



**CIAT**

International Center for Tropical Agriculture  
*Since 1967 Science to cultivate change*

**Strategic and applied research  
to meet the demand of beans  
in Africa and Latin America**

**A Common Bean Flagship**

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# Strategic and applied research to meet the demand for beans in Africa and Latin America

## A Common Bean Flagship

### Background

Common beans (*Phaseolus vulgaris* L.) have formed a part of the research agenda of the CGIAR since the establishment of the Bean Program in CIAT in 1973. As a Grain Legumes CRP took form in 2012, beans participated in three product lines focused on abiotic stress: on drought and low soil phosphorus with cowpeas and soybean; on heat tolerance with faba bean, lentils and chickpeas; and on nitrogen fixation with chickpea, faba bean and soybean. Technical exchanges focused on cross-legume physiology and phenotyping derived from that knowledge. As the CRPs moved into phase II around an organizing principle of agri-food systems, the Grain Legumes and Dryland Cereals CRPs were fused with the Dryland Systems CRP, giving the research agenda a decidedly dryland focus. In this context, the ISPC and later an expert panel questioned the appropriateness of the presence of common bean in the new Grain Legumes-Dryland Cereals (GLDC) CRP. As a result common bean, a crop with more presence in humid areas was left out from GLDC CRP. However the need to address research on common bean remains, and the potential for synergies with research on other legumes continues. The System Management Board (after their December, 2017 meeting) requested that CIAT develop a proposal for a common bean flagship research program and the optimal location of that work. In this context, the Directors of CIAT and GLDC, in consultation with the System Management Office, agreed to a new mode of collaboration. GLDC will host the flagship on common bean, building on residual synergies with other legumes in a relationship of alignment and complementarity to existing flagships, while respecting the dryland systems focus of the CRP (for further explanation of the hosting relationship, please refer to section 1.12 Flagship management).

### 1.1. Rationale and scope

*The role of legumes:* Increasingly edible legumes or pulses are being rediscovered in their multiple roles both in traditional food systems and for urbanized populations. The United Nations designated 2016 as the International Year of Pulses, and a recent World Bank study highlighted nutrient-dense foods such as pulses as an integral part of healthy diets [39]; as sources of protein, complex carbohydrates and minerals (iron and zinc) [36]; as a preventative measure against obesity [37], diabetes [33], cardio-vascular disease [17, 20, 21] and certain types of cancer [24, 38]. Much of the evidence for the health effects of edible legumes is derived from common bean. These and other references can be found in [Annex 1](#).

*Population growth of bean-consuming countries:* Common beans are the grain legume preferred by some 400 million inhabitants in Eastern and Southern Africa, and another 400 million in Latin America. Furthermore, several countries in Africa present levels of population growth above 2% per year. Ethiopia and Rwanda display relatively low population increase, but will still experience 81% and 74% growth, respectively, in a single generation by 2050 ([Annex 2](#)). Kenya and South Sudan



will double in population in this period, Madagascar and Mozambique will grow by 116% and 122%, respectively, while Burundi, Tanzania, Uganda and Zambia will grow by a staggering 140%. Overall, population in bean-consuming countries in Africa will grow by about 116%. As an important nutritional component in the region, bean productivity must improve significantly.

Latin America represents about 40% of world production of bean and is its center of diversity. The SRF (p. 10) commits to dedicating 20% of CGIAR resources to “poverty hotspots in Latin America.” Population growth of bean-consuming countries ranges from 4% in El Salvador to 63% in neighboring Guatemala, with an overall increase of 20% by 2050. Genetic improvement could keep pace readily if the goal were to maintain the status quo. However, growth in bean production has lagged behind population growth for several years, and prices are currently prohibitive. A higher rate of yield gain is needed to put prices within the reach of the poor.

*Levels of poverty and malnutrition:* Africa is a hotspot of poverty and malnutrition, and bean-producing and consuming countries are no exception, presenting from 40% to more than 70% poverty, based on per capita earning of less than US\$1.90 per day ([Annex 3](#)). Rates of anemia range from 46–67% in children under 5, and in pregnant women from 31–49%, although this is due to both iron deficiency and to disease load, especially malaria. Stunting of under-5’s ranges from 27–57%, implying chronic undernutrition often associated with protein and/or zinc deficiency. In Latin America, Guatemala and Honduras continue to have serious problems, while Haiti presents levels of poverty and anemia comparable to Africa. Stunting is often over 20% in Central America, while Guatemala, Nicaragua and especially Mexico have alarming levels of diabetes. It is urgent to restore beans as a cornerstone of the diet, starting with an increase in availability and lower prices.

### *Assumptions*

Our hypothesis is that improved productivity of bean, linked to better functioning markets, will contribute to improved food security, nutrition, health, and farm income. The assumptions behind this hypothesis apply to both Africa and Latin America and are the following.

- There is significant unmet demand for beans in Africa and Latin America – a fact that demands attention to productivity. For example, Kenya imports 40% of its bean requirements, and results of the Living Standards Measurement Studies (LSMS) in Uganda and Tanzania indicate that bean consumption in lower income families is scarcely 40% of that in higher income brackets ([Annex 4](#)). Consumption is limited by purchasing power, and increased availability with lower prices would increase total consumption. Latin America is a net importer of bean with Mexico and Brazil experiencing large deficits, and expanding deficits in these countries will drain beans across the entire region. While we recognize that yield increases alone are insufficient to meet development goals, the current deficit in beans is an imperative to increase productivity. In Africa this deficit can only grow in light of population growth, and in Latin America bean production is under short-term threat from climate change.
- Increased consumption will lower food insecurity and improve nutrition and health. Many of the world’s poor are under a double threat of undernutrition and so-called “over nutrition” – that is, diets heavy on calories leading to obesity and a syndrome of diabetes, cancer and

heart disease. Latin America is entering this mode (at an estimated cost due to diabetes of US\$65 billion per year [3]), and this may foreshadow public health problems in other regions. Reestablishing bean as a regular component of a traditional diet will be an important preventative measure [33].

- Ample genetic variability is available to improve productivity by both alleviating yield constraints, and by enhancing yield potential. Cultivated common bean has two major gene pools [6, 8], as well as secondary and tertiary gene pools with potential to confront extremes of climate and soil constraints, as well as yield traits.
- Market channels exist and bean value chains can be improved to mobilize production to both rural and urban consumers more efficiently. Eight production-to-consumption market corridors in Africa are being characterized with regard to multiple actors of the value chain. