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Benefit-Cost Analysis

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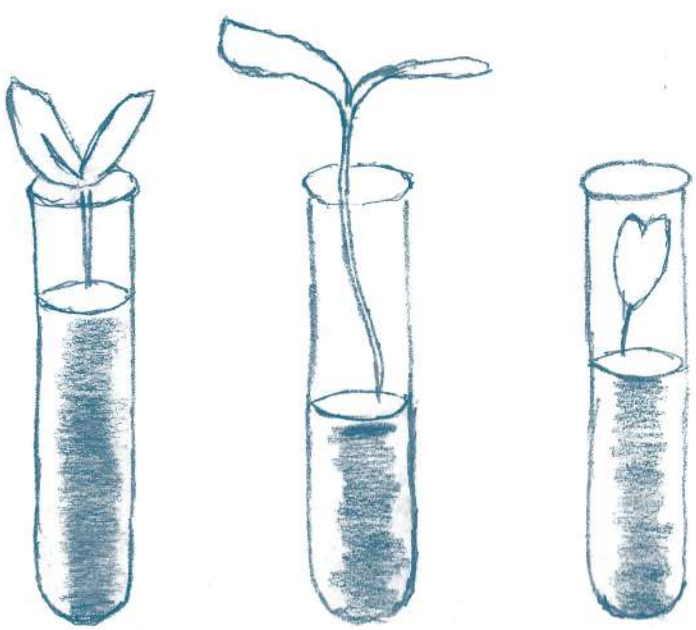

Copenhagen Consensus Center

Haïti Priorise

Un plan de **développement** alternatif

Costs and Benefits of Investment in Agricultural Research and Development (R&D) in Haiti

Haïti Priorise

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Working paper as of April 3, 2017.

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This work has been produced as a part of the Haiti Priorise project.

This project is undertaken with the financial support of the Government of Canada. The opinions and interpretations in this publication are those of the author and do not necessarily reflect those of the Government of Canada.

Academic Abstract

There have been no sustained investments in agricultural research and development (R&D) in Haiti. This paper estimates the net social benefits that could accrue from an annual investment of $25.0 million to support the establishment of a research institution that is likely to help transfer cutting-edge agricultural technology to Haiti's farmers. Two traditional economic measures, net present value (NPV) and benefit cost ratio (BCR), are used to evaluate the benefits/returns from this investment. The results show that, calculated at their 2017 present value, future net benefits are estimated to be between $-66 and $327 million for the period 2017-2050. The calculation of these benefits depends on assumptions of productivity gains, the costs required to set up a research institution, discount rates, and the rate of technological adoption. The results also show that estimated BCR ranges between 0.70 and 1.60. This implies that if one dollar is invested, the return would be expected to be between $0.7 and $1.60. In other words, an agricultural R&D investment in Haiti is unlikely to generate any significant amount of social benefit to its society.

Key words: agricultural productivity, benefit-cost ratio (BCR), net present value (NPV), research and development (R&D), and adoption of technology.

1. Introduction

Haiti is a small country with a surface area of 27,750 square kilometers. Its current population is approximately 11.0 million, half of whom live in rural areas (UN data, 2016). Agriculture still plays a crucial role in the economy even as its share in the national gross domestic product (GDP) is declining, with a current GDP share of around one-sixth.[1] The total amount of agricultural land in Haiti is roughly 1.80 million hectares, of which more than half is suitable for crop cultivation (arable land) (FAOSTAT 2016). Fifty percent of Haitians depend on agriculture, either directly or indirectly (Oxfam, 2010).The average farm size is small: generally around 0.50 hectares, and farmers are dependent on subsistence farming (WB, 2010).

The main cereal crops that are grown in Haiti are maize, rice, and sorghum (MARNDR, 2014), which also make up the staple food of the population. Currently these crops are cultivated in approximately one-third of the total agricultural land (Table 1) or just over one-half of the country's arable land[2].

[1] The value of GDP was $8,599 million (current prices) in 2015 (UN data, 2016).
[2] The share of these crops, in terms of the value of gross agricultural production is small, about 10% (last column, Table 1), because these are low-value crops.

Table 1. Main agricultural crops in Haiti†

	Area ('000 hectares)	% of total agricultural area⊥	Quantity produced ('000 tons)	Value of production ($ million)	% of gross agricultural production value‡
Cereals (considered in this study)					
Maize	361	19.9	299	42	3.78
Rice	60	3.3	154	43	3.82
Sorghum	119	6.6	105	17	1.54
Other food crops					
Bananas/Plantain	105	5.8	692	131	11.64
Beans, dry	160	8.8	103	60	5.38
Cassava	87	4.8	386	40	3.61
Potato/Sweet potato	87	4.8	569	45	4.05
Yams	40	2.2	350	89	7.93

Notes:
† 2011-2013 average values were considered; gathered from the FAOSTAT (2016).
‡ The average gross agricultural value was around $1.122 billion (2004-06 prices).
⊥ The average total agricultural area was 1.80 million hectares, while total arable land was 1.043 million hectares.

In addition to their contribution to the GDP, these cereal crops are very important for Haitians in terms of their food and nutritional security. These crops supply around 37.5% and 38.1% of the population's total calorific and protein intakes, respectively (Table 2).

Table 2. Food balance sheets in 2013

Items	Food supply		Protein supply	
	kcal/capita/day	% of total	g/capita/day	% of total
Rice (milled equivalent)	426	20.4	8.4	17.6
Maize and products	217	10.4	5.7	11.9
Wheat and products	141	6.7	4.1	8.6
Roots	281	13.5	3.2	6.7
Pulses	186	8.9	11.7	24.6
Oil and oil crops	288	13.8	1.3	2.8
Vegetables	16	0.8	0.8	1.7
Meat and animal products	154	7.4	10.2	21.3
Others	380	18.2	2.3	4.8
Total	2089	100.0	47.7	100.0
Required level	2500		56.0	
Food deficit	511		7.3	

Notes: Author's own calculation based on data gathered from the FAOSTAT (2016); kcal = kilocalories; g = gram.

Rice alone supplies nearly one-fifth of the total energy, or protein, consumption. It should be noted that the per capita consumption of rice has increased significantly in the last two decades. For example, it increased nearly six-fold (5.6) between 1990-91 and 2016-17. However, the per capita consumption of maize has remained almost constant during the same period, and sorghum consumption has declined (Table 3). This implies that the preferences for certain staple foods have changed in Haiti.

Table 3. Trends in area, production, and consumption of staple foods in Haiti

Crops	Attribute	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11	2016-17
	Population (million)	3.94	4.79	5.82	7.24	8.69	10.14	11.00
Maize	Area (000 ha)	300	310	250	175	350	350	350
	Production (tmt)	325	240	295	170	300	250	250
	Import (tmt)	0	0	5	0	0	0	10
	Consumption (tmt)	325	240	300	170	300	250	260
	Per capita consumption (kg/yr)	82.4	50.1	51.6	23.5	34.5	24.6	23.6
Milled Rice	Area (000 ha)	45	75	75	50	52	75	75
	Production (tmt)	33	52	52	62	78	78	69
	Import (tmt)	0	0	0	1	252	332	471
	Consumption (tmt)	33	52	52	63	330	410	540
	Per capita consumption (kg/yr)	8.4	10.8	8.9	8.7	38.0	40.4	49.1
Sorghum	Area (000 ha)	0	220	160	140	115	115	115
	Production (tmt)	0	210	180	110	90	90	90
	Consumption (tmt)	0	210	180	110	90	90	90
	Per capita consumption (kg/yr)	0.0	43.8	30.9	15.2	10.4	8.9	8.2
Total cereals	Area (000 ha)	345	605	485	365	517	540	540
	Production (tmt)	358	502	527	342	468	418	409
	Import (tmt)	0	0	5	1	252	332	481
	Consumption (tmt)	358	502	532	343	720	750	890

Notes: Data sourced from USDA PS&D (2016); tmt = thousand metric tons; ha = hectare; kg = kilogram, yr = year.

Food shortages are common in Haiti meaning that per capita energy and protein intakes are significantly less than the required levels. The average energy intake is around 511 kilocalories lower than the required level, of 2500 kilocalories per day, whereas protein intake is nearly 7.3 grams lower than the required level of 56 grams per day (Table 2). This food shortage could be reduced, if the rice supply were to be increased and the entire food deficit gap could be reduced if rice consumption were to double. A Haitian's annual per capita rice consumption is around 59 kilograms, compared to 110 kilograms per person in the major rice-consuming countries[3].

The food shortage could be reduced by adapting several differing strategies.

One strategy could be to increase the amount of rice that is imported into Haiti, in order to offset the total food shortage. Currently, Haiti imports 471 thousand metric tons of milled-rice annually, and this amount comes mainly from the USA. However, most Haitians are poor[4] and it is possible that they may not be able to afford imported rice at market prices[5]. In this case, the Haitian government could adopt initiatives (e.g. subsidized programs, such as the 'social safety net' that Bangladesh and India introduced for ensuring the food security of their poor people) to provide rice to the country's extreme poor, at below market prices. However, this would require an enormous amount of budget which the Haitian government cannot afford.

Another strategy could be to increase rice production. This could be a viable option for Haiti because its current crop productivity (per hectare yield) is among the lowest in the countries of the Latin American region (LACs) (Table 4). The productivity of maize, rice, and sorghum in Haiti is presented in Figure 1, which shows that yields have been declining since the 1990s.

