: Benefit-cost ratios are rounded to the nearest whole number. Benefit-cost ratios close to 1 were: 30% coverage, 5% discount rate: 1.3; 30% coverage, 12% discount rate: 0.5; 60% coverage, 12% discount rate: 1.1

Intervention 2: Wheat flour fortification with multiple micronutrients, including iron and folic acid

Wheat is not grown in Haiti, but large amounts of raw wheat are imported and milled in country. Wheat flour is also imported directly (estimated to be ~13% of total wheat products imported) (Food Fortification Initiative, 2017), and we consider this to be a candidate for fortification, as norms can be rewritten to mandate fortification of imported flour. We assumed that a single program monitoring strategy, and associated costs, would cover both imported and domestically milled wheat flour.

Costs

The largest mill in Haiti was estimated in 2011 to have a production capacity of 80-85% of national demand (Alvarado, 2012). Although fortification is mandatory in Haiti (Food Fortification Initiative, 2017), our correspondence suggests that the flour is not fortified. Thus, we assumed that setup costs would be provided to the primary mill and two potential smaller mills as required for a new program: dosing equipment, internal monitoring equipment, and miller training. In addition, costs were included for meetings and trainings to reformulate the norms to include folic acid in the premix (current policy specifies iron, but not folic acid (Food Fortification Initiative, 2017)). An additional consideration in this process will be the price of flour and related products, and the potential need to raise prices to cover the cost of premix. We also included estimated costs for a national survey of micronutrient status, to be conducted prior to scale-up of the fortification program, to verify the need for the program and to serve as a baseline for later impact evaluation of the effect of the program on micronutrient status, as recommended by WHO guidelines on food fortification (Allen et al., 2006). As of 2011, there was no external reference laboratory with capacity to measure candidate nutrients such as iron, so costs are included for equipment and training for a lab to measure food samples.

The bulk of recurring costs are for concentrated micronutrient premix, including the product cost, taxes, and shipping. Premix costs depends on the types and amounts of nutrients included in the formula. Premix cost estimates from the Food Fortification Initiative for multi-micronutrient formulations ranged from US$1.5-2.9, excluding shipping costs (Sarah Zimmermann, personal communication). We thus assumed premix cost of $2.65 per metric ton of wheat milled, increased by 50% to $4 per metric ton, to account for shipping, taxes, and premix loss. This estimates if for a premix containing a minimum of iron and folic acid, the two nutrients for which relevant nutritional benefits were estimated. A sensitivity analysis including the cost of premix including additional essential nutrients, such as vitamin A, zinc, and other B vitamins, is included below. Total cost of premix was calculated by multiplying the cost per metric ton by the total wheat product supply (estimated from FAO Food Balance Sheets to be 166,000 metric tons in 2013, the most recent year available).

The second category of recurring costs is for program monitoring, including one full-time position (based on CC-provided assumptions of average monthly salary), 2 coordination meetings per year, and travel costs for inspections and sample collection. The cost of consumable supplies for fortified food analysis is included, assuming weekly analysis of 20 samples (1,040 samples yearly; an intensive monitoring program) using a rapid analyzer device (assuming $10/sample, including reagent cost, shipping, and taxes).

As noted above, efficacy studies have demonstrated the effects of flour fortification on anemia; however, industry compliance may limit the effects in practice. Thus, we include costs for a full-time monitoring position, in addition to travel, analytical supplies, and support for coordination meetings, to reflect the efforts needed to ensure that the program is implemented as planned. We do not, however, include costs for promotion of fortified wheat flour to the public, as there is evidence that fortification programs can be effective in the absence of sustained social promotion, and limited evidence that behavior change messages increase the purchase and consumption of fortified versions of staple foods by consumers (this may be different for fortified processed foods such as instant noodles or beverages that are marketed as providing health benefits through added nutrients). As an example, work in Cameroon showed that although <5% of women in a representative survey of urban areas were familiar with the wheat flour fortification program, > 80% of women had consumed wheat flour in the past week and iron and folate status of women increased following fortification (Engle-Stone et al., in review).

Benefits

The predicted benefits of wheat flour fortification comprise 1) reduction in years of life lost due to neural tube defects in infants and 2) reduction in disability-adjusted life years through anemia reduction among women of reproductive age (15-49 y), school-age children (5-14 y), and preschool children (6-59 mo.).

Wheat flour consumption

The benefits of food fortification accrue only to individuals who routinely consume the fortified foods. We analyzed ECVMAS data to estimate the proportion of rural and urban households that routinely purchase wheat flour and its products. The ECVMAS food list includes wheat flour, bread, and biscuits or beignets; >90% of both urban and rural households had consumed any of these products in the previous 7 days, owing largely to consumption of bread (Table 4). However, daily consumption of bread was reported by only 18-23% of households. Quantitative data on the amount of wheat flour consumed by individual household members would be necessary to estimate the impact of flour fortification on adequacy of micronutrient intakes. For the purpose of this analysis, we selected a weekly household frequency of bread consumption of ≥3-4 days per week as the best estimate of the proportion of the population likely to benefit from flour fortification (41% of urban households; 34% of rural households).

The proportion of wheat flour that is adequately fortified (at target levels) was assumed to increase gradually over time as the program scales up (0% Y1, Y2; 50% Y3, 75% Y4, 85% Y5, and 95% thereafter). Sensitivity analyses related to these critical assumptions (proportion of regular wheat flour consumers, and proportion of flour adequately fortified) are presented below.

Table 4. Proportion of households reporting consumption of wheat flour and products in the previous 7 days.

	Total metro and urban (%)	Rural (%)
Any wheat flour and products in past 7 days	94	90
Any wheat flour in past 7 days	36	35
Any biscuit or beignet in past 7 days	20	10
Any bread in past 7 days	93	88
Bread purchased at least 3-4 times in last 7 days	41	34
Bread purchased daily or every other day in past 7 days	33	27
Bread purchased daily in past 7 days	23	18

*Source: Authors' calculations from ECVMAS data.

Deaths averted due to reduction in spina bifida and anencephaly

The effect of fortification on neural tube defects was estimated according to the method presented in Arth et al., 2016. As described above, this method categorizes neutral tube defects into 1) conditions that are not preventable by folic acid, which are considered to occur at a rate of 5 per 10,000 live births regardless of folic acid intervention, and 2) "folic-acid preventable spina bifida and anencephaly", which can occur at varying rates depending on the population. The estimated prevalence of NTDs among live births in Haiti was 18/10,000 (Food Fortification Initiative, 2017); subtracting the underlying non-folic acid preventable rate (assumed to be 5/10,000) yields 13/10,000 cases that are potentially preventable by folic acid. Based average per capita wheat flour availability in the food supply (44 g/d; FAO Food Balance Sheets), fortification of all flour at 5 mg/kg would provide, on average, an additional 220 µg folic acid per day, above the threshold of 200 µg/d suggested as necessary to prevent all FAPSBA (Arth et al.). To predict the proportion of folic acid-preventable spina bifida and anencephaly that would be averted by fortification, the number of cases of FAPSBA was then multiplied by the proportion of the population that regularly consumes wheat flour (minimum of 3-4 times/week, as described above), and the proportion of wheat flour assumed to be adequately fortified, an adaptation of the approach outline by Arth et al. In high-income settings, the mortality rate for anencephaly is 100%, but approximately 25% of spina bifida cases survive past 5 years of age (G. Oakley, personal communication). The mortality rate for spina bifida in a setting with poor health infrastructure is unknown but is likely to be higher than in areas with strong health care systems. For simplicity, we assumed 100% mortality at birth for both folic acid-preventable neural tube defects (anencephaly and spina bifida). Years of life lost were calculated as 63.5 years (undiscounted) per death.

DALYs averted through reduction in iron-deficiency anemia

To estimate the effect of fortified flour consumption on anemia prevalence, we applied benefits of fortified flour consumption only to regular consumers of wheat flour who consume flour that is adequately fortified. Among this subset, the reduction in the prevalence of anemia among women and children (preschool and school-age) was calculated using estimates from a recent meta-analysis of the effect of iron fortification on anemia (Das et al., 2013). In the meta-analysis, the relative risk was 0.55 (45% reduction) in anemia among children for all forms of iron fortification. Because the relative risk for staple food fortification with iron was lower, we applied the reduction in anemia prevalence only to the proportion of anemia cases estimated to be due to iron deficiency (under the assumption that 50% of anemia is due to iron deficiency, consistent with estimates for the Caribbean reported in Black et al., 2013). Thus, the overall effect of iron fortification on anemia was 45% x 50%, which is more consistent with the RR= 0.81 reported for staple food fortification among young children. For women, we followed the same procedure, but applying the overall RR for iron fortification for women (RR: 0.68, 95% CI: 0.49, 0.93) to the 50% of anemia cases that were estimated to be due to iron deficiency.

DALYs were calculated according to Fox-Rusby and Hanson (2001) without age weight, using disability weights from the Global Burden of Disease 2015, and assuming a one-year duration (i.e., individuals are protected from anemia only during the years during which they are consuming adequately fortified flour). Separate disability weights were included for mild and moderate anemia (proportions estimated from DHS 2012).

Benefit-Cost Analyses

With DALYs valued at 1XGDP, the benefit: cost ratio ranges from 9 (3% discount rate) to 6 (12% discount rate)(**Table 5**).

Table 5. Benefits, Costs, and Benefit-Cost Ratios at different discount rates

Intervention	Discount	Benefit	Cost	BCR
Wheat flour fortification with multiple micronutrients	3%	3,551,263,161	376,300,834	9
	5%	2,646,021,438	331,312,834	8
	12%	1,313,937,192	222,722,324	6

Notes: Analysis assumes DALYs are valued at 1XGDP.

Sensitivity analyses

Monitoring of fortification programs and ensuring adherence to technical standards can be challenging in low-resource settings (Luthringer et al., 2015). We conducted a sensitivity analysis to assess the combined effects of 1) various assumptions regarding the proportion of the population regularly consuming wheat flour, and 2) the proportion of wheat flour fortified at target levels. The results indicate that the benefit: cost ratios are favorable even at very low levels of reach and program compliance (**Table 6**).

Table 6. Benefits, Costs, and Benefit-Cost Ratios at different levels of program compliance

Reach (% of households consuming wheat flour)	Compliance (% of flour adequately fortified)	Benefit-Cost Ratio
90%	0% Y1-2; 90% Y3-12	19
	0% Y1-2; 60% Y3-12	17
	0% Y1-2; 30% Y3-12	13
70%	0% Y1-2; 90% Y3-12	15
	0% Y1-2; 60% Y3-12	13
	0% Y1-2; 30% Y3-12	10
40%	0% Y1-2; 90% Y3-12	8
	0% Y1-2; 60% Y3-12	8
	0% Y1-2; 30% Y3-12	6
20%	0% Y1-2; 90% Y3-12	4
	0% Y1-2; 60% Y3-12	4
	0% Y1-2; 30% Y3-12	3

Notes: All figures assume a 5% discount rate and DALYs valued at 1XGDP. Reach values of 20%, 40%, and 90% were based roughly on the proportion of households that consumed bread daily, at least every 3-4 days, and at least once per week, respectively, from the authors' analysis of ECVMAS data.

Additionally, the effect of staple food fortification on anemia may be attenuated among very young children who may consume relatively small quantities of staple foods relative to their high micronutrient requirements. In a subset of 5 studies of staple food fortification (as opposed to processed foods) reviewed by Das et al. (2013), the RR for anemia reduction was 0.81 (95% CI: 0.60, 1.10), but a positive effect was observed on hemoglobin concentrations (standard mean difference = 0.44; 95% CI: 0.10, 0.79). We conducted a sensitivity analysis to assess the BCR assuming reductions in anemia 1) only among women of reproductive age, 2) among women and school-age children only, and 3) among women, school-age children, and preschool children, while keeping program costs constant (Table 7). The results indicate that the benefit: cost ratios are favorable, even when potential reductions in anemia prevalence among children are excluded.

Table 7. Benefits, Costs, and Benefit-Cost Ratios assuming effects on iron deficiency anemia among various target beneficiary groups

Compliance (% of flour adequately fortified)	Group(s) benefiting from anemia reduction	Benefit-Cost Ratio
0% Y1, Y2; 50% Y3, 75% Y4, 85% Y5, and 95% Y6-12	WRA, SAC, PSC	8
	WRA, SAC	6
	WRA	4

Notes: All figures assume a 5% discount rate and DALYs valued at 1XGDP. Reach values of 41% urban and 34% rural were based on the proportion of households that consumed bread at least every 3-4 days, from the authors' analysis of ECVMAS data. PSC, pre-school age children; SAC, school-age children; WRA, women of reproductive age. BCR also includes DALYs from deaths averted from neural tube defects due to addition of folic acid to flour.

We estimated the costs of premix containing a minimum of iron and folic acid. Inclusion of other micronutrients in the fortification premix is feasible and may be desirable if deficiencies in multiple micronutrients are present in Haiti. Costs of a premix formulation that includes the different micronutrients present in current Latin American formulas, in addition to vitamin A, vitamin B-12, and zinc, would cost approximately US$7.50 per MT. Assuming an additional ~$1.50 per MT for shipping and storage, the total premix cost would be US$9/MT. This would increase annual costs in year 6 (the first year that the program is assumed to achieve 95% of flour adequately fortified) from 45,586,560 to 75,569,273 Gourdes, reflecting the fact that the bulk of annual operating costs are for the procurement of premix. As shown in Table 8, this price increase would decrease the BCR from 9 to 6 assuming a 3% discount rate and from 6 to 4 assuming a 12% discount rate, if benefits are assumed to remain constant (i.e., benefits from addition of other nutrients are not included).

Table 8. Benefits, Costs, and Benefit-Cost Ratios assuming effects on iron deficiency anemia among various target beneficiary groups

Premix cost, US$ per MT of wheat milled	Discount rate	Benefit-Cost Ratio
4	3%	9
	5%	8
	12%	6
7.5	3%	6
	5%	5
	12%	4

Notes: All figures value DALYs at 1X GDP. In all scenarios, the program is assumed to scale up as follows: 0% Y1, Y2; 50% Y3, 75% Y4, 85% Y5, and 95% Y6-12.

Intervention 3. Provision of micronutrient supplements to young children

The WHO Guideline on micronutrient powders for young children suggests the following dosing scheme for children 6-23 months where the prevalence of anemia is >=20%: one sachet per day, "at a minimum for a period of 2 months, followed by a period of 3-4 months off supplementation, so that use of the micronutrient powders is started every 6 months" (WHO 2011). We estimate the costs of providing 2 courses of MNP per year to children 6-23 months of age through health centers and rally posts. The benefits are estimated as the reduction in DALYS due to resolution of anemia among young children.

Costs and benefits were estimated over 12 years, assuming that distribution of the recommended two courses of MNP per year is gradually scaled up over time. CC-provided estimates indicate that 45% of children receive all 8 vaccines (most of which are received before 12 months of age). For these scenarios, MNP distribution was assumed to be a "passive" program that relies on child or caregiver attendance at health centers to distribute the MNP. We thus 'anchor' the scale-up estimates with the assumptions that 1) vaccine coverage (the proxy variable for 2 health center visits per year by children 6-23 mo. of age) is 45% in Year 1 and increases by 1 percentage point per year thereafter, and 2) MNP distribution is gradually scaled up from 0% to 100% of children 6-23 months of age who visit health centers (with a maximum of 51.2% of *all* children 6-23 mo. of age in the final year of the scenario). We assume a gradual increase from 0% in Y1 and Y2 to full coverage of children who attend health centers only in Y8; however, this assumption is unlikely to affect the BCR because the major program costs relate to the MNP cost, which increases with each child covered.

Costs

Three primary types of costs are estimated: 1) recurring costs for MNP procurement and storage, and 2) recurring costs for distribution by health workers, and 3) training and startup costs.

The costs of MNP procurement are estimated as the cost of the MNP sachets themselves (assuming a relatively low price of $0.017 per sachet (http://www.resultsfordevelopment.org/sites/resultsfordevelopment.org/files/resources/Nutrition-for-a-Better-Tomorrow-Full-Report_0.pdf), 2 courses of 60 sachets each, per child reached, per year), and estimated costs for shipping and storage. We assume that MNP purchases match program coverage rates (i.e., that all stocks of MNP are distributed). Together, the costs of MNP procurement, shipping, and storage represent over 90% of estimated total program costs (in this "passive distribution" scenario in which MNP are distributed to caregivers of children who attend health centers and rally posts); the cost of the MNP alone (120 sachets per child per year) represents more than 2/3 of total program costs in this projection.

The cost of health worker time to distribute MNP was estimated as the number of additional health workers needed annually to add the distribution of MNP to other health worker responsibilities while maintaining an 8-hour work day. We assume that each program contact (MNP distribution twice per per year per child reached) requires 15 minutes to instruct the caregiver on the use of the product and that annual health worker salary is 4,830 Gourdes. Additional supervision costs are also included, assuming one additional supervisor for every 20 health workers.

We estimate startup costs as 2-day initial trainings for all health workers, including additional health workers hired as a result of increased health worker time demand to administer the MNP program. TA 1-day refresher training is also included annually. To support program coordination and planning, two full-time positions are included in the first 3 years, and a single position in the remaining years.

Benefits

The reduction in the prevalence of anemia among women and children (preschool and school-age) was calculated using estimates from the effectiveness study of MNP distribution in Haiti (Menon et al., 2007). Based on this study, we estimated the reduction in anemia as the ratio of the age-adjusted anemia prevalence in the MNP vs comparison group after 2 months of intervention: 24%/43% = 0.56, or approximately a 44% reduction.

Scale-up of MNP coverage was estimated with the assumptions that 1) vaccine coverage (the proxy variable for 2 health center visits per year by children 6-23 mo. of age) is 45% in Year 1 and increases by 1 percentage point per year thereafter, and 2) MNP distribution is gradually scaled up from 0% to 100% of children 6-23 months of age who visit health centers (with a maximum of 51.2% of *all* children 6-23 mo. of age in the final year of the scenario). The reduction in anemia was then applied to the proportion of children covered.

DALYs for anemia were calculated according to Fox-Rusby and Hanson (2001) using disability weights from the Global Burden of Disease 2015 and assuming a one-year duration (i.e., individuals are protected from anemia only during the years during which they are consuming adequately fortified flour). Separate disability weights were included for mild, moderate, and severe anemia (proportions estimated from DHS 2012).

Benefit-Cost Analysis

With DALYs valued at 1XGDP, the benefit: cost ratio ranges from 3 (3% discount rate) to 2 (12% discount rate)(**Table 9**).

Table 9. Benefits, costs, and benefit cost ratios for provision of multiple micronutrient powders to children 6-23 months of age.

Intervention	Discount Rate	Benefit (in gourdes) (DALY value = 1xGDP)	Cost (in gourdes)	BCR
Provision of multiple micronutrient powders to young children	3%	478,108,831	185,666,158	3
	5%	400,225,200	157,324,005	3
	12%	223,422,103	91,665,515	2

Sensitivity Analyses

Others have assumed a cost of $1.80 per child per year for MNP only (assuming 60 sachets per year, i.e., $0.03 per sachet). Applying this change to the scenario described above would reduce the BCR to 2. Bhutta et al. (2013) assumed a cost of $1.80 per child per year, and further assumed that distribution doubles the cost, i.e., to $3.60 per child per year. Our estimated distribution costs were much lower than the cost of the MNP product, but distribution costs would be higher for a more intensive distribution program.

The MNP study in Haiti (Menon et al., 2007) reported a greater reduction in anemia prevalence compared to the meta-analysis that was used to inform the WHO guideline on MNP provision to young children (De-Regil et al., 2011). As a sensitivity analysis, we applied the estimated from the meta-analysis of RR=0.69 (31% reduction in anemia). The resulting BCR was 2, regardless of the discount rate applied.

Limitations of Cost and Benefit Estimates

General limitations

Several general limitations of this analysis should be noted. First, micronutrient malnutrition and related health consequences are typically the product of underlying determinants such as poverty, food systems, health infrastructure, and access to education. These underlying determinants will not be resolved by the proposed interventions. In addition, other types of nutrition-specific and nutrition-sensitive interventions, such as breastfeeding promotion, obesity prevention strategies, agricultural interventions, etc. may have broader positive effects on nutritional status and health beyond micronutrient nutrition. Nevertheless, the strategies described in this report represent options for minimizing the consequences of micronutrient deficiencies while efforts to address underlying determinants of malnutrition are being developed.

An additional caveat is that there is overlap in the pathways through which these interventions are expected to yield health benefits. For example, a case of iron-deficiency anemia in a pregnant woman that is prevented by a multiple micronutrient supplement delivered to the pregnant woman would no longer be available for prevention by wheat flour fortification with iron, and vice versa. Similarly, one could imagine synergies in program costs, particularly regarding the procurement and distribution of supplements for young children and pregnant women. Thus, while implementation of multiple programs may be necessary to minimize micronutrient malnutrition and its consequences, the costs and the benefits of the specific intervention scenarios modeled in this report should *not* be considered additive.

As in any such exercise, these estimates of costs and benefits rely on assumptions about the population and program implementation, some of which are well-documented and others less so. We did not attempt to present standard errors, but we have examined the effects of selected key assumptions as sensitivity analyses.

Several related micronutrient interventions (in particular, rice fortification and preventive zinc supplementation) may be promising in this setting, but detailed analyses of the costs and benefits of these programs were beyond the scope of the current paper. First, although this analysis focused on large-scale fortification of wheat flour, rice is commonly consumed in Haiti, and thus industrial rice fortification could have similar benefits and a similar benefit-cost ratio. Second, an alternative (or potential addition) to distribution of micronutrient powders to include could include distribution of preventive zinc supplements. Zinc supplementation reduces mortality from diarrhea and pneumonia in populations where zinc deficiency is likely common (Yakoob et al., 2011). Although most MNP formulations contain zinc, controlled trials have not provided clear evidence for an effect of MNP on typically "zinc-responsive" outcomes such as linear growth, plasma zinc concentration, or diarrhea reduction. Zinc supplement distribution would incur similarly high costs to procure supplements and support additional health care workers, but the benefits (as measured by DALYS) would be expected to be much greater than for MNP due to the potential impact on mortality reduction.

Limitations related to micronutrient supplementation in pregnancy

We have assumed that distribution of supplements would occur through the antenatal care system, relying on these services to be available and accessible to women and that women would utilize those services. We have included some program cost estimates for ANC strengthening to reach more women with micronutrients. We have likely underestimated the total costs for training new health facility staff, as our focus was specifically on training related to micronutrient supplement distribution. We also have not factored in costs in time and transportation expenditures for women to travel from their homes to visit the clinics. Additionally, we assume that the first ANC visit would occur relatively early in pregnancy so that women would receive a full 8-month course of supplements; in practice, additional communication efforts or home visits might be necessary to reach women this early in pregnancy. Therefore, we may have underestimated the total costs. However, we have also not factored in potential benefits of ANC beyond those attributed to micronutrient supplements. Additional benefits may include improved tetanus toxoid vaccine coverage, HIV detection and treatment, early detection of multiple births or other pregnancy complications, and treatment of infections, all of which lead to improved pregnancy outcomes, improved maternal and newborn survival, and reductions in morbidity (WHO, 2016). For this reason, we would expect that a full accounting of the benefit cost ratios for ANC strengthening would be favorable.

Limitations related to folic acid

Consistent with recent global estimates (Arth et al., 2016) and due to lack of reliable data on the effect of folic acid fortification on stillbirths and miscarriages, we did not estimate the additional reduction in mortality from miscarriages and stillbirths that might be expected from folic acid fortification. In addition, estimated the reduction in neural tube defects by multiplying total preventable cases by the estimated proportion of flour fortified and the proportion of households regularly consuming flour (as opposed to only multiplying by the proportion of flour fortified, as in Arth et al., 2016). On the other hand, we assumed 100% mortality among spina bifida cases, but in high-income settings the mortality rate has been estimated as closer to 88%

(100% for anencephaly and 75% over 5 years for spina bifida, assuming each condition accounts for half of folic acid-preventable neural tube defects). The net effect is likely an underestimate of the benefits of folic acid fortification because deaths from miscarriage and stillbirth are not included.

Limitations related to effects of iron fortification and MNP on anemia

Iron deficiency is considered a primary cause of anemia in most settings, but anemia can be caused by many factors. Studies of iron interventions typically report reductions in total anemia following the intervention period, but presumably the reduction is due to iron deficiency anemia in the context of randomized, controlled trials that provided only iron. Differences in the proportion of anemia due to ID in the trial populations and in Haiti would influence the extent to which it is appropriate to apply these results to Haiti. This is less of a concern for MNP because we applied results from a trial in Haiti. For wheat flour, because the effect sizes for staple food fortification for anemia reduction were lower than the combined results for all iron-fortified products (Das et al., 2013), we elected to apply the reductions in anemia only to the proportion of the population estimates to have IDA. This may underestimate the benefits of wheat flour fortification with iron, but even under these assumptions the BCR were quite high, so this does not affect the conclusion that flour fortification has a high BCR.

These calculations may underestimate the overall benefits of wheat flour fortification with iron because 1) we applied reductions in total anemia only to the proportion of the population estimated to have iron deficiency anemia, as described above, 2) we excluded estimates of the effect of wheat flour fortification on severe anemia, under the assumption that severe anemia is more likely to be due to causes other than iron deficiency (with the exception of pregnant women, above, and for MNP, because there is stronger direct evidence of a benefit in this age group), and 3) we assumed that the prevalence of iron deficiency anemia among men 15+ years of age is negligible, which may not be true in communities that rely on unfortified cereal grains as staples, with low animal-source food consumption. On the other hand, if the proportion of anemia due to iron deficiency is lower than assumed, the benefits would be reduced. Nevertheless, the BCR for flour fortification are quite high, even when benefits to both preschool children and school-age children are excluded. Thus, uncertainty around the effectiveness of flour fortification on anemia among young children does not affect our conclusion that wheat flour fortification is a good investment, although it suggests that complementary interventions (such as MNP or other young child feeding interventions) might be necessary to further reduce anemia among young children.

Finally, the estimated benefits of providing iron include only DALYS averted due to reduction in anemia. Correction of iron deficiency (without anemia) through either iron fortification or distribution of MNP may have other long-term benefits for cognitive development and productivity which are not included in these estimates.

Limitations related to micronutrient powder estimates

We elected to estimate the costs and benefits of a "passive" distribution program, in which MNP are provided to children who visit health centers with their caregivers, with the rationale that 1) this represents a more realistic scenario (at least initially) than intensive distribution efforts, and 2) because limited data are available to estimate the costs and achieved coverage of a hypothetical intensive program, including a strong behavior change message component and outreach, such as home visits in remote areas. WHO recommends that MNP distribution be accompanied by behavior change communication around a range of infant feeding practices (WHO, 2011). This intervention could have many benefits beyond anemia reduction, particularly encouragement of continued breastfeeding. Such efforts would likely increase the benefits of the program, by reaching more children and possibly leading to improved infant feeding practices which would have many benefits beyond anemia reduction, but these efforts would also incur substantial costs related to health worker time, travel, and communications.

For this "passive distribution" version of the program, we did not include the cost of caregiver time to travel to the clinic to pick up the MNP, or for the additional daily step of mixing the MNP into the child's food. Assuming travel time of 1 hour/clinic visit, 2 visits/year, and daily MNP preparation time of 5 minutes/day for 120 days/year, the caregiver total time burden per child reached would be approximately 12 hours/year.

Likewise, children 24-59 mo. of age were not included because the WHO guideline is specific to 6-23 months of age. Expansion of the target age range would increase the benefits of the program, but would also likely require greater investments in outreach and in caregiver time if children 24-59 mo. of age are less likely to routinely visit MNP distribution points after they have completed the series of essential vaccinations.

Finally, we used optimistic assumptions about caregiver compliance in giving MNP to the child as instructed. Low compliance would reduce the benefits without reducing the costs to procure and distribute the MN

4. Conclusion

We reviewed the potential for implementation (or scale-up) in Haiti of several preventive nutrition interventions: multiple micronutrient and calcium supplementation of pregnant women, wheat flour fortification with multiple micronutrients, delivery of micronutrient powders to young children, and salt iodization. Following review of the literature on salt iodization and the current structure of the edible salt industry in Haiti, we elected to postpone calculations of costs and benefits of salt iodization until the results are available from an ongoing survey on iodine nutrition. We completed estimates of the costs and benefits for the remaining interventions, as summarized in **Tables 10-12**. We found favorable BCR estimates for all 3 interventions, ranging from 8 for MNP delivered to children to 24 for wheat flour fortification (assuming DALYs valued at 3XGDP and 5% discount rate).

Table 10. Summary of benefits and costs of preventive nutrition interventions, with DALYs valued at 1XGDP

Interventions	Discount Rate	Benefit (in gourdes)	Cost (in gourdes)	BCR	Quality of Evidence
Multiple micronutrients and calcium in pregnancy	3%	52,556,371,712	8,608,059,239	6	Strong
	5%	30,425,572,341	7,637,956,645	4	
	12%	8,350,723,777	5,277,011,789	2	
Wheat flour fortification with multiple micronutrients	3%	3,551,263,161	376,300,834	9	Strong
	5%	2,646,021,438	331,312,834	8	
	12%	1,313,937,192	222,722,324	6	
Micronutrient supplements to young children	3%	478,108,831	185,666,158	3	Strong
	5%	400,225,200	157,324,005	3	
	12%	223,422,103	91,665,515	2	

Table 11. Summary of benefits and costs of preventive nutrition interventions, with DALYs valued at 3XGDP

Interventions	Discount Rate	Benefit (in gourdes)	Cost (in gourdes)	BCR	Quality of Evidence
Multiple micronutrients and calcium in pregnancy	3%	134,225,463,045	8,608,059,239	16	Strong
	5%	79,844,981,881	7,637,956,645	10	
	12%	23,585,423,755	5,277,011,789	4	
Wheat flour fortification with multiple micronutrients	3%	10,653,789,483	376,300,834	28	Strong
	5%	7,938,064,315	331,312,834	24	
	12%	3,941,811,576	222,722,324	18	
Micronutrient supplements to young children	3%	1,434,326,493	185,666,158	8	Strong
	5%	1,200,675,600	157,324,005	8	
	12%	670,266,308	91,665,515	7	

Table 12. Summary of benefits and costs of preventive nutrition interventions, with DALYs valued at 8XGDP

Interventions	Discount Rate	Benefit (in gourdes)	Cost (in gourdes)	BCR	Quality of Evidence
Multiple micronutrients and calcium in pregnancy	3%	338,398,191,375	8,608,059,239	39	Strong
	5%	203,393,505,731	7,637,956,645	27	
	12%	61,672,173,701	5,277,011,789	12	
Wheat flour fortification with multiple micronutrients	3%	28,410,105,288	376,300,834	75	Strong
	5%	21,168,171,508	331,312,834	64	
	12%	10,511,497,536	222,722,324	47	
Micronutrient supplements to young children	3%	3,824,870,647	185,666,158	21	Strong
	5%	3,201,801,599	157,324,005	20	
	12%	1,787,376,822	91,665,515	19	

Relationship to other literature

The favorable BCR estimates reported here are consistent with a growing body of literature on the returns of early investments in nutrition, particularly in the "first 1000 days" of life, i.e., the period from conception until 2 years of age (Shekar et al., 2017). For example, the benefit: cost ratio for folic acid fortification for averting neural tube defects in South Africa was estimated to be 46 to 1 (Sayed et al., 2008).

Quality of evidence

Micronutrients in pregnancy: Although there is some uncertainty around the potential coverage of this intervention, and thus the program costs, we considered the quality of evidence for the potential benefits to be high. Thus, we consider the overall quality of evidence for the BCR to be strong.

Flour fortification: There is a relatively large body of evidence related to the costs and benefits of flour fortification. Although the potential health benefits are clear, the studies of health benefits were conducted in diverse populations, so the exact magnitude that would be expected in Haiti is uncertain (in part because recent data on the outcomes expected to respond to this intervention are not available for Haiti). For this reason, we elected to be conservative in the calculations (erring on the side of a lower BCR) and conducted a number of sensitivity analyses. Given that the conservative estimates consistently yielded favorable BCRs, we consider the conclusions about the BCR estimates to be strong.

MNP: There is good evidence from a number of randomized, controlled trials that consumption of MNP according to the recommended schedule reduces anemia among children, including evidence from a study conducted in Haiti. Thus, we characterize evidence that the intervention will have the intended effect as strong. However, there is some uncertainty about the costs of MNP distribution in this setting. In particular, we assumed a "passive distribution" scenario and did not include estimates for a more intensive distribution program, which would have much higher costs but would also presumably confer greater benefits with regard to anemia reduction and possibly other outcomes related to the other micronutrients included in MNP and the child feeding messages that are usually delivered in tandem with MNP distribution. Therefore, we consider the quality of evidence for the overall BCR to be moderate.

Gender

The first intervention is delivered only to women and a subset of the expected benefits (reduction in maternal anemia and maternal mortality) are expected to directly affect the women who receive the program. Several of the expected benefits of maternal supplementation relate to birth outcomes and health of the child; in this case, both male and female children would benefit from reduced risk of complications of preterm birth and low birth weight.

Wheat flour fortification would be expected to reach similar proportions of males and females, assuming that dietary habits are similar. However, we expect that reductions in anemia among adults will occur primarily among women, because women are more likely to suffer from iron deficiency anemia compared to men. Other expected benefits of wheat flour fortification (reduction in anemia among preschool children, and reduction in deaths due to neural tube defects) would generally affect both sexes equally.

Finally, reductions in anemia due to receipt of MNP would also be expected to benefit male and female children equally, if caregivers are equally likely to administer the supplements to male and female children.

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Public health gardens to fight malnutrition

Haiti Priorise

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The Haitian Institute of Statistics and Informatics (IHSI) estimates the Haitian population to be 10,911,819 inhabitants in 2015 (1) of which more than 25% reside in the metropolitan area of Port au Prince. And it could reach 11.7 million inhabitants by 2020 (2). For the period 2015-2020, life expectancy at birth is estimated at 64.2 years (60.6 years for the period 2005-2010), the gross birth rate is estimated at 24.1 per 1000 inhabitants and the gross mortality at 8.2 deaths per 1000 inhabitants (2). The total fertility rate is declining steadily from 4 children per woman in 2006 to 3.5 in 2012 (3). The country is therefore in a position to take advantage of this demographic dividend insofar as the working age population increases faster than the dependent population. But men and women must be healthy and well fed.

The 2014 national income per capita PPP-PPP is estimated at 820 USD by The World Bank. With a population growing at an annual average of 2%, GDP growth of less than 2% does not compensate for the demographic pressure. The Haitian state is deprived of resources which prevents it from carrying out social programs and sustainable economic development. Haiti imports three times more than it exports. External donations have already decreased by 75% between 2010 (US $ 1.8 billion) and 2015 (US $ 488 million). In 2015 there was a drought that has seriously affected the agricultural sector, which makes up one-fifth of the GDP mainly for the poor who tend to have malnourished children. Then there was the natural disaster Matthew, which caused losses of nearly $ 2.7 billion, thus causing the decapitalization of farmers, pastoralists and fishermen. So this poverty, which already affects two thirds of the population, could increase the acute, moderate and severe cases of malnutrition.

Hunger is the expression of the absence of decent and productive employment. Decent employment enables households to generate income, increase their purchasing power and thus reduce their level of food insecurity. According to data from the post-earthquake household survey (ECVMAS) in 2012, food expenditure accounts for 65% of total household expenditures. This shows that the poorest households spend almost three-quarters of their total income on food. Even among the wealthiest households, more than half of the expenditure is devoted to food. (38). As part of an important initiative to eliminate malnutrition at the global level, concrete commitments have been made to implement policies and investments aimed at ensuring a healthier and more sustainable diet for all. So The Rome Declaration on Nutrition establishes the right of every person to access safe, nutritious food in sufficient quantities. It urges governments to prevent malnutrition in all its forms, including hunger, micronutrient deficiencies and obesity.

During this meeting, Mrs. Margaret Chan, Director-General of the WHO, stated that "the world food system - due to its dependence on industrial production and market globalization - produces abundant supplies, but it also creates some public health problems. Part of the world has very little to eat, making millions of people vulnerable to illness and death due to nutritional deficiencies while another parts of the world eats too much, which spreads obesity, reduced life expectancy and pushes health care costs to astronomical levels. "

The signatory countries have committed themselves to achieving specific results by 2025 on nutrition targets, including existing targets for improving maternal, infant and early childhood mortality, and to reduce risk factors related to nutrition, which are responsible for non-communicable diseases such as diabetes, cardiovascular accidents and certain cancers

Sustainable food systems are essential to promote healthy eating. Governments are encouraged to promote agriculture which promotes good nutrition by integrating nutrition goals into the design and implementation of agricultural programs.

