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CHAPTER 14

IDENTIFICATION OF OPTIMAL INVESTMENTS

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ABSTRACT

Biofortification is regarded as a complement to supplementation, industrial fortification and dietary diversification in the fight against micronutrient deficiencies. It is important therefore to first identify areas where biofortification may have high impact and prioritize these areas for more in-depth analysis. HarvestPlus has developed the Biofortification Prioritization Index (BPI), which ranks countries globally according to their suitability for investment in biofortification interventions. HarvestPlus is also conducting ex ante micronutrient intervention portfolio analyses, designed to simulate the implementation and impact of a biofortification program in countries which have been identified as suitable candidates for investment. Micronutrient intervention portfolio studies offer the ability to distinguish production, consumption and inadequate micronutrient intake at a more disaggregated level and offer a complementary design and planning tool to simulate the implementation of biofortification and examine its potential impact and cost-effectiveness among different approaches. In addition, these studies are designed to examine multiple interventions within a country, to better understand biofortification's role in reducing micronutrient deficiency when considered among a suite of interventions. This case study of Zambia demonstrates how these tools can be used to assess the potential impact of biofortification, quantify its cost-effectiveness and examine how it interacts with and complements other interventions. Given the long-term nature of biofortification as an intervention investment, future analyses should continue to incorporate various scenarios including continued investment in sustainable development and the effects of climate change which are likely to condition the impact of biofortification and other interventions.

Key words: Biofortification, Biofortification Priority Index (BPI), Cost-effectiveness, Household Consumption and Expenditure Surveys (HCES)

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INTRODUCTION

Biofortification is regarded as a complement to supplementation, industrial fortification and dietary diversification in the fight against micronutrient deficiencies, both in terms of impact and targeting [1]. It is not expected to be a panacea or a standalone approach. For example, multiple interventions may be necessary in order to reduce micronutrient deficiencies to prevalence levels below which they are not considered a public health problem. In addition, biofortification initially may be relatively better at targeting rural areas, where poor, smallholding farmers primarily produce staple crops – the targets of biofortification – and rely on them for the majority of their household members' daily energy intake.

Ultimately, the most cost-effective application and greatest impact of biofortification is likely to be in areas where production and consumption of biofortifiable staple crops are high, and where related micronutrient deficiencies are also prevalent. The ability of other interventions to target specific areas is also an important consideration. It is important therefore to first identify areas where biofortification may have high impact and prioritize these areas for more in-depth analysis. Such analyses can confirm these findings and help to better understand the parameters that condition the impact of biofortification. These results can then also be used to design the intervention to best ensure its optimal implementation, in terms of targeting and coupling with other interventions.

The purpose of this paper is to discuss two tools for identifying optimal investments for biofortification: the Biofortification Prioritization Index (BPI), and micronutrient intervention portfolio analysis. Section 2 discusses the development of the BPI and how it is used to identify priority areas for biofortification. Section 3 shows how portfolio analysis can provide a more detailed understanding of the costs, benefits, cost-effectiveness of biofortification, and its role when considered among other intervention options, using Zambia as a case study.

BIOFORTIFICATION PRIORITIZATION INDEX

As momentum for biofortification builds and stakeholders become increasingly interested in investing in it, evidence-based information is needed to aid decision making about how and where to target biofortified crops to most cost-effectively achieve nutritional impact. To this end, HarvestPlus has developed the Biofortification Prioritization Index (BPI), which ranks countries globally according to their suitability for investment in biofortification interventions [2].

The BPI is a geometric mean of three sub-indices, which are based on country-level crop production and consumption data from the Food and Agriculture Organization (FAO) of the United Nations, and country-level iron, zinc, and vitamin A deficiency data from the World Health Organization (WHO). The production sub-index (1) captures the extent to which a country is a producer of one of the staple crops targeted by HarvestPlus for biofortification, while factoring in the amount of output retained for domestic consumption. The consumption sub-index (2) captures the proportion of the crop under domestic production that is consumed by the country's population. The micronutrient sub-index (3) captures the extent to which a country's population suffers from the respective micronutrient deficiency, i.e., vitamin A, zinc, or iron.