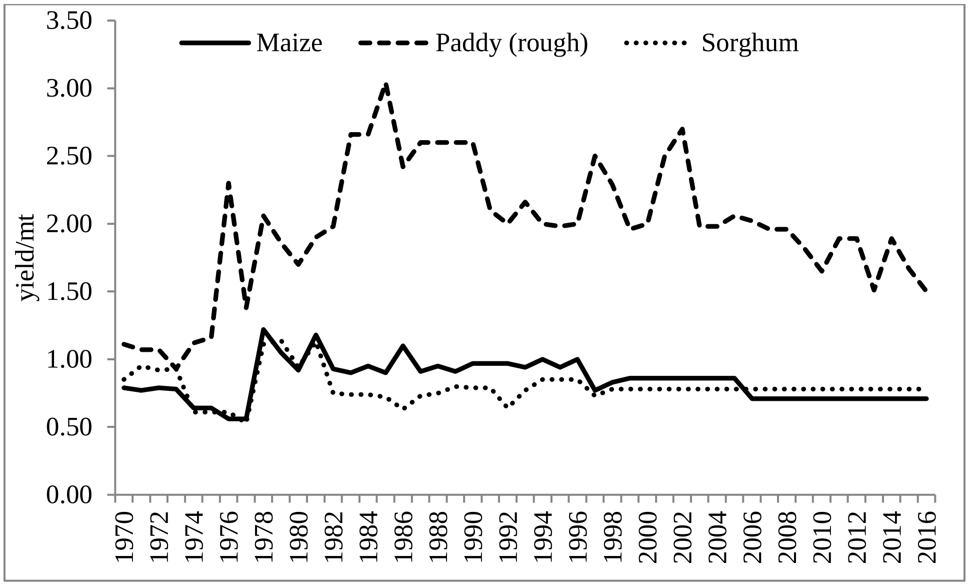
[3] Average per capita consumption in Bangladesh, India, Nepal, and Sri Lanka was considered.
[4] Approximately 59% of Haitians live under the national poverty line of $2.42 per day, and 24% live under the extreme poverty line of $1.23 per day (ECVMAS 2012 cited in WB 2016).
[5] The cost of imported rice from the U.S. is less than the locally grown rice (Garth, 2013; Cochrane *et al.*, 2016)

Table 4. Maize, rice, and sorghum yields (metric tons/hectare) in the LACs

Country	2013-14 to 2015-16 average (USDA PS&D 2016)			2012-2014 average (FAOSTA 2016)		
	Maize	Paddy (rough)	Sorghum	Maize	Paddy (rough)	Sorghum
Argentina	8.15	6.68	4.48	6.39	6.63	4.38
Bolivia	2.30	2.72	2.81	2.37	2.70	2.35
Brazil	4.88	5.26	2.43	5.15	5.00	2.78
Chile	11.32	6.44		10.49	6.16	
Colombia	3.64	4.45	4.26	3.10	4.48	3.35
Costa Rica	1.80	3.43		2.09	3.71	
Cuba	2.31	3.20		2.35	3.32	1.10
Dominican Republic	1.51	4.97	1.78	1.54	4.35	1.43
Ecuador	3.78	3.38	2.00	2.85	3.98	1.58
El Salvador	2.64	5.79	1.53	2.94	6.15	1.57
Guatemala	1.98	3.23	1.18	2.08	2.94	1.74
Haiti, a	0.71	1.69	0.78	0.83	2.49	0.88
Honduras	1.39	3.93	1.14	1.63	6.20	1.20
Mexico	3.43	5.65	3.69	3.23	5.59	3.91
Nicaragua	1.47	4.12	2.00	1.50	4.09	2.02
Panama	1.68	2.76		2.01	2.47	4.05
Paraguay	4.62	5.85	1.37	3.70	5.98	4.23
Peru	3.24	7.74	1.00	3.25	7.70	3.93
Uruguay	4.94	8.21	4.01	4.73	7.93	4.17
Venezuela	2.94	3.90	1.11	3.74	5.05	2.23
Median (without Haiti), b	2.94	4.45	2.00	2.94	5.00	2.35
% higher than Haiti's current yield, $c = \frac{b-a}{a} * 100$	315	164	156	252	100	167
Expected yield, $d = \frac{3}{4} * b$	2.20	3.53	1.59	2.20	4.16	1.86
% higher than Haiti's current yield, $e = \frac{d-a}{a} * 100$	210	109	104	168	67	111

Source: Author's own computations.

Figure 1. Trends in yield of major grain foods in Haiti



Source: USDA PS&D (2016).

After reviewing these facts some questions that suggest themselves are: Why has crop productivity been declining in Haiti? Why has Haiti not yet taken the opportunity to adopt the same cutting-edge agricultural technologies (e.g. high yielding and stress-tolerant varieties, climate-smart management technologies) as are already available in other parts of the world?

One explanation could be the different obstacles that the Haitian's agriculture sector has encountered. These include a lack of quality seeds, a lack of an irrigation infrastructure, weak governmental extension services, a lack of access to credit, poor quality of soil and water, and natural disasters (Cochrane, *et al.* 2016, MARNDR, 2015; Oxfam, 2010, WB, 2010). Most importantly, there have been no investments in agricultural research and development (R&D) in Haiti, thus far (pers. com. with a sector specialist in Haiti). It is likely that many of these obstacles could have been overcome if agricultural investments had been made, which might have resulted in higher crop productivity.

Previous studies have shown that agricultural R&D investments have been proved to be an engine of productivity growth, as well as a way of lifting tens of millions out of poverty and hunger, in differing countries in the world (Evenson and Gollin 2003, Thirtle *et al.* 2003, Fan *et al.*

2007, Raitzer and Kelly 2008, Alene *et al.* 2009, Alston 2010, Renkow and Byerlee 2010, Hurley *et al.* 2014).

A study by Evenson and Gollin (2003) was the first (and only) comprehensive global evaluation of the impact of the investment made by the Consultative Group on Agricultural Research consortium (CGIAR)[6], which has invested tens of billions of dollars in genetic crop improvement (CGI) programs. The study evaluated the investments of eight CGIAR centers' made in ten crops, worldwide, during the period 1965-1998. They found that the impact, in terms of adopted area and yield growth, was the highest in rice, wheat and maize. They estimated that the global contribution of CGI on yield growth, for these three crops, was between 0.70 to 1.0% annually, whereas, CGIAR's contribution was between 0.19 to 0.37%. The annual yield growth for sorghum alone was impressive: around 0.19 to 0.20%. Evenson and Gollin (2003) also distributed the CGI contribution by regions. They found that the total contribution to yield growth for these ten crops was highest in Asia (0.88%), followed by Latin America (0.66%), and then Sub-Saharan Africa (0.28%). It should be noted that at that time, the CGIAR's CGI annual contribution to Latin America was around 0.35 to 0.39%.

The overall returns/benefits from the productivity gains, in terms of monetary values, were significant (Hurley *et al.* 2014, Renkow and Byerlee 2010, Alston 2010, Raitzer and Kelley 2008, Fan *et al.* 2007, Thirtle *et al.* 2003, Evenson and Gollin 2003)[7]. Fan *et al.* (2007) estimated that, in 2000, the contribution to national and international rice research, in India and China, was around $3.6 billion and $5.2 billion, respectively. Another study by Raitzer and Kelley (2008) estimated that the annual benefit of CGIAR research in rice (Asia only) was around $10.8 billion, whereas, for maize (CIMMYT only) it was between $0.6 to 0.8 billion.

Citing Hazell (2009), Raitzer and Kelley (2008) and Maredia and Raitzer (2006) and Renkow and Byerlee (2010) reported the benefits and costs of CGIAR research investment over the period of its lifetime. They noted that investments in the CGIAR generated nearly $14-$120 billion in net

[6] CGIAR is a global agricultural research partnership and currently comprises of a group of 15 international agricultural research centers. It was founded in 1971 and its core mission includes agricultural productivity, poverty alleviation and environmental sustainability. Since it was founded, it has spent billions of dollars to attain these goals.
[7] A detailed review on the benefits from investment in international agricultural research can be found in a recent study by Renkow and Byerlee (2010), Alston (2010), and Hurley *et al.* (2014).

present value, under different scenarios. The overall benefit-cost ratio (BCR) was estimated to be between 1.94 and 17.26; for the African countries, it was around 1.12-1.64. With regard to the LACs, previous studies in Argentina, Chile, and Peru found that BCRs for research investment, in maize crops alone, were 11.4, 3.3, and 9.1, respectively, while in Mexico it was between 15 and 27 for wheat crops (Himes, 1972; Yrarrázaval *et al.*, 1982; Cap and Miranda, 1994; Marasas *et al.*, 2003; Barkley *et al*., 2008 cited in Pardey *et al.*, 2016). Finally, a recent study by Hurley *et al.* (2014) reviewed 2,242 published studies on the evaluations of investments in food and agricultural related research and development, of which roughly 28% reported BCR estimates. The researchers reported that the mean and median BCRs were 22.9 and 10.5, respectively. Therefore, it can be concluded that international investments in agricultural R&D have paid world societies well.

As mentioned earlier, investments in agricultural R&D are also a way of lifting millions of poor people out of poverty and hunger. The pathway to reducing poverty and hunger can be also linked to reductions in food prices that are the result of the productivity gains that stem from the adoption of modern varieties of cereal. Fan *et al.* (2007) estimated that between 1981 and 1999 more than 6.75 million Chinese, and 14.0 million Indians, were lifted out of poverty because of the investments made in rice research by the International Rice Research Investment (IRRI). Furthermore, In Africa, Alene *et al.* (2009) estimated that, in Africa, maize research investment helps 740 thousand people out of poverty annually.

Finally, based on the evidence above, it can be concluded that investment in agricultural R&D helps to increase crop productivity, generates billions of dollars' worth of social benefits, and alleviates poverty and hunger. Similar benefits could be expected for the Haitian people if a research investment was made in their agricultural development. Given these reasons, this paper explores the costs and benefits that the establishment of a research institution that is likely to bring, in helping to transfer cutting-edge agricultural technology to farmers and possibly resulting in increased crop productivity.

2. Theory

2.1 Methods to Estimate Costs and Benefits

This following section describes the quantitative methods that were used to estimate the benefits of agricultural R&D investment in Haiti.

2.1.1 Direct costs

National expenditure on agricultural research

It would seem that there is no formal agricultural research institution in Haiti. For this reason, it is assumed that the establishment of a new research institution could be useful in several ways: it could assist in spending the allocated disbursement for agricultural research efficiently, it could introduce new technology that is already available in other countries, and it could disseminate this to local farmers. A substantial amount of agricultural research expenditure would be required to achieve this. In this study, the required spending is calculated based on the following four assumptions:

(i) 1.0% of the total agricultural GDP (AgGDP) is spent on agricultural R&D,

(ii) $3.32 million is spent per million of the country's population,

(iii) $0.15 million is spent, per researcher, with a total of 165 FTEs, and

(iv) $4.14 million is spent for every 100,000 farmers.

Based on these assumptions, the total spending required for agricultural R&D in Haiti is estimated to be between $15.13 and $36.50 million (the mean is $25.50 million). The rationale of the above assumptions and the calculations of these estimates are described below.

The United Nations' (UN) minimum set target for spending on national agricultural research is 1.0% of a country's AgGDP. It should be noted that the average spending by the 28 LACs and the Caribbean was 1.3% annually in 2012-13 (Stads *et al.* 2016). Based on this minimum target, research spending for Haiti is required to be around $15.13 million (1% of $1.513 billion of AgGDP). The second assumption is based on the total spent per million of population. On average, a Latin American county spends about $6.53 million (constant 2011 PPP dollars), per million, of their population. In contrast, a low-spending county[8] spends approximately $3.32 million, on average (Table 5).

Table 5. National expenditure of the Latin American Countries (LACs) on agricultural research, in 2013

Country	Total spending (million 2011 PPP $)	Spending as a share of AgGDP	Million constant 2011 PPP $/ million population	Million constant 2011 PPP $/ 100,000 farmers	Million constant 2011 PPP $/ FTE
Brazil	2,704	1.82	13.50	26.48	0.46
Argentina	732	1.29	17.66	53.13	0.13
Mexico	710	1.05	5.81	9.09	0.18
Colombia	254	0.79	5.25	7.32	0.23
Chile	186	1.65	10.58	19.50	0.26
Venezuela	86	0.31	2.84	12.55	0.17
Peru	83	0.35	2.75	2.21	0.24
Uruguay	77	1.40	22.73	42.09	0.21
Bolivia	59	0.93	5.52	2.74	0.31
Costa Rica	37	1.06	7.73	11.67	0.15
Ecuador	27	0.18	1.73	2.15	0.18
Paraguay	27	0.26	3.93	3.10	0.13
Dominican Republic	20	0.30	1.97	4.59	0.10
Nicaragua	17	0.38	2.92	5.07	0.13
Guatemala	16	0.14	1.03	0.73	0.11
Panama	15	0.74	4.08	6.05	0.11
Honduras	8	0.17	0.95	1.13	0.09
All countries average	298	0.75	6.53	12.33	0.19
Low spending countries (average)⊥⊥	25	0.46	3.32	4.14	0.15

Sources: Author's own calculations, based on data gathered from the Agricultural Science and Technology Indicators (ASTI) led by International Food Policy Research Institute (IFPRI), available at http://www.asti.cgiar.org/.
Notes: ⊥⊥ Low-spending countries are defined as those countries that spend less than $ 60 million per year. AgGDP = agriculture gross domestic product.

Given that Haiti has a total population of 11.0 million, the total required spending would be around $36.50 million. The third assumption is based on the total spent per full time researcher. Table 5 shows that the nine low-spending countries had, on average, 165 full-time researchers (FTEs) and their spending per researcher was around $0.15 million. Allowing this same amount for Haiti, approximately $24.75 million would be required to set up a research institution. Finally, the fourth assumption is based on how much a Latin American country spends on agricultural research, per farmer. Table 5 shows that low-the spending countries, spent approximately $4.14

[8] A low-spending country is defined as a country that spends less than $60 million, annually, on agricultural research and development. Bolivia, Costa Rica, Ecuador, Paraguay, the Dominican Republic, Nicaragua, Guatemala, Panama, and Honduras are in this list.

million, per every 100,000 farmers. In Haiti, there are 630 thousand rice, maize, and sorghum farmers (WB 2010), so the total AgR&D spending would be $26.07 million per year.

In summary, based on the four assumptions, the estimations for total spending are found to be reasonable. The considered mean spend, required for Haiti's annual national agricultural research expenditure, is $25.50 million. It should be noted that this expenditure is expected to be used as salaries, program operating costs, and capital investments. In addition, a one-time fixed cost of around 5.0 million is arbitrarily assumed (i.e. for building, materials, etc.). Thus, at time t the research costs, C_t, would be $30.50 million and $t+1$ and in the following years it would be $25.50 million (column 2, Table 6), which are he factors used for the benefit-cost calculation.

Table 6. The undiscounted research costs and benefits (in million $) from agricultural research investments in Haiti

Year	Time, t	Research costs, C_t	Baseline value of production	Productivity benefits, B_t	
				50% adoption	60% adoption
2017	0	31.6		-	-
2018	1	26.6		-	-
2019	2	26.6		-	-
2020	3	26.6	141	-	-
2021	4	26.6	145	0.2	0.2
2022	5	26.6	149	0.5	0.6
2023	6	26.6	153	1.0	1.1
2024	7	26.6	157	1.8	2.1
2025	8	26.6	161	3.1	3.7
2026	9	26.6	165	5.2	6.2
2027	10	26.6	169	8.3	9.9
2028	11	26.6	173	12.7	15.2
2029	12	26.6	177	18.4	22.2
2030	13	26.6	181	25.3	30.5
2031	14	26.6	186	32.6	39.4
2032	15	26.6	191	39.6	47.9
2033	16	26.6	196	45.8	55.5
2034	17	26.6	201	51.0	61.7
2035	18	26.6	206	55.0	66.6
2036	19	26.6	210	58.0	70.3
2037	20	26.6	215	60.5	73.3
2038	21	26.6	220	62.5	75.8
2039	22	26.6	225	64.3	78.0
2040	23	26.6	230	66.0	80.0
2041	24	26.6	234	67.2	81.5
2042	25	26.6	239	68.6	83.2
2043	26	26.6	245	70.1	84.9
2044	27	26.6	250	71.6	86.8
2045	28	26.6	256	73.1	88.6
2046	29	26.6	261	74.4	90.3
2047	30	26.6	266	75.9	92.0
2048	31	26.6	272	77.4	93.9
2049	32	26.6	277	79.0	95.8
2050	33	26.6	283	80.6	97.7

Notes: Author's own estimation; value of production comprised of the values of maize, rice, and sorghum.

2.1.2 Direct benefits

Productivity gain

The research estimated, expenditure above, is likely to boost crop yield in Haiti. However, the question remains how much yield gain could be achieved. It is expected that a crop yield could be obtained similar to those already achieved by the other LACs. The median yields of maize, paddy (rough), and sorghum in the other LACs (except Haiti) are approximately 2.94, 4.45, and 2.00 metric tons per hectare (mt/ha), respectively (row 21, Table 4), whereas for Haiti these are 0.71, 1.69, and 0.78 mt/ha, respectively (row 12, Table 4). In other words, the median yields of maize, rice, and sorghum in Haiti are about 4.15, 2.64, and 2.56 times lower than the respective median yields of the other LACs[9]. It should be noted that historically Haiti has the lowest crop yield among the LACs. Therefore, reducing the yield gap is a must, if food and nutrition security are to be ensured. Currently, high-yielding varieties with biotic and abiotic stress traits are available. Adopting these varieties could even generate even higher yields. For example, in a randomized control experiment, Dar *et al.* (2013) found that a flood-tolerant rice variety had a yield that was up to 45% higher than traditional varieties. Moreover, the adoption of modern and/or climate-smart management practices could increase yield again and could save irrigation and fertilizer costs. If an agricultural research institution were to be set up in Haiti, it could reduce the yield gap by assisting in the transfer of cutting-edge technologies (i.e. stress-tolerant varieties, climate-smart management practices) and disseminating them among farmers. This study assumes that, in Haiti, yields of maize, paddy, and sorghum could be achieved of up to three-fourths of the median yields of the other LACs; that is around 210%, 109%, and 104% (respectively) higher than Haiti's current level yields (see the last row of Table 4). In other words, this intervention[10]could generate expected maize, rice, and sorghum yields of 2.20, 3.53, and 1.59 mt/ha. Finally, it is assumed that these yield gains could only be realized in the irrigated areas of Haiti.

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[9] Rice yield data as reported by the FAO and USDA do not agree, however, the relative measures are the same, irrespective of the referred data source.

[10] The estimation process is reported in the lower part of the Table 4. For instance, for maize, it can be expressed mathematically as: $y_{expected} = (1 + g)\ y_{current} => (1 + \frac{210}{100}) * 0.71 => 2.20$.

Adoption path

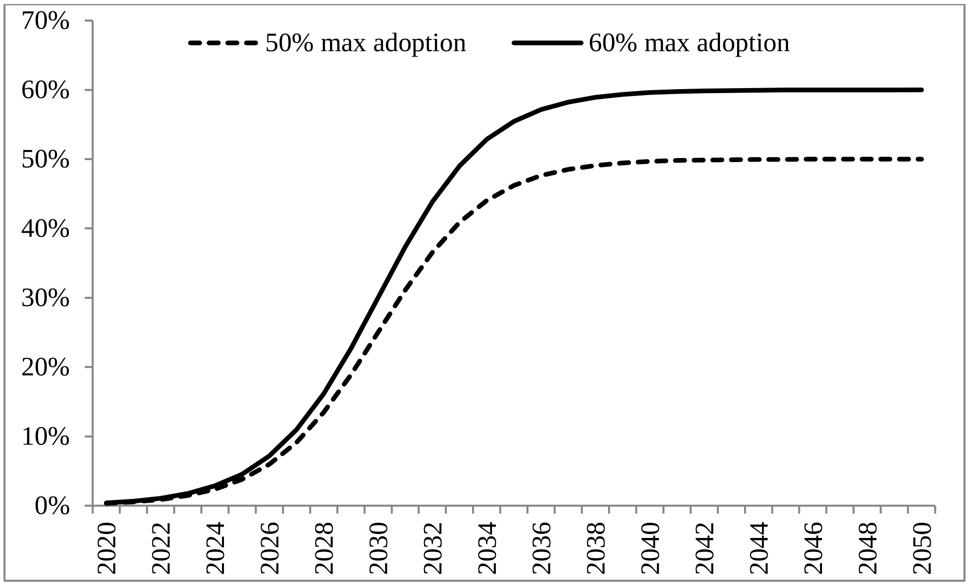
The aforementioned yield gains could not be realized simultaneously in all areas in Haiti. The dissemination of any innovation usually takes years and follows an adoption path. Experience has shown that the adoption of any new agricultural technology generally takes about 15-20 years to reach its maximum level. After that, it will either continue at the maximum level or it will deteriorate because of the availability of other, better technologies. Experience has also shown that the maximum adoption level ranges between 50% and 70%. For example, the popular high yielding rice varieties in Bangladesh, Indonesia, and the Philippines reached up to 50% to 60% and it took around 12-15 years (Raitzer *et al.* 2015; Hossain *et al.* 2012) to reach this point. Regarding the adoption of modern maize varieties, the maximum adoption levels that were reached were between 45% and 50% in Latin American countries, and 35% to 60% in African countries (Byerlee, 1994, Byerlee and Heisey, 1996, Morris and Lopez-Pereira, 1999, Alene *et al.* 2009, La Rovere *et al.* 2014, Walker *et al.* 2014). Finally, the maximum adoption level of modern sorghum cultivars has reached up to 70%, in all of India, in the last 30 years (Charyulu *et al.* 2013).

This study considered two adoption levels that are expected to reach maximum levels of 50% and 60% in 2040. The research lag is assumed to be four years, so benefits would begin to be realized in 2020 and would continue until 2050. Moreover, it is assumed that the technological adoption would follow a logistic type curve, which is widely used in the literature. Following the specification made by Bairagi (2015), the logistic function can be expressed as:

$$A = \frac{\phi_1}{1 + exp^{[(\phi_2 - t)/\phi_3]}} \qquad (1),$$

where, ϕ_1 is the upper asymptote, ϕ_2 is the time at which the response is half its asymptotic value, and ϕ_3 is the adoption parameter. Here, $\phi_1$to be 0.5 or 0.6 as 50% and 60% are the maximum levels of adoption, ϕ_3 is set to be 2, which is basically concerned with the shape of the curve, and $\phi_2 = 2030$, median of time, $t = 2020, \dots, 2040$. The posited adoption rates there were estimated, using these parameters, are reported in Figure 2.

Figure 2. Posited agricultural technology path



Source: Author's own calculation based on equation 1.

Expected future benefits from technology adoption

This study used the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) to estimate the future benefits of technological adoption. This is a partial equilibrium, multi-commodity, multi-country model, that was developed by the International Food Policy Research Institute (IFPRI)[11]. In this model, the demand for an agricultural commodity is specified as a function of prices, income, and population growth, and supply is determined by crop and input prices, productivity growth rate, and water availability. This model uses demand and supply elasticity to approximate the demand and supply functions, and iteratively solves world prices, as well as satisfying international market clearing conditions. Finally, and based on historical information, it projects food supply, demand, trade, and prices up till 2050, which is hereafter called the baseline results.

I simulated this model incorporating the feasible yield gains, estimated above, (210%, 109%, and 104% yield gain for maize, rice, and sorghum, respectively in Table 4) along with the estimated

[11] Detailed model descriptions (both graphical and mathematical) can be found in Rosegrant *et al.* (2002), Cline and Zhu (2008), Rosegrant and the IMPACT Development Team (2012), and Robinson *et al.* (2015).

adoption rates as shown in Figure 2. This will give another set of outcomes that is hereafter called the simulated results. Finally, the baseline and simulated results are compared in order to estimate productivity benefits. Mathematically, the aggregate benefits, B, at year t can be expressed as:

$$B_t = \sum_{i=1}^{3} p_{it}^{s} q_{it}^{s} - \sum_{i=1}^{3} p_{it}^{b} q_{it}^{b} \qquad (2),$$

where, superscripts ^{b} and ^{s} are the simulated and baseline outcomes; $i =$ maize, rice, and sorghum; p and q are the price and production quantities of the respective crops; and $t = 0, 1, \ldots .33$. It should be noted that yield gain could only be realized in the irrigated areas in Haiti.

2.2 Measuring Discounted Costs and Benefits

Two traditional and widely used economic measures: Net Present Value (NPV) and Benefit-Cost Ratio (BCR), are used in this study, in order to evaluate the payoff of agricultural research and development.

2.2.1 Net Present Value (NPV)

Net present value, NPV, is defined as the sum of the present value of benefit and cost flows over a period of time. Following Alston *et al.* (1995), NPV can be expressed as:

$$NPV = \sum_{t=0}^{33} \frac{B_t - C_t}{(1+\delta)^t} \qquad (3)$$

where B_t and C_t are the annual research benefits and expenditure, as defined earlier, and δ is the discount rate. Following the Copenhagen Consensus Center's (CCC) guidelines for Haiti, three different levels of discount rates, 3%, 5%, and 12%, are used in this study.

2.2.2 Benefit Cost Ratio (BCR)

Benefit Cost Ratio (BCR) is a relative measure of benefit-cost analysis, which can be calculated as:

$$BCR = \frac{\sum_{t=0}^{33} \frac{B_t}{(1+\delta)^t}}{\sum_{t=0}^{34} \frac{C_t}{(1+\delta)^t}} \qquad (4)$$

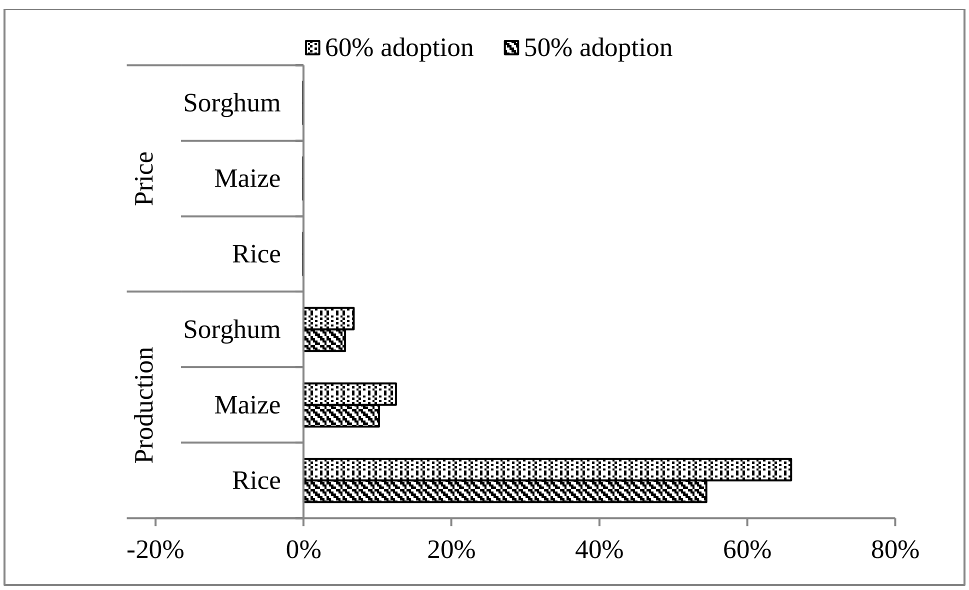
All the parameters in equation 4 are defined above.

3. Results and Discussions

3.1 Impact on production and price

Figure 3 illustrates the effects of agricultural research and development on cereal production and market price, in Haiti, keeping in mind that the research lag is assumed to be four years and that the adoption of agricultural technology is expected to start in 2020, reaching its maximum level (50%-60%) in 2040. The results show that by 2040, rice production in Haiti could increase by approximately 55% to 66% compared to the baseline values (last panel of Figure 3).

Figure 3. Effect of investment in agricultural R&D on commodity supply in Haiti, compared to the baseline values of 2040



Source: Author's own calculation based on a simulated model.

In other words, rice production is likely to increase by 81 to 98 thousand metric tons (tmt) by 2040, because of agricultural research investments. In addition, the production of maize and sorghum could increase by about 10% to 12% (41-51 tmt), and 6% to 7% (18-22 tmt), respectively. This increased commodity supply would push the market prices down, however the simulated results show that the price effect is not significant, resulting in a decrease of less than 0.5% Figure 3). Nevertheless, it is expected that consumption of these commodities would increase following this small decrease in price. This would mean that, on the whole, people in Haiti would be more food secure. However, in order to achieve/ensure food security, Haiti would also have to increase its cereal crop imports by approximately 19-23% in comparison to the baseline import of 2040.

The difference between the simulated and baseline values of aggregate cereal production (maize, rice, and sorghum) is reported in Table 6 (column 3-4). The aggregate productivity benefits of investments in agricultural research and development, in Haiti, could range between $66 million and $80 million (undiscounted) by 2040 and $81-$98 million by 2050, depending on the adoption level. It should be noted that the baseline results suggest the value of production is estimated to be around 230 million in 2040 and 283 million in 2050 (current price) (Table 6).

3.2 Discounted social benefits

The benefits from investment in agricultural research and development for the period 2017-2050 are reported in Table 7. The results show that at present 2017 values, future net benefits are estimated to be between $-66 to $327 million (discounted) (Table 7).

Table 7. Discounted social benefits (at the 2017 price) from investment in agricultural R&D in Haiti: 2017-2050

Discount rate, δ	Investment decision criteria	50% adoption	60% adoption
$\delta = 3\%$	Benefits ($ million)	719	871
	Costs ($ million)	544	544
	NPV ($ million)	175	327
	BCR	1.32	1.60
$\delta = 5\%$	Benefits ($ million)	487	589
	Costs ($ million)	418	418
	NPV ($ million)	69	172
	BCR	1.16	1.41
$\delta = 12\%$	Benefits ($ million)	146	177
	Costs ($ million)	212	212
	NPV ($ million)	-66	-35
	BCR	0.69	0.83

Source: Author's own estimation.

The calculation of these benefits depends on the assumptions of productivity gains, the cost of establishing a research institution, discount rates, and the technological adoption rate. It should be noted that the estimated social benefits could have been greater, if the indirect (i.e. the spillover impact of technology) and life-long (perpetuity) benefits had been considered.

Finally, the benefit cost ratio (BCR) has also been calculated for investment in agricultural R&D in Haiti. The estimated BCR ranges between 0.69 and 1.60 (Table 7). This implies that if one dollar is invested, the return is likely to be between $0.69 and $1.60. In other words, agricultural R&D investment in Haiti is unlikely to generate a significant amount of social benefits, although research has shown that agricultural research investments in other LACs are beneficial. Keep in mind that BCRs for research investment in maize crops only, in Argentina, Chile, and Peru are 11.4, 3.3, and 9.1, respectively, while wheat crops in Mexico they are between 15 to 27 (Himes, 1972; Yrarrázaval *et al.*, 1982; Cap and Miranda, 1994; Marasas *et al.*, 2003; Barkley *et al.*, 2008 cited in Pardey *et al.*, 2016). Given this, Haiti could learn from the aforementioned countries' experiences of investment in agricultural R&D, in order to gain the same increased social benefits as were generated in those locations.

3.3 Study limitations and risks of implementing the proposed intervention

This study assumed the proposed new agricultural research center would focus on only three commodities: maize, rice, and sorghum. Consequently, one might question why other high value crops (i.e. beans, bananas, and yams), and beef, that are also important for Haiti, were not considered. As mentioned before, the three crops considered in this study constitute about 30% of the total agricultural areas and these are the staple food for Haitians (see Table 1). Since more farmers are engaged in the value chain of these crops than alternatives, gains from research are likely to be spread more equitably across the agricultural sector by focusing on rice, maize and sorghum. If a Haitian research institution were able to lift productivity across a wide breadth of commodities, the benefits could be much larger.

It is not realistic that Haiti, or indeed most low-income developing countries that benefited from agricultural research investments can allot resources and attention to more than a handful of different commodities within a given research center. For instance, in Bangladesh rice crop is under a single research institution: Bangladesh Rice Research Institute (BRRI). Beef falls under yet another entity, the Bangladesh Livestock Research Institute (BLRI). Currently, Bangladesh is one of the top rice producing countries in the world and feeds around 160 million of its population from domestic production only; in India, banana falls under National Banana Research Center for Banana (NRCB); in Colombia, the Banana Research Center; in Costa Rica, the National Banana Corporation.

Secondly, the yield gains that were postulated in this study could be -underestimated because of the intervention itself; this is keeping in mind that the yield benefits were 210%, 109%, and 104% higher than the current level for maize, rice, and sorghum, respectively, and these gains would only be realized in the irrigated areas of Haiti. In terms of percentage gains, it seems large, but in absolute terms, these are 2.20, 3.53, and 1.59 metric tons per hectare, which are significantly lower than the potential yield levels of the available high-yielding varieties.

Thirdly, favorable conditions are obviously essential to realize significant gains from research. A research entity alone cannot ensure benefits from an intervention. In Haiti, access to other production inputs such as roads, irrigation infrastructure, and marketing and postharvest systems are weak. Yield gains could be higher and the benefit-cost ratio of agricultural R&D, if these pre-conditions were met. Indeed, millions of dollars have already been spent on agricultural development activities in Haiti, by various international organizations with little evidence of systemic benefits across Haitian agriculture (pers. com. a sector expert).

Finally, historical precedent suggests there is non-trivial continuation risk in establishing an agricultural R&D center in Haiti. There is uncertainty about the supply of funds required for operating the proposed research center. The initial establishment fund, of $25.0 million, could be found, but the center's required annual operating costs may be difficult to find (pers. com. a sector expert). In Haiti, the agriculture ministry has established twenty research entities, but around half of those were unsuccessful and had ceased operations (pers. com. a sector expert). Therefore, one pre-condition for a successful research entity would be to find a source of funds for both the initial set-up and the future operating costs.

4. Conclusion

This paper estimated the social net benefits of an annual investment of $25.0 million in agricultural R&D in Haiti. It is assumed that this investment would be used to set up a national center for agricultural research. The proposed center would facilitate the introduction of available cutting-edge agricultural technology and would help disseminate this to local farmers. It is also assumed that this investment would result in approximately 210%, 109%, and 104% increases in maize, paddy, and sorghum yields, respectively. Two traditional economic measures, NPV and BCR, were used to evaluate the benefits of this investment in agricultural R&D. The results show that at the present 2017 value, future net benefits are estimated to be between $-66 to $327 million.

The calculation of these benefits depends on the assumptions of productivity gains, the costs of establishing a research institution, discount rates, and the technological adoption rate. The results also show that the BCR is estimated to be a little over one, if 3% and 5% discount rates are considered, while it could be between 0.69 and 0.83 if a 12% discount rate was considered. As agriculture is a risky business in Haiti, assuming a high discount rate would be reasonable.

Consequently, this implies that an investment in agricultural R&D is unlikely to generate any significant amount of social benefit to its society.

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6. Tables and Figures

Table 1. Main agricultural crops in Haiti[†]

	Area ('000 hectares)	% of total agricultural area[⊥]	Quantity produced ('000 tons)	Value of production ($ million)	% of gross agricultural production value[‡]
Cereals (considered in this study)					
Maize	361	19.9	299	42	3.78
Rice	60	3.3	154	43	3.82
Sorghum	119	6.6	105	17	1.54
Other food crops					
Bananas/Plantain	105	5.8	692	131	11.64
Beans, dry	160	8.8	103	60	5.38
Cassava	87	4.8	386	40	3.61
Potato/Sweet potato	87	4.8	569	45	4.05
Yams	40	2.2	350	89	7.93

Notes:
[†] 2011-2013 average values were considered; gathered from the FAOSTAT (2016).
[‡] The average gross agricultural value was around $1.122 billion (2004-06 prices).
[⊥] The average total agricultural area was 1.80 million hectares, while total arable land was 1.043 million hectares.

Table 2. Food balance sheets in 2013

Items	Food supply		Protein supply	
	kcal/capita/day	% of total	g/capita/day	% of total
Rice (milled equivalent)	426	20.4	8.4	17.6
Maize and products	217	10.4	5.7	11.9
Wheat and products	141	6.7	4.1	8.6
Roots	281	13.5	3.2	6.7
Pulses	186	8.9	11.7	24.6
Oil and oil crops	288	13.8	1.3	2.8
Vegetables	16	0.8	0.8	1.7
Meat and animal products	154	7.4	10.2	21.3
Others	380	18.2	2.3	4.8
Total	2089	100.0	47.7	100.0
Required level	2500		56.0	
Food deficit	511		7.3	

Notes: Author's own calculation based on data gathered from the FAOSTAT (2016); kcal = kilocalories; g = gram.

Table 3. Trends in area, production, and consumption of staple foods in Haiti

Crops	Attribute	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11	2016-17
	Population (million)	3.94	4.79	5.82	7.24	8.69	10.14	11.00
Maize	Area (000 ha)	300	310	250	175	350	350	350
	Production (tmt)	325	240	295	170	300	250	250
	Import (tmt)	0	0	5	0	0	0	10
	Consumption (tmt)	325	240	300	170	300	250	260
	Per capita consumption (kg/yr)	82.4	50.1	51.6	23.5	34.5	24.6	23.6
Milled Rice	Area (000 ha)	45	75	75	50	52	75	75
	Production (tmt)	33	52	52	62	78	78	69
	Import (tmt)	0	0	0	1	252	332	471
	Consumption (tmt)	33	52	52	63	330	410	540
	Per capita consumption (kg/yr)	8.4	10.8	8.9	8.7	38.0	40.4	49.1
Sorghum	Area (000 ha)	0	220	160	140	115	115	115
	Production (tmt)	0	210	180	110	90	90	90
	Consumption (tmt)	0	210	180	110	90	90	90
	Per capita consumption (kg/yr)	0.0	43.8	30.9	15.2	10.4	8.9	8.2
Total cereals	Area (000 ha)	345	605	485	365	517	540	540
	Production (tmt)	358	502	527	342	468	418	409
	Import (tmt)	0	0	5	1	252	332	481
	Consumption (tmt)	358	502	532	343	720	750	890

Notes: Data sourced from USDA PS&D (2016); tmt = thousand metric tons; ha = hectare; kg = kilogram, yr = year.

Table 4. Maize, rice, and sorghum yields (metric tons/hectare) in the LACs

Country	2013-14 to 2015-16 average (USDA PS&D 2016)			2012-2014 average (FAOSTA 2016)		
	Maize	Paddy (rough)	Sorghum	Maize	Paddy (rough)	Sorghum
Argentina	8.15	6.68	4.48	6.39	6.63	4.38
Bolivia	2.30	2.72	2.81	2.37	2.70	2.35
Brazil	4.88	5.26	2.43	5.15	5.00	2.78
Chile	11.32	6.44		10.49	6.16	
Colombia	3.64	4.45	4.26	3.10	4.48	3.35
Costa Rica	1.80	3.43		2.09	3.71	
Cuba	2.31	3.20		2.35	3.32	1.10
Dominican Republic	1.51	4.97	1.78	1.54	4.35	1.43
Ecuador	3.78	3.38	2.00	2.85	3.98	1.58
El Salvador	2.64	5.79	1.53	2.94	6.15	1.57
Guatemala	1.98	3.23	1.18	2.08	2.94	1.74
Haiti, a	0.71	1.69	0.78	0.83	2.49	0.88
Honduras	1.39	3.93	1.14	1.63	6.20	1.20
Mexico	3.43	5.65	3.69	3.23	5.59	3.91
Nicaragua	1.47	4.12	2.00	1.50	4.09	2.02
Panama	1.68	2.76		2.01	2.47	4.05
Paraguay	4.62	5.85	1.37	3.70	5.98	4.23
Peru	3.24	7.74	1.00	3.25	7.70	3.93
Uruguay	4.94	8.21	4.01	4.73	7.93	4.17
Venezuela	2.94	3.90	1.11	3.74	5.05	2.23
Median (without Haiti), b	2.94	4.45	2.00	2.94	5.00	2.35
% higher than Haiti's current yield, $c = \frac{b-a}{a} * 100$	315	164	156	252	100	167
Expected yield, $d = \frac{3}{4} * b$	2.20	3.53	1.59	2.20	4.16	1.86
% higher than Haiti's current yield, $e = \frac{d-a}{a} * 100$	210	109	104	168	67	111

Source: Author's own computations.

Table 5. National expenditure of the Latin American Countries (LACs) on agricultural research, in 2013

Country	Total spending (million 2011 PPP $)	Spending as a share of AgGDP	Million constant 2011 PPP $/ million population	Million constant 2011 PPP $/ 100,000 farmers	Million constant 2011 PPP $/ FTE
Brazil	2,704	1.82	13.50	26.48	0.46
Argentina	732	1.29	17.66	53.13	0.13
Mexico	710	1.05	5.81	9.09	0.18
Colombia	254	0.79	5.25	7.32	0.23
Chile	186	1.65	10.58	19.50	0.26
Venezuela	86	0.31	2.84	12.55	0.17
Peru	83	0.35	2.75	2.21	0.24
Uruguay	77	1.40	22.73	42.09	0.21
Bolivia	59	0.93	5.52	2.74	0.31
Costa Rica	37	1.06	7.73	11.67	0.15
Ecuador	27	0.18	1.73	2.15	0.18
Paraguay	27	0.26	3.93	3.10	0.13
Dominican Republic	20	0.30	1.97	4.59	0.10
Nicaragua	17	0.38	2.92	5.07	0.13
Guatemala	16	0.14	1.03	0.73	0.11
Panama	15	0.74	4.08	6.05	0.11
Honduras	8	0.17	0.95	1.13	0.09
All countries average	298	0.75	6.53	12.33	0.19
Low spending countries (average)[┴┴]	25	0.46	3.32	4.14	0.15

Sources: Author's own calculations, based on data gathered from the Agricultural Science and Technology Indicators (ASTI) led by International Food Policy Research Institute (IFPRI), available at http://www.asti.cgiar.org/.
Notes: [┴┴] Low-spending countries are defined as those countries that spend less than $ 60 million per year. AgGDP = agriculture gross domestic product.

Table 6. The undiscounted research costs and benefits (in million \$) from agricultural research investments in Haiti

Year	Time, t	Research costs, C_t	Baseline value of production	Productivity benefits, B_t	
				50% adoption	60% adoption
2017	0	31.6		-	-
2018	1	26.6		-	-
2019	2	26.6		-	-
2020	3	26.6	141	-	-
2021	4	26.6	145	0.2	0.2
2022	5	26.6	149	0.5	0.6
2023	6	26.6	153	1.0	1.1
2024	7	26.6	157	1.8	2.1
2025	8	26.6	161	3.1	3.7
2026	9	26.6	165	5.2	6.2
2027	10	26.6	169	8.3	9.9
2028	11	26.6	173	12.7	15.2
2029	12	26.6	177	18.4	22.2
2030	13	26.6	181	25.3	30.5
2031	14	26.6	186	32.6	39.4
2032	15	26.6	191	39.6	47.9
2033	16	26.6	196	45.8	55.5
2034	17	26.6	201	51.0	61.7
2035	18	26.6	206	55.0	66.6
2036	19	26.6	210	58.0	70.3
2037	20	26.6	215	60.5	73.3
2038	21	26.6	220	62.5	75.8
2039	22	26.6	225	64.3	78.0
2040	23	26.6	230	66.0	80.0
2041	24	26.6	234	67.2	81.5
2042	25	26.6	239	68.6	83.2
2043	26	26.6	245	70.1	84.9
2044	27	26.6	250	71.6	86.8
2045	28	26.6	256	73.1	88.6
2046	29	26.6	261	74.4	90.3
2047	30	26.6	266	75.9	92.0
2048	31	26.6	272	77.4	93.9
2049	32	26.6	277	79.0	95.8
2050	33	26.6	283	80.6	97.7

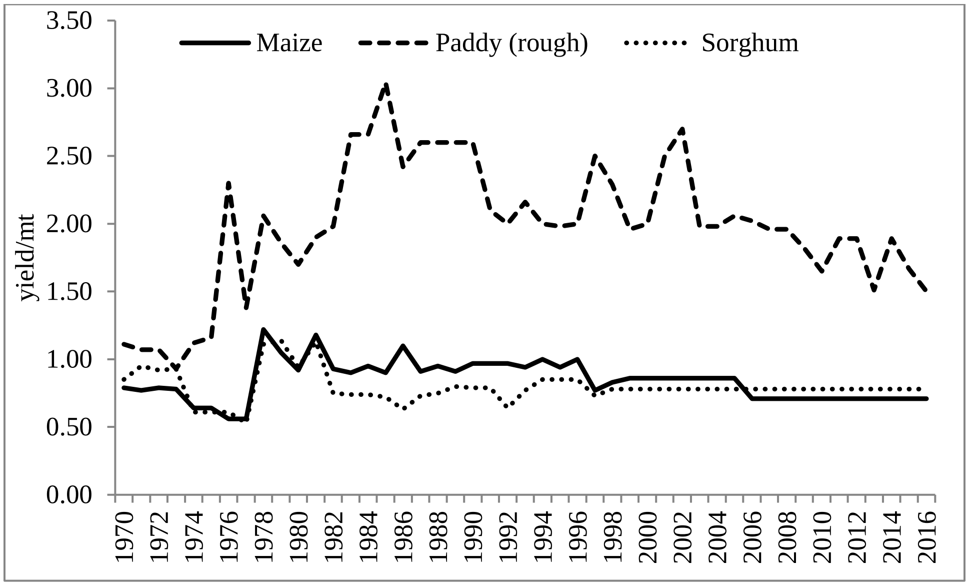
Notes: Author's own estimation; value of production comprised of the values of maize, rice, and sorghum.

Table 7. Discounted social benefits (at the 2017 price) from investment in agricultural R&D in Haiti: 2017-2050

Discount rate, δ	Investment decision criteria	50% adoption	60% adoption
$\delta = 3\%$	Benefits ($ million)	719	871
	Costs ($ million)	544	544
	NPV ($ million)	175	327
	BCR	1.32	1.60
$\delta = 5\%$	Benefits ($ million)	487	589
	Costs ($ million)	418	418
	NPV ($ million)	69	172
	BCR	1.16	1.41
$\delta = 12\%$	Benefits ($ million)	146	177
	Costs ($ million)	212	212
	NPV ($ million)	-66	-35
	BCR	0.69	0.83

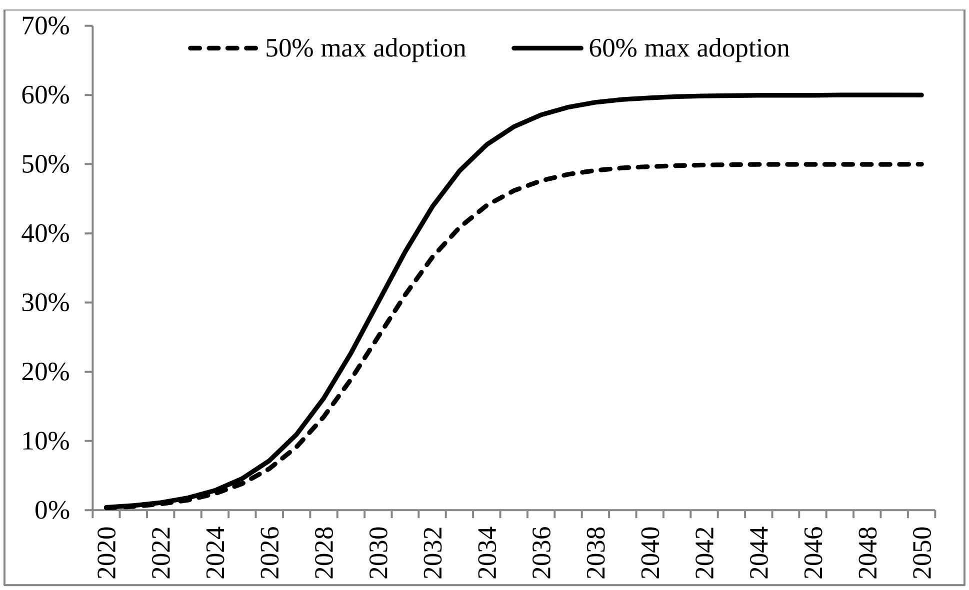
Source: Author's own estimation.

Figure 1. Trends in yield of major grain foods in Haiti



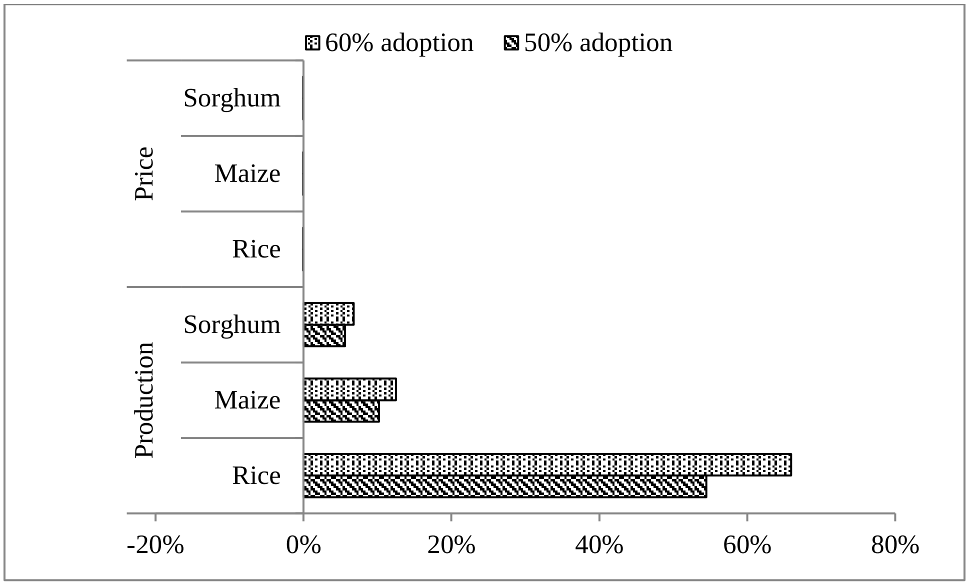
Source: USDA PS&D (2016).

Figure 2. Posited agricultural technology path



Source: Author's own calculation based on equation 1.

Figure 3. Effect of investment in agricultural R&D on commodity supply in Haiti, compared to the baseline values of 2040



Source: Author's own calculation based on a simulated model.

Agricultural Research: A Great Opportunity to Increase Agricultural Production in Haiti recherche agricole : une grande opportunité vers une augmentation

Haiti Priorise

Hugues Charles

Introduction

At one time, Haiti was considered an essentially agricultural country, because the economy of the country was mainly based on agriculture. The country was a major producer and exporter of foodstuffs such as coffee, cocoa, food, cotton and even logwood. Haiti was able to produce enough food to feed its population. However, this phenomenon has not existed for many years, since the country now does not produce enough to meet the food needs of its population. Everything is imported. More than 60% of the products consumed in the country are imported from abroad. Despite this decline in the sector, agriculture remains the sector that employs the largest number of people. Nearly half of Haitians depend directly or indirectly on agriculture. However, the development of the agricultural sector has not been considered as a priority for successive governments during the last thirty years.

Playing the role of primary sector in the Haitian economy for a very long time, agriculture has continued until 2016 to contribute 20% of the national GDP. In 2016, the country grew by 1.4% thanks to a 3% positive growth in the agricultural sector. Yet this sector, despite its great potential, continues to be treated as a poor relation by our politicians. During fiscal year 2015-2016, only 9.7% of the national budget was allocated to this sector while the last government (2011-2016) regarded agriculture as a growth driver. This percentage has been reduced to 5.9% in the 2016-2017 budget, while agriculture is once more seen as one of the country's two top priorities.

Several bi- and multilateral donors and non-governmental organizations have financed and executed major agricultural projects in the country for several decades, but the results are not convincing, as agricultural production continues to decline year after year. The Ministry of Agriculture, despite its many efforts, is no longer able to make the agricultural sector the spearhead of production.

What explains why, despite the many agricultural development plans, projects and programs prepared and implemented throughout the country by both donors and MARNDR, national agricultural production is only decreasing? Why can we not truly exploit all these opportunities to make agriculture a real growth driver? Why is the country unable to produce enough agricultural products to feed the majority of its population? Why are we obliged to import more than 60% of food products from abroad when the country has an agricultural area of 1.80 million hectares, more than half of which is destined for cultivation (arable land) (FAOSTAT 2016)?

A recent study by a Subir Bairagi Agricultural Economist on behalf of the 2016 Haiti Priorise project cited structural causes among many others to explain the decline of our agriculture. He cited, among other things: lack of quality seeds, lack of irrigation infrastructure, poor government extension services, lack of access to credit, poor quality of soil and water (Cochrane et al., Oxfam, 2010, 2010), and limited investment in agricultural research and development (RD) to date. This last constraint seems to be the most important since Haiti has never made research one of its priorities. In the Latin American and the Caribbean region, Haiti is the only country in which the government does not make any significant investment in agricultural research.

In his study, economist Bairagi chose to emphasize the problem of lack of investment. Based on his calculations, analyses and existing data, he concluded that if Haiti agrees to make significant investments in agricultural research to set up a research center, this could facilitate the availability of cutting-edge agricultural technology and diffusion to local farmers and, at the same time, an increase of about 210%, 109% and 104% in the yield of corn, rice and sorghum crops, respectively. But, given the many constraints faced by the agricultural sector and Haitian small farmers, are the results of this study—limited to only three cereal crops (rice, corn and sorghum)—relevant to the problem to be solved of low production and food deficit? What are the implications of such an important investment in public policy? While attempting to provide some answers to these questions, this paper, considering factors other than lack of investment, will also attempt to show how agricultural research could be an alternative for the recovery and increase in agricultural production in Haiti.

History of Agricultural Research and Dissemination in Haiti

Agricultural research truly started in Haiti in the late 1960s and early 1970s. But 40 years later, where are we? What has been done? What is left of agricultural research and dissemination in the country?

At the very beginning, the agricultural research issue was under the supervision of the Ministry of Agriculture. In 1923, after the creation by the Americans of the "Agriculture and Vocational Education Technical Service," hereinafter Ministry of Agriculture, about fifty farms-schools were established and scattered throughout the country. Their mission was to provide a theoretical training which would be adapted to farming life. These entities served as model farms and local centers for the dissemination of new methods.

By the 1950s and until the 1980s, the Haitian government had agreed to make significant investments by putting in place institutions active in the agricultural sector for the benefit of farmers. The implementation of major projects, including the ODVA (Organisme de Développement de la Vallée de l’Artibonite or Artibonite Valley Development Agency), coincides with the generalization, through the services of the Ministry of Agriculture, of agricultural dissemination and technical advice to farmers. Next, the state created the Bureau de Crédit Agricole (or Agricultural Credit Bureau, BCA) and the Agricultural and Industrial Development Institute (IDAI), which were not research institutes but financial institutions to provide supervised bank credit to farmers.

In the mid-1970s, there was the creation of one of the most important research-development-training centers in the country, that of Madian-Salagnac. It depended on the Ministry of Agriculture and was an attempt to respond to an admitted failure to popularize the technical themes transmitted in the framework of community development. The actions and interventions of the Madian-Salagnac Center revolved around two main axes: research and training. This center was the main research center for students of the Faculty of Agronomy of the State University of Haiti.

In 1986, despite political unrest, the Ministry of Agriculture was still responsible for nearly fifty agricultural sites, including five EMA schools (advanced vocational training schools) that trained senior technicians and agricultural agents, two vocational training schools for young farmers, five training centers providing on-going training and about thirty state-owned farms devoted to agricultural research and outreach, which provided training or applied research programs. In 2005, there remained only about twenty, and among them eleven were more or less active during the year and were still under the supervision of the Ministry of Agriculture.

The Ministry of Agriculture had also established the CRDA (Center for Research and Agricultural Development), which had become the designated research authority of MARNDR. Its responsibility was to promote national agricultural research policy, to manage it and to coordinate it at the level of the agricultural public sector as well as of all the research in progress in the country. But the CRDA struggled to assert its leadership, to ensure the co-ordination of the system and to guarantee its coherence, for lack of human resources, adequate financial resources, strong policy instruments, an operational plan and a law defining and clearly specifying its remit and dictating clear rules.

In 2010, a proposal was made in MARNDR's 2010/2025 Agricultural Development Comprehensive Policy document to provide the ministry with two new instruments: (a) firstly, the creation of the National Research Agency for Sustainable Agriculture (ANARAD) and (b), secondly, the establishment and consolidation of the Innovation Department (DI). As stated in the paragraph above, the latter is currently regarded as the main research instrument of MARNDR. Financially, this department is dependent on another bigger instrument, the FONRED (Research and Development Fund) from the Ministry of National Education and Professional Training (MENFP). The FONRED was created by the MENFP and was based on the fundamental idea that research should play its role once again in the reconstruction of Haiti. But these two instruments, the DI and the FONRED, cannot operate autonomously since they do not have a budget. And it is this lack of Haitian state financial resources for research and agricultural development that facilitated the interventions of NGOs in this domain.

Thus, over the past ten to fifteen years, agricultural research and development has been taken over either by donor-funded projects or by non-governmental organizations (NGOs). Currently, the project AREA (Support to Agricultural Research and Development) is funded by the United States Agency for Development (USAID), which carries out the largest research project in the country. This is a $15 million project with a duration of five years (2015-2020). This is not, unfortunately, a project of the Haitian government.

Other agronomic and environmental science training institutions also carry out research projects. This is the case of the Faculty of Agronomy of the State University (FAMV) and the Faculty of Agricultural and Environmental Sciences of Quisqueya University (a private university/UNIQ) to name but a few. UNIQ conducts its research thanks to financial support from external donors. The same applies to part of the research carried out by the FAMV.

Up to the present, the Ministry of Agriculture has not had a real policy and has not had a budget for agricultural research. At present, it can be said that agricultural supervision in the field is, in principle, ensured by the deconcentrated structures of the MARNDR, specifically by about fifteen departmental directorates and sub-directorates and about forty agricultural offices (BAC). The distribution of technical packages is supposed to be ensured by these structures, which are found in the ten geographical departments of the country.

According to the 2012 DEFI summary document on agricultural research, the future of research by state bodies is not certain. It depends on a set of social, economic, technical, environmental and institutional factors. And, in the report on agricultural research centers, Damais and Angrand 2005, the state of decline in agricultural research is highlighted after the disappearance of certain agricultural experimentation and research services dealing with this topic within the same ministry and in other autonomous bodies of the state.

Some Achievements of Agricultural Research in Haiti

Approaches promoted through agricultural research and dissemination by the Ministry in the late 1970s and early 1980s, through "the establishment of major projects, development agencies and specialized financial institutions (ODVA , IDAI, BNDAI[1] and BCA) in order to carry out modernizing technical packages adapted to agricultural diffusion, enabled the development and dissemination of improved crop varieties such as rice and corn, introduction of more productive bovine breeds and a real increase in yields and agricultural productivity in a set of pockets of intensification, mainly in the irrigated plains (Artibonite, Saint Raphael, Plaine des Cayes, etc.). The considerable efforts of training agronomists, agricultural technicians and extension workers at the Agricultural Faculty of the State University of Haiti, in EMA and training centers, which

[1] *Banque de développement agricole et industriel*

have accompanied this policy, will also have made highly skilled human resources available to the agricultural sector."

"Of all the experiments in the framework of the research done by the Ministry of Agriculture, the Madian-Salagnac project has had the most sustainable results in improving the living conditions of producers despite the weakness of resources deployed and the cessation of project support for some time. The causes of these success stories are, among other things, an approach to dissemination that is part of a research and development approach that, thanks to an excellent knowledge of the environment, has enabled us to identify the themes and the solutions most adapted to the local realities and to avoid the formulation of a master formula; an approach favoring farmer-farmer exchanges, guaranteeing access to essential inputs, and benefiting from the existence of a safe, remunerative and accessible market. In terms of impact, Madian-Salagnac center interventions have made it possible to introduce and have contributed directly to the development of income-generating market gardening crops on the Plateau du Rochelois (Nippes department), which still supplies the market of Port-au-Prince with vegetable products (cabbages, carrots) and now tubers, such as yams."

How Research Can Contribute to Increased Agricultural Production in Haiti

Several conclusions from studies carried out by both local and foreign experts have revealed that any program to revive agricultural production in order to address food security problems and, more generally, the socio-economic problems of the Haitian population should normally involve a revaluation of agricultural research. Because, with respect to the many challenges that the agricultural sector has been facing for decades, without evolution and a technological and quality leap forward of the latter (the agricultural sector), the country will not be able to achieve this. According to the study "Inventory of Applied Research Activities Underway in Haiti in the Agricultural Field, Summary Document, DEFI 2012," while it is clear that guidelines and policy for the sector are indispensable and significant investments are necessary, the technological leap referred to cannot be realized without significant input from agricultural research. Yet it is known that Haiti is the only country in the Latin American and Caribbean region where there has been no major investments made by the state in research.

The recent study by Mr. Bairagi, Agricultural Economist of the 2016 Haiti Priorise project, corroborated this fact by pointing out that there has been little or no investment in agricultural research and development in Haiti. It estimated the net social benefits that a multi-million dollar ($ 27.0 million) annual investment could bring with the establishment of a research facility that could contribute to the transfer of cutting-edge technologies to farmers.

But the 2012 DEFI document, on the other hand, showed that significant investment in research is a necessary but not sufficient condition for improving agricultural productivity. Because of the complexity of the problems posed in the sector, the important questions to be answered and the urgent need to implement innovative and effective solutions speak deeply to agricultural research. In view of the constraints faced by the latter, but also by the rural world, the solutions proposed should, above all, not be inadequate or inefficient and should contribute to national development, notably by significantly improving the population's living conditions.

In analyzing the considerations of some specialists, it is believed that any new agricultural research program will have to take into account the achievements already made and all that is related to this topic in Haiti. We above all cannot start from scratch. The achievements are, for example, the results of studies and research carried out in the country during the last 20 to 25 years both in research centers[2], national agricultural farms[3] and projects with research components[4] that could be capitalized upon.

In his study, having demonstrated the advantages of research in agricultural production, Mr. Bairagi considered only three crops—corn, rice and sorghum. But we believe that research in Haiti should not be limited to a limited number of crops even if they are considered to be part of the Haitian population's basic diet. There are other crops considered to be as important in the diet that must also be considered at the level of research protocols.

Several entities operating in the country and working on the theme "food security" have researched various categories of crops and livestock units in the country within the framework of research (Inventories... DEFI 2012). Table 1 below gives an idea of the principal crops and livestock units considered, while Table 2 shows the sub-thematic areas and research programs related to the food security theme on which trials and studies have already been or are being carried out in the country by a number of institutions, NGOs or research projects.

Normally, any research program in Haiti should prioritize these issues because by targeting increased agricultural production of staple foods and increased farmers' incomes, it is almost certain to address the problem of food security.

[2] *The Madian-Salagnac Center in Nippes and Limbé in the Nord*
[3] *The farms of Levy in the Sud, Savane Zombie in Forêt des Pins, Baptiste in the Plateau Central*
[4] *Multiple projects funded by American, Canadian, Chinese (in the Artibonite Valley) and French cooperation*

Table 1: Crops and Livestock Units

CATEGORIES	SUB-CATEGORIES	CROPS/LIVESTOCK
Crops	Staple food crops	Rice, corn, beans, sorghum, peanuts, vegetables and market-gardening crops, yams, potatoes, cassava, bananas
	Market-gardening crops	Cabbage, carrot, eggplant, tomato, chili
	Fruit crops	Mango, avocado, citrus, other fruits (papaya, melon, pineapple)
	Dual purpose crops (local consumption and exportation)	Coffee, cocoa, vetiver, mango
Livestock units	Poultry	Chickens
	Small and large ruminants	Goats (imported and local breeds), cattle (milk production)
	Fish	Fish farming, fishing

Source: Inventory of applied research activities underway in Haiti in the field of agriculture. Summary document, MARNDR/DEFI June 2012

Table 2: Sub-Topic and Programs Related to the Topic: A. Food Security.

SUB-TOPICS	PROGRAMS	INSTITUTIONS DEVELOPING PROJECTS, PROTOCOLS, STUDIES
Increase in agricultural production and yields	Varieties and species yields/productions; Resistance to diseases; Uses, needs and tastes of consumers	Research centers and institutions, agricultural farms, local and international NGOs, donor projects and programs, universities, MARNDR, producer associations, etc.
	Technical arrangements: farming techniques and livestock management	
	Fertilization	
Slaughtering, warehousing, packaging and processing of agricultural products	Revenue development	
	Testing equipment	
	Quality process	
	Evaluation of consumer taste	
	Packaging and transport	

Source: Inventory of applied research activities underway in Haiti in the field of agriculture. Summary document, MARNDR/DEFI June 2012

Taking into account the complexity of sector problems previously mentioned, research should not be viewed in isolation. There are other important factors to be taken into account if appropriate solutions are to be found capable of solving specific problems, solutions that can significantly increase agricultural productivity. Thus, the establishment of optimal conditions to maximize the beneficial results of research already carried out throughout the country is a necessity. These optimal conditions can be: the existence of functional irrigation systems, availability and access to quality agricultural inputs (quality seeds and fertilizers), access to credit, adapted agricultural mechanization that meets the needs of farmers, and the organization and regulation of the land property system. These conditions are therefore necessary and indispensable for the increase of yield at the level of farmers' plots. To create them, investments will be required.

Yet, according to Damais & Angrand in the final 2005 report on research centers, "the agrarian history of the country shows that producers' innovation capacities and the possibilities for rapid progress in production and income cannot exist in an incentive framework without adapted and effective support mechanisms being put in place. For example, in the Plaine des Cayes (Laborde region), it has been shown that varietal research on corn and beans and the diffusion of animal-drawn cultivation, fertilization and treatment techniques have made it possible to move to three cycles of annual crops with cereal yields approaching three tons per hectare per crop. This has been made possible by the combined and long-term action not only of service-providing organizations, but also of significant public investments facilitating and making available certain production factors. Today, Laborde and the Plaine des Cayes constitute a privileged region from an agricultural point of view, with farms possessing a sometimes considerable production capital (harnessed traction, use of improved seeds and fertilizers) and an economic and social infrastructure (schools, health centers) which is also above the national average."

These results demonstrate once again that the research must be comprehensive if it is to be carried out with the dual objective of increasing production and meeting the needs of the farmer. It should be part of a local community development process. It must be conducted to meet specific needs and demands of the farmer. For this reason, it is necessary to reason in terms of rural activities and to go beyond the supply of services alone to agricultural production. The survival strategies of the great majority of the rural population today depend on the diversification of activities, not only for the poorest but also for those with above-average resources. Thus, any support for agricultural intensification through agronomic research and dissemination must be designed and implemented within the framework of a broad farmer participation and start with the realization of a diagnosis of the constraints of the producers.

Another element to be taken into account in the setting up of optimal and complementary conditions for research is access to agricultural credit. Currently, Haiti has no financial institution for agricultural development. It is microfinance institutions and the Haitian caisses populaires, with significant support from international cooperation, that truly invest in agricultural credit. The state will have to facilitate access to agricultural credit by agreeing to make investments in terms of setting up credit lines, guarantee funds or agricultural insurance funds, or even subsidies in certain cases.

At the institutional level, the existing infrastructure must be taken into account when setting up optimal conditions and capitalizing on achievements. Currently, there are about twenty public entities (one training center, four EMA agricultural schools, five state farms or public centers, fifteen public institutions and a university) distributed throughout the country that are involved in the research, although some of them are not functional. These public entities (public institutions and state centers and farms) are found in the greatest numbers and represent about 35% of all 57 entities[5] existing in the country. Therefore, the rehabilitation and revitalization of the activities of the research and training centers managed by the Ministry of Agriculture should be considered, because these infrastructures spread throughout the country represent the ideal channel through which dissemination of research results and utilization of the knowledge and skills of Ministry of Agriculture officials involved in research will pass.

The rehabilitation of these entities, particularly agricultural farms and EMA schools, will offer rural people (especially farmers) different public services for which they will express demand in order to improve their living conditions. Their mandate must go beyond that of agronomic research and agricultural dissemination to tackle the greater problems of local development (support to local authorities, support for non-agricultural economic development, and local management of natural resources). The centers must respond to demands for the public services of training, information, applied research and advisory support in the following areas: 1) agricultural intensification, 2) the establishment of productive alliances between the private sector and small-scale farmers, and 3) local governance (Damais, 2005).

Implications of Agricultural Research for Public Policy

But can a national agricultural research and development program be envisaged without having implications for public policy? This question can be answered in the negative. If agricultural research is considered as one of the main priorities of the state, it will necessarily have consequences or implications for public policy. The first implication of this decision will be a reorganization of the national budget and more particularly that of the Ministry of Agriculture,

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[5] *Source: Inventories of Research Actions….DEFI 2012.*

because it will be necessary to accept making important investments in the field. Based on the predictions of Mr. Bairagi's study, the Haitian state will need to set up an agricultural research program through the establishment of a research center—more than a half-billion dollars for the next 20 years in terms of direct costs. Secondly, the indirect costs associated with it (establishment of optimal conditions, capitalization and systematization of existing assets, rehabilitation and operation of agricultural research centers and farms, etc.) must be considered. It should be noted that the percentage allocated to agriculture in the 2016-2017 budget is 5.9%. The budget for this year is estimated at 121 billion gourdes.

Consequently, the Haitian state will have to make agricultural production one of its principal priorities for the next 15 to 20 years, with agricultural research and development as the main pivot. This will help restore agriculture to a greater share of national GDP. Currently, agriculture represents 20% of GDP.

Again with regard to the consequences for public policies, the Haitian state will have to start taking action in terms of gradual reduction of food imports into the country in order to really encourage national agricultural production. In this sense, the Haitian parliament will have a role to play not only in protecting this vital sector, but also in curbing, through legislation, the problem of environmental degradation, whose consequences are harmful to agricultural production. The Ministry of the Environment (MDE) will also be an important player in this new policy, even if it is not directly concerned, since agricultural production cannot be done in good conditions without a protected and adequate environment. Watershed protection is a sine qua non. Priorities will also have to be defined in relation to the main axes of intervention of this ministry to create favorable conditions for good agricultural production. These priorities will also require some reallocation of funds at the level of the national budget.

The Ministry of National Education and Professional Training and the State University of Haiti will also be concerned by the decision to make agricultural research a priority. Training programs in vocational institutes and faculties of agronomy should be modified and aligned with research programs.

Finally, the Ministry of Planning and External Cooperation will also be concerned by this decision to enhance agricultural research and development in the country. It is through this ministry that all the support of international co-operation goes. This ministry may have to redefine and fix, in collaboration with MARNDR, the MDE and the Haitian parliament, the conditions for certain interventions by donors or NGOs related to agricultural research.

Conclusion

Taking into account all the results of studies and research and of all the considerations made in this document, it can be said that agricultural research can effectively be considered as a real alternative for the improvement of Haiti's agricultural production if it is carried out according to a comprehensive approach involving all the entities concerned. It should not be carried out in isolation or on a limited number of crops. Efforts will have to be made by this country's leaders, both humanly and financially, to better organize research and give it a new impetus. The state must imperatively address the problem of lack of agricultural research policy and resolutely guide the latter and the actors involved in it towards agreed priorities.

The involvement and participation of all actors, institutions and organizations, as well as all stakeholders, will be fundamental to the success of such a project. New partnerships will also have to be developed between institutions and organizations operating in the country as well as international centers and foreign universities, especially those with experience in the redefinition and implementation of efficient and competitive research systems. The problems of the agricultural sector and the rural world are so complex that any agricultural research program must be designed to address the problems of food dependence and food insecurity in order to bring about a significant improvement in the living conditions of the population.

To complete this text, we believe that it is necessary to repeat a few points mentioned in the document "Inventory of Research Actions... DEFI 2012" in relation to the future of research in Haiti. According to the document, the future of agricultural research in Haiti as well as the prospects that emerge will depend on:

- the capacity for the state, and in particular the MARNDR, to regain leadership and to acquire the means to ensure the dynamic management of agricultural research
- the will to work together to define clear and consensual objectives validated by all
- the establishment of mechanisms enabling effectiveness and efficiency on priority themes and programs
- the capacity of the scientific community to rebuild
- the generalization of the capitalization/systematization processes
- the guarantee of quality training for professionals in the agricultural sector, integrating basic skills in research
- the assurance of a close and intelligent support from international cooperation

- the resumption and development of sustained links with research centers and regional and international research networks
- the establishment at a national level of a fund for agricultural research to which actors will have access on a competitive basis
- training of young researchers and high-level professionals on the basis of academic excellence
- the reconstruction, on an ethical and excellence basis, of an agricultural scientific community that is dynamic, engaged, responsible and united, not only within the community (among peers) but also towards producers/farmers and businesses involved in the sector on a daily basis
- the development and implementation of a national agricultural research policy and an operational strategy plan for agricultural research
- the establishment of regulations, standards, in particular for the supervision of procedures, and legislation

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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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