For this purpose, governments are encouraged to strengthen national food production and processing, especially among smallholder farmers and family farmers, with particular attention to the empowerment of women.

Malnutrition does the most harm in the early stages of life. As a result, countries must focus their efforts to meet the nutritional needs of mothers before and during pregnancy and infants during the first "1,000 days", from conception to age two. In this regard, exclusive breastfeeding should be promoted and supported for the first six consecutive months after birth and continued breastfeeding until the age of two years or beyond.

If one wants to fully understand how hunger will lead to malnutrition, we must just look at "Asefi", a child under 6 months old who cries non-stop because she is hungry and her mother who is breastfeeding exclusively is not available to console him with the breast. Or her 3 other children who are hungry and who do not hope to have a meal during the day. And quite naturally these children will become malnourished which will represent a considerable socio-economic cost for society. This money could have been invested in other sectors that could be productive in the context of economic growth for the development of our country.

Haiti, which was known as an essentially agricultural country, currently has few resources in terms of strong demographic pressure. Poverty is omnipresent and the living conditions of families remain very fragile: agricultural households are unable to produce enough grain to cover their needs. The rural population depends on family farming that is fragile and extremely vulnerable to climatic hazards. The food shortage in households has a direct impact on the nutritional status of the population.

This situation is directly related to women's lack of access to land, their lack of access to non-cereal foods, low literacy rates, poor hygiene and inadequate childcare practices (such as early weaning, use of inadequate complement foods, reduced dietary diversity).

Therefore, in order to achieve improved prospects and eliminate malnutrition in the country, it is important to successfully implement a program aimed at reducing the economic vulnerability of the poorest families in the country, and promote the adoption of good child-care practices. Public health agriculture will be promoted through the use of "*Public Health Gardens*" which are based on:

- The development of vegetable gardens (production of fruits, vegetables, cereals and peanuts) both for family consumption and for resale in markets;
- Promoting good nutritional practices through training and awareness-raising sessions (breastfeeding, hygiene, food and nutrition);
- Culinary demonstrations of balanced recipes, based on the availability of vegetable garden products and other commonly used local foods.
- The promotion of enriched infant flours produced by local promotion units for the prevention of malnutrition should be integrated into the demonstrations.

It is important to increase the number of jobs mentioned above to increase agricultural post-production activities (conservation, processing, vegetable storage) in order to improve the preservation of food during periods of drought.

All this will be done in order to concretely allow:

- The increased availability and access to diversified quality foods
- Improving the health of families and children
- Creating spaces for exchange and discussion in the community and between communities
- Increasing family incomes

These Public Health Gardens will be an effective approach to tackling nutritional deficiencies and enable farmers to have money and improve the fight against malnutrition.

For some time we have been promoting Moringa, which may be one of the plants of these public health gardens. From a nutritional point of view, its leaves are particularly interesting.

The Haitian population suffers from certain deficiencies, in particular, a lack of vitamin A, iron and iodine. Now this molecule plays a primordial role in vision; the decrease in visual acuity is one of the first signs of vitamin A deficiency.

Moringa appears to be interesting in the context of vitamin A supplementation: easy access, 3 grams of dry Moringa powder covers a person's daily vitamin A requirements. One tree can easily cover the needs of an entire family. If in some countries the leaves are traditionally eaten rather than infused in sauce, soup or salad; the nutritional properties of Moringa are altered when cooking: it is better to consume them in a salad or sprinkled on meals. The vitamin A intake can be added through fruit (banana, mango, etc.).

In Moringa, iron intakes (58 µg of iron / gram of dried leaves)[1] and proteins (0.25 g / gram of dried leaves) are also just as important. Therefore the introduction of Moringa leaves into the diet should be encouraged.

The many nutritional qualities of this plant enable it to be promoted in many development programs as a means of fighting malnutrition.

If we want to solve the problems of food insecurity, we must really invest in agriculture, which represents the key sector and therefore the engine of the country's economic development. And so the development of the country's agriculture and public health gardens will be able both to meet the demographic challenge in terms of food self-sufficiency and to allow the return of foreign exchange in the country and thus eliminate malnutrition.

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Haiti faces some of the most acute social and economic development challenges in the world. Despite an influx of aid in the aftermath of the 2010 earthquake, growth and progress continue to be minimal, at best. With so many actors and the wide breadth of challenges from food security and clean water access to health, education, environmental degradation, and infrastructure, what should the top priorities be for policy makers, international donors, NGOs and businesses? With limited resources and time, it is crucial that focus is informed by what will do the most good for each gourde spent. The Haïti Priorise project will work with stakeholders across the country to find, analyze, rank and disseminate the best solutions for the country. We engage Haitans from all parts of society, through readers of newspapers, along with NGOs, decision makers, sector experts and businesses to propose the best solutions. We have commissioned some of the best economists from Haiti and the world to calculate the social, environmental and economic costs and benefits of these proposals. This research will help set priorities for the country through a nationwide conversation about what the smart - and not-so-smart - solutions are for Haiti's future.

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