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The combined number of the three sub-indices is rescaled into a score that ranges from 0 to 100, where a score of 0 indicates low priority and a score of 100 indicates a high-priority country for consideration of a biofortification intervention. For each crop, BPI scores are then ranked in descending order (from highest to lowest) such that the country with the highest BPI score receives a rank of 1 and the country with the lowest score receives the last rank among all countries in terms of the suitability of investment. For example, since Brazil is ranked 11 among the 81 countries that produce beans out of the 127 countries in the database, it is a good candidate for biofortification investment in iron beans; however, it is ranked 58 among the 75 sweet potato-producing countries for vitamin A[1] orange sweet potato and so is deemed relatively low priority for investment in vitamin A sweet potato biofortification. Scores are further divided into priority quintiles for each crop, with five distinct groups ranging from the top 20 percent to the lowest 20 percent: Top Priority, High, Medium, Low, and Little/None. **Figure 14.1** below provides an illustration of the BPI for vitamin A maize and indicates that countries within sub-Saharan Africa as well as Mexico and Nepal are most suitable for investment in vitamin A maize[2]. To date BPIs have been calculated for seven staple crops (vitamin A maize, zinc rice, zinc wheat, vitamin A sweet potatoes, high-iron beans, high iron pearl millet, and vitamin A cassava) in 127 countries in Africa, Asia, and Latin America and the Caribbean.

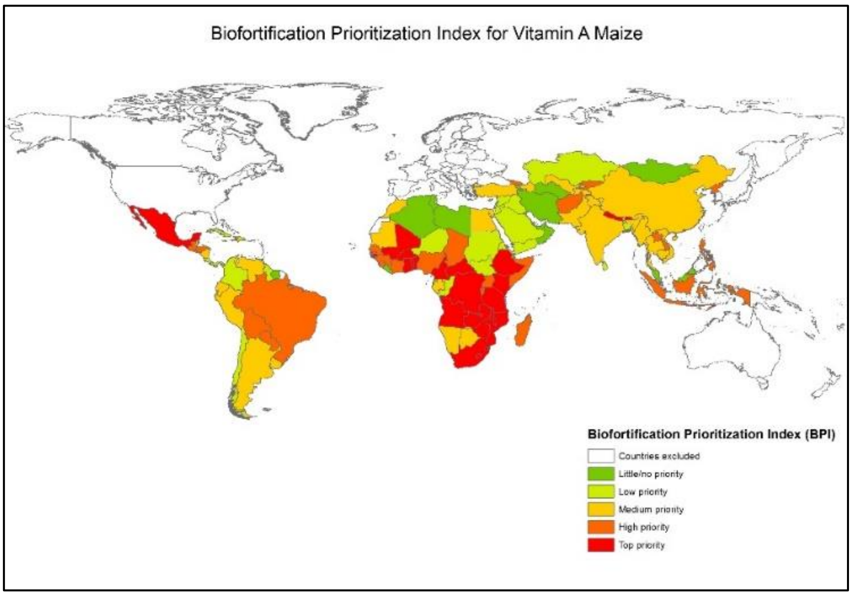

Figure 14.1: Biofortification Prioritization Index for Vitamin A Maize

[1] It is important to note that crops do not produce the active form of vitamin A (retinol) which can be toxic if overdosed, but rather provitamin A carotenoids which the human body converts into vitamin A only to the extent that it needs it. Because of this natural regulation, biofortification is a safer delivery platform for vitamin A than those that provide preformed vitamin A.

[2] An online and interactive BPI tool has been developed and is available at the following link: http://www.ifpri.org/publication/biofortification-priority-index

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One of the limitations of the BPI is that it draws on national-level data, which does not allow for investigation of variations in production, consumption, and micronutrient deficiency within a country. It is likely, therefore, that the BPI overlooks countries with promising "pockets" for biofortification investment. In some cases, though a country exhibits high levels in all three sub-indices, areas in which the crop is produced and consumed and areas in which there is significant micronutrient deficiency may not overlap. Furthermore, larger countries tend to have regional diversity in agroecology, culture and related crop production/consumption patterns, as well as in income, and hence and may also have significant regional diversity in the types, levels and severity of micronutrient deficiencies. In order to address these limitations, subnational BPIs which use disaggregated production, consumption and micronutrient deficiency data are under development for large countries such as Ethiopia, Colombia, Brazil, Nigeria, and India. **Figure 14.2** exemplifies the importance of a subnational BPI. It provides an analysis of zinc rice in Colombia, suggesting that while Northern Colombia may be well suited for this biofortified crop, this may not be the case for other regions.

Figure 14.2 (b) complements the BPI results and classifies geographic regions as areas of intervention and/or impacts. Geographic areas were classified as: (1) areas of "impact and intervention" or "hot spots" if they have high consumption, high production, and high micronutrient deficiency; (2) areas of "impact" if they have high consumption and high risk of micronutrient deficiency but with low or no production; and (3) areas of "intervention" if they have high production but with low risk of micronutrient deficiency and low or no crop consumption. Four (Choco, La Guajira, Cesar, and Putumayo) out of 32 departments are classified as areas of "impact and intervention" and have the potential to reach approximately 10 percent of the population. Areas of "intervention" (Tolima and Huila) represent major rice surplus-producing areas that ship rice surpluses to large rice-deficit destination areas such as urban markets (i.e. Bogota and Cali) that have high prevalence of zinc deficiency among children (50% and 52%, respectively) [3].

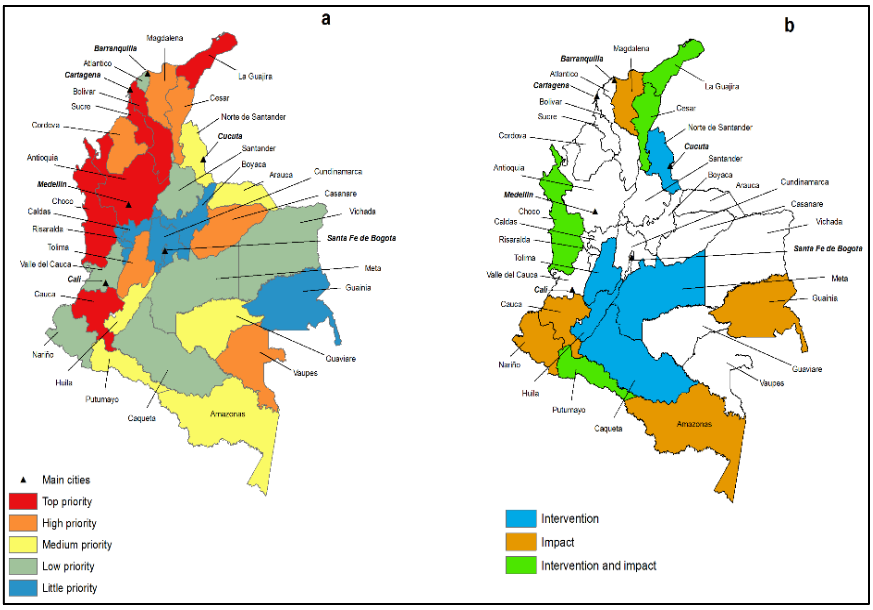

Figure 14.2: Geographic sites in Columbia for Biofortification of Rice with Zinc: (a) Rice BPI (b) Recommended Areas for Intervention and/or Impact

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MICRONUTRIENT INTERVENTION PORTFOLIO ANALYSES

Ex ante micronutrient intervention portfolio analyses are cost-effectiveness analyses designed to simulate the implementation and impact of a biofortification program in a specific country identified as a suitable candidate for investment. These analyses factor in country-specific planning scenarios, adoption, supply and demand parameters (including those associated with price changes over time), subnational variation, market aspects (i.e. growers vs. purchasers), and the costs of research, development, and delivery. In addition, these studies are designed to examine multiple interventions within a country, to better understand biofortification's role in reducing micronutrient deficiency when considered among a suite of interventions. An in-depth portfolio analysis was carried out for vitamin A maize in Zambia. An overview of the case study and its results are described below.

The Zambia Vitamin A Portfolio, 2013-2042

According to the BPI, Zambia ranks 3rd highest for suitability in investment for vitamin A maize (VAM) due to its high production and per capita consumption and high prevalence of vitamin A deficiency. Zambia has fortified sugar with vitamin A since 1996, and since 1998 has distributed vitamin A capsules twice annually to children 6-59 months of age as part of Child Health Weeks (CHW). In considering the best investment for Zambia, what might be VAM's impact? Will it be cost-effective?

To address these questions the Zambia 2006 Living Conditions Monitoring Survey was used to conduct a portfolio analysis of six feasible vitamin A program interventions—the existing sugar fortification and CHW programs, the recently implemented VAM program, and three hypothetical programs: fortification of vegetable oil, maize meal and wheat flour. The simulations considered scenarios individually and in various combinations and were projected over a 30-year horizon. **Figure 14.3** presents the conceptual and analytic approach to the analysis[3] [4].

Coverage of CHW was based on the percentage of children under 5 that reported receiving a vitamin A capsule within the last 6 months. It was assumed that all fortification scenarios would be mandated and that 100% of each fortification vehicle (i.e. vegetable oil, sugar, wheat flour and maize meal) obtained from purchases would be fortified. For VAM, it was conservatively assumed that an adoption ceiling of 20% of maize farmers would be achieved over the 30-year period. With these results and parameters, each intervention's additional vitamin A intakes, impacts and cost-effectiveness were estimated [4, 5].

[3] A similar conceptual framework has also been applied to portfolio case studies for high zinc rice in Bangladesh and high iron pearl millet in Rajasthan, India using other Household Consumption and Expenditure Surveys (HCES) specific to those countries.

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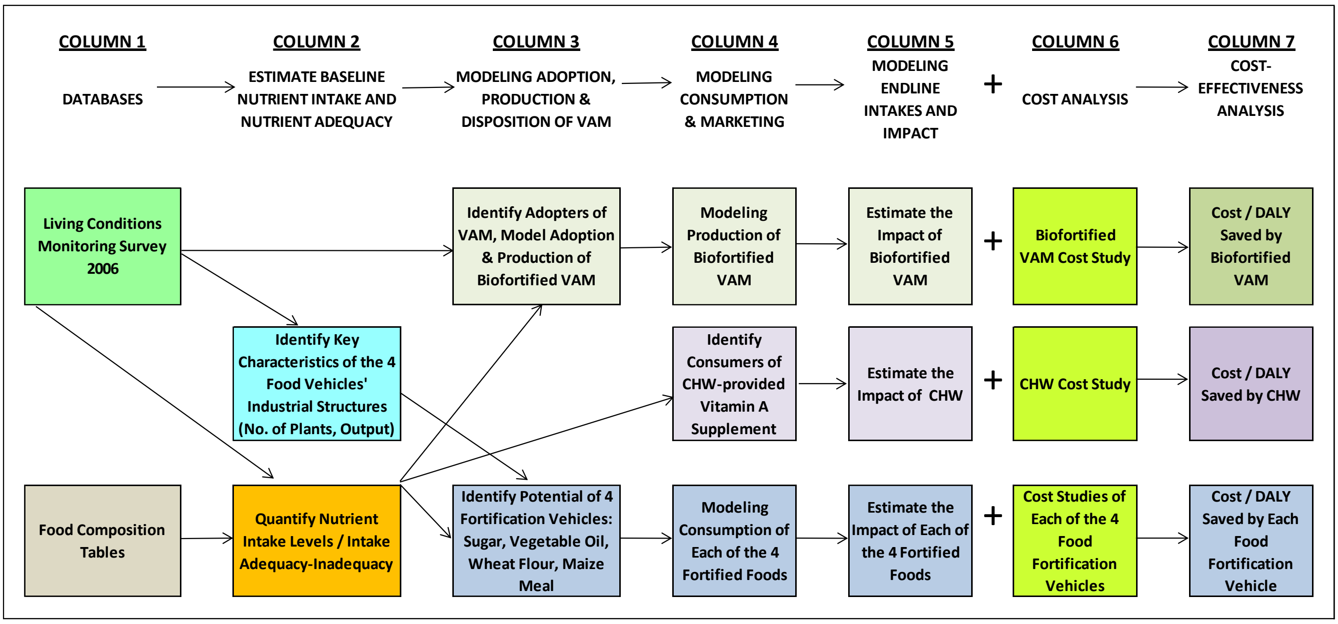

Figure 14.3: Estimating the Cost, Coverage, Impact and Cost-Effectiveness of Each of Zambia's Six potential Vitamin A Program Interventions

Figure 14.4 models how the annual distribution of total VAM consumption progresses. Southern, Central, Copperbelt and Eastern Provinces in Zambia will account for the majority of VAM consumed. It is estimated that VAM will deliver about 12% of the Estimated Average Requirement (EAR) as it scales up (**Figure 14.5**). However, among adopting farmers, VAM will deliver between 35% and 40% of the EAR at its peak. It is estimated that the prevalence of inadequate vitamin A intake is 87% nationwide in the absence of sugar fortification. While nationwide VAM will reduce the prevalence of inadequate intake by 3 percentage points, among adopting farmers the reduction is estimated to be 9 percentage points, on average, varying from 5 to 15 percentage points across provinces (**Figure 14.6**).

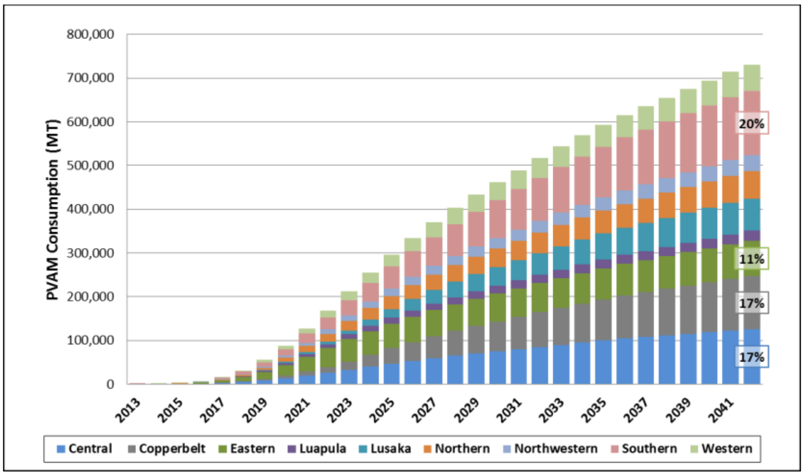

Figure 14.4: Annual VAM Consumption by Province, Zambia, 2013-2042

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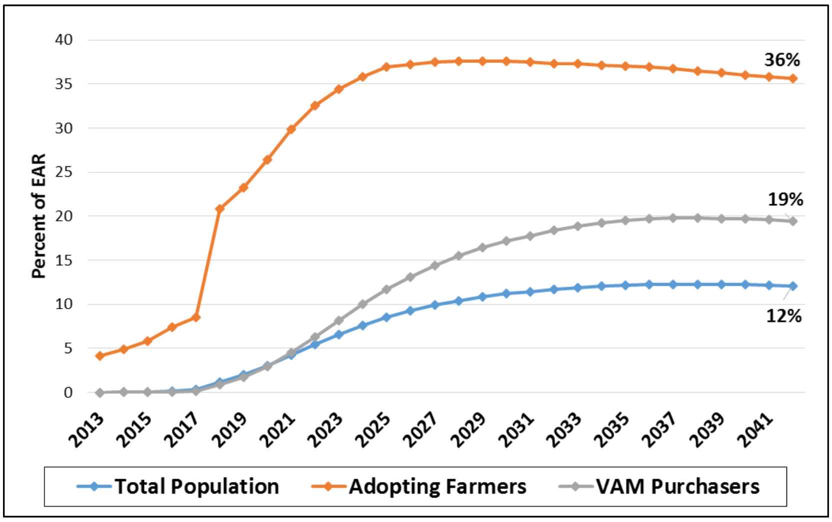

Figure 14.5: Average Annual Percent of the EAR Delivered with VAM, Zambia, 2013-2042

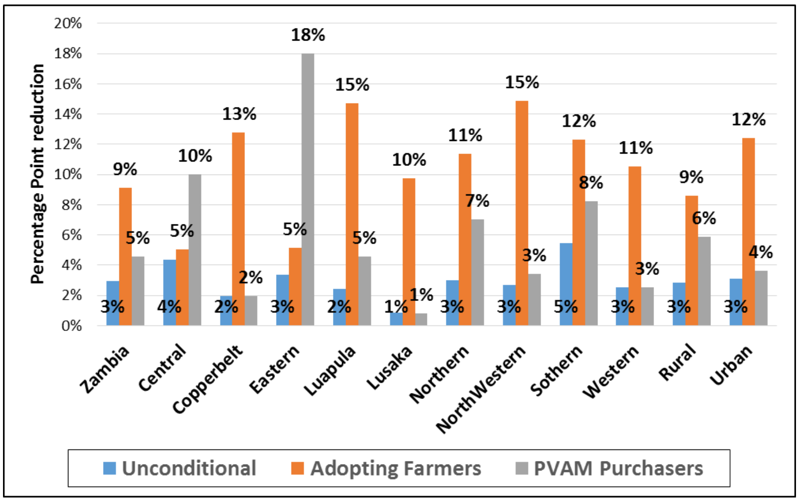

Figure 14.6: Reduction in the Prevalence of Inadequate Intake with VAM, Zambia 2042

Table 14.1 illustrates the differences in bio/fortification vehicles with respect to coverage, consumption, added nutrient levels, and the percent of supply that is bio/fortified. After retention and bioconversion are considered, maize offers the lowest concentration of retinol activity equivalents (RAE) when biofortified at 15 µg/g, but the concentration is offset to some extent by its much greater average level of consumption compared with other vehicles. Based on projected 2042 conditional consumption levels, vegetable oil and wheat flour are likely to deliver the highest percent of the EAR nationally, followed by maize (in the form of VAM). However, the highest percent of the EAR is expected to be delivered by VAM in the rural areas and wheat flour in urban areas.

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Ultimately the unconditional average percent of the EAR delivered and overall impact will also depend on the percent of the population consuming the vehicle in its bio/fortified form and the percent of the supply of the vehicle that is bio/fortified. With the exception of maize meal, in 2013 the coverage of the fortification vehicles is surprisingly high, even in rural areas. The growth in their coverage through 2042, however, is slower—at best one-fourth—than that of VAM. Yet based on achieving 20% farmer adoption, in 2042 all vehicles with the exception of maize meal will have coverage roughly equal to or greater than VAM. In addition, while 100% of all fortification vehicles obtained through purchases are expected to be fortified due to mandates, only 48% of the maize supply will be biofortified by 2042. The result is that nationally VAM will supply 12% of the EAR unconditionally, while oil, wheat flour and sugar will supply 54%, 33%, and 30%, respectively. In the case of biofortification, then, achieving high adoption and production are essential to achieving the highest potential impact.

Figure 14.7 shows the interventions' costs per Disability-Adjusted Life Year (DALY) saved[4] averaged over the entire 30 years, with both costs and benefits discounted at 3%. Future costs over the 30-year period were not adjusted upward for inflation and so are current to 2012. Fortified oil is the most cost-effective intervention with a cost per DALY saved of current US$4. At US$24, VAM is the fourth most cost-effective of the six individual interventions. The World Development Report for 1993 regarded interventions costing less than $150 per DALY averted as "highly cost-effective" [7]. According to this threshold, all six of these nutrition interventions are highly cost-effective health interventions.

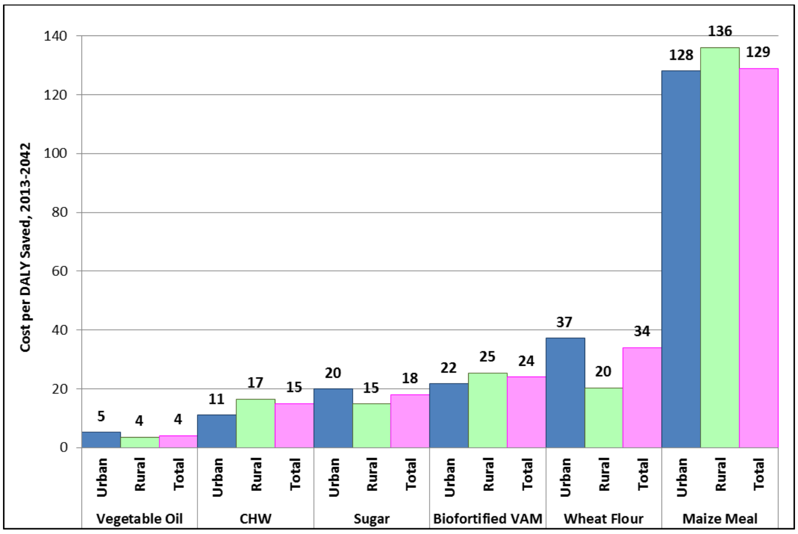

Figure 14.7: Variations in Rural-Urban-Total Cost/DALY Saved of the Six Independent Vitamin A Interventions, Zambia 2013-2042

[4] The DALY is an indicator that combines mortality and morbidity into a single metric that is expressed in terms of the number of full-quality years of life lost. This enables making comparisons across micronutrient deficiencies (that may not all cause either death or disability) and interventions. Using a standard value for a DALY also enables making comparisons across countries. For more information see Stein [6].

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In order to examine what the most optimal intervention package would entail, combinations of 2, 3, 4, and 5-intervention packages of the six basic interventions were modeled. **Figure 14.8** rank orders those with a cost per DALY saved of less than $50 (most well below the World Bank threshold). After fortified oil (alone), the next most cost-effective portfolio is a combination of VAM and vegetable oil (BO), with a cost per DALY saved of $13. This is largely due to the complementary coverage that VAM offers, allowing for a significant increase in benefits with the additional costs. The most cost-effective 3, 4 and 5-intervention packages consist of CHW, VAM, and oil; CHW, sugar, VAM and oil; and CHW, sugar, VAM, oil, and wheat flour, respectively.

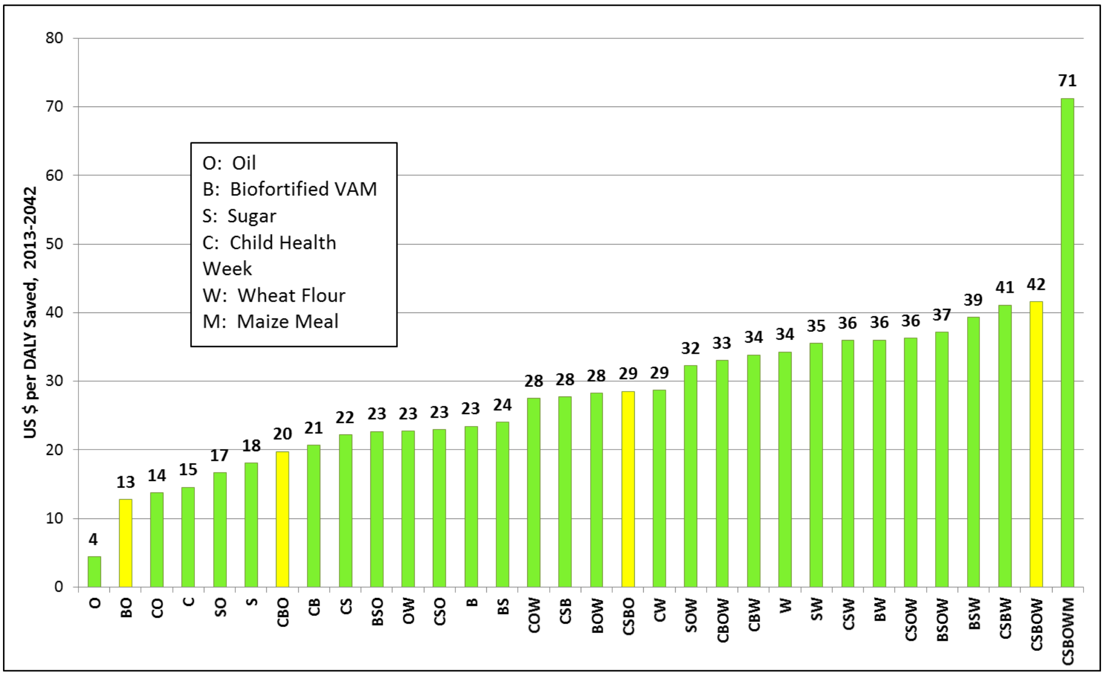

Figure 14.8: Vitamin A Program Portfolios with Discounted Cumulative Costs per DALY Saved Less than $50 Plus CSBOMW, 2013-2042

While the cost-effectiveness results provide guidance in terms of program efficiency (getting the best value for the money), other criteria must be taken into account so that portfolios with similar cost-efficiency but different public health impact can be distinguished and that selected portfolios remain within total budgets while achieving public health targets. These include total costs, total persons with inadequate intake who are covered, or total reduction in disease burden measured by the number of total DALYs saved. Given that Zambia has high levels of inadequate vitamin A intake despite existing sugar fortification and CHW programs, it may be more relevant to examine what additional program(s) might be added to the current portfolio in the status quo, rather than analyzing what portfolios would be most cost-effective if they were designed from scratch, as had been done in Figure 14.8. If Zambia were to consider relative average cost-effectiveness levels of the other possible portfolios, as **Figure 14.9** illustrates, VAM would be added first, followed by oil (CBSO), then wheat flour (CBSOW) and finally maize meal (CBSOWM). But while adding all interventions results in a cost-effective portfolio, only the addition of VAM to the current portfolio significantly increases

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coverage (18%) while adding wheat flour and maize meal increase the total cost of the portfolio over 45% and 70% respectively. Figure 14.9 further shows what incremental additions would mean in terms of all four of the criteria that have been discussed; cost-effectiveness, cost, public health impact (DALYs saved) and coverage.

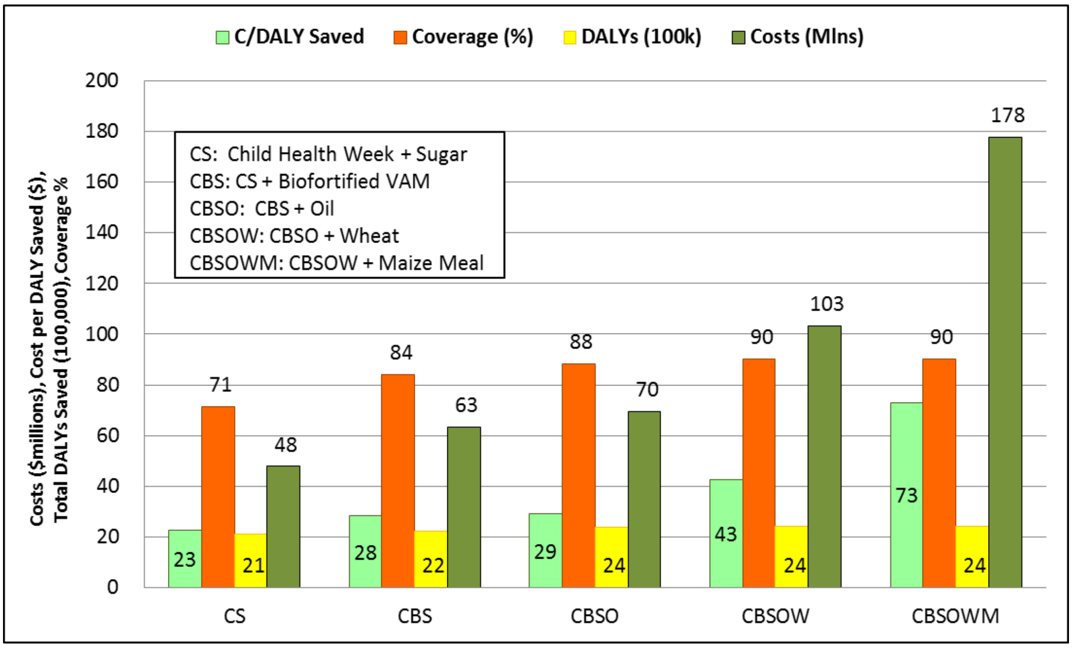

Figure 14.9: Total Costs, Cost per DALY Saved, Total DALYs Saved and Coverage of Zambia's Current and Potentially Evolving Portfolio Mix over Time

CONCLUSION

We have shown how the BPI and micronutrient intervention portfolio studies can be used to provide policy makers with a useful, empirical basis for making investment decisions about biofortification. The BPI is a powerful tool for donors and policymakers to screen many countries and subnational regions for their potential suitability for biofortification. Micronutrient intervention portfolio studies offer the ability to distinguish production, consumption and inadequate micronutrient intake at a more disaggregated level and offer a complementary design and planning tool to simulate the implementation of biofortification and examine its potential impact and cost-effectiveness among different approaches.

The BPI ranks Zambia as the 3rd highest priority country for investment in biofortification of vitamin A maize. Under modest assumptions of farmer adoption, portfolio analysis shows that VAM would be a highly cost-effective intervention. However, because most of VAM’s costs are incurred early in implementation, while its benefits accumulate slowly, VAM must be regarded as a long-term strategy, taking perhaps 10-15 years to reach maximum uptake. By 2042, under the assumption of 20%

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farmer adoption and assuming status quo trends in economic growth[5] it will account for about 12% of Zambian's daily VA EAR, but as high as 35-40% among the farmers who grow it. At that time multiple interventions will still be necessary—even with all six interventions, the prevalence of inadequate vitamin A intake will still be 39% [5]. VAM will make a significant contribution and will be an important complementary intervention. Moreover, VAM will extend coverage to 12% of all Zambians and 18% of rural residents who would not otherwise have any vitamin A program coverage, and will have its greatest impact in Central, Copperbelt, Eastern and Southern provinces, the provinces with lowest vitamin A intakes in 2013.

In addition, biofortification will be the most dynamic of the interventions and offer the most potential for achieving greater coverage and impact from the selected intervention portfolios. For example, several of the assumptions made in this study could prove to be overly pessimistic. If vitamin A content in VAM is increased beyond the 15 µg/g assumed here, if provitamin A retention among biofortified varieties during storage and food preparation is further improved, or if elevated vitamin A content becomes a standard breeding target also for other maize varieties—in a manner like zinc, which has been mainstreamed in the International Rice Research Institute's work—then the magnitude and the speed of the impacts discussed here would be understated. The results of two similar studies of biofortified staples—of high zinc rice in Bangladesh and high iron pearl millet in Rajasthan—suggest that accelerating adoption, production, and availability of a biofortified crop can translate more quickly into greater impacts with little additional cost and even higher levels of cost-effectiveness.

Finally, further analyses of these types should examine the extent to which these results hold under other important scenarios contributing both positively and negatively to the annual status quo considered as the counterfactual in these analyses. For example, the initiatives of the Sustainable Development Goals (SDGs) may accelerate economic growth and/or positively impact health indicators leading to improved annual status quo conditions and a diminished impact from specific interventions. Yet the competing forces of climate change may undermine some of these advances leading to a continued need to examine appropriate portfolios of interventions. The analyses illustrated here will help to identify and examine these portfolios in order to maximize the complementary nature of various interventions.

[5] Outputs from the IFPRI IMPACT model on changes in production and demand over 30 years were used to calculate rates of change in maize production and food consumption in this analysis [4, 5].

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Table 14.1: Coverage, Consumption and Added Nutrient Levels of Bio/Fortification Vehicles

Vehicle	Bio/Fortification Level	Net Additonal Concentration of VA	2042 Mean Conditional* Consumption	2042 Conditional* VA Delivered	2042 Conditional* % EAR	% of Persons Consuming as Bio/Fortified		% of Food Consumed as Bio/Fortified	2042 Unconditional* % EAR Delivered
	(µg/g RAE)	(µg/g RAE)	(g/AME/day)	(µg RAE/d)	%	2013	2042	%	%
National									
1. Sugar	10	7.20	37.6	271	43%	62%	69%	100%	30%
2. Oil	30	20.40	24.5	499	80%	61%	67%	100%	54%
3. WFE	5.9	4.66	77.7	362	58%	46%	57%	100%	33%
4. Maize Meal (B&R)	1	0.79	302.8	239	38%	24%	24%	100%	9%
5. Maize	15	0.87	345.8	299	48%	6%	54%	48%	12%
Rural									
1. Sugar	10	7.20	29.6	213	34%	57%	63%	100%	22%
2. Oil	30	20.40	13.5	276	44%	57%	63%	100%	28%
3. WFE	5.9	4.66	46.3	216	35%	32%	41%	100%	14%
4. Maize Meal (B&R)	1	0.79	349.3	276	44%	5%	5%	100%	2%
5. Maize	15	0.87	358.7	310	50%	6%	42%	57%	12%
Urban									
1. Sugar	10	7.20	49.1	354	57%	73%	81%	100%	46%
2. Oil	30	20.40	33.6	685	110%	68%	74%	100%	81%
3. WFE	5.9	4.66	104.1	485	78%	73%	87%	100%	68%
4. Maize Meal (B&R)	1	0.79	294.7	233	37%	59%	59%	100%	22%
5. Maize	15	0.87	319.8	277	44%	6%	75%	40%	13%

* "Conditional" averages include only consumers of the food vehicle while "Unconditional" averages include consumers and non-consumers

WFE: Wheat Flour Equivalents; B&R: breakfast and roller meal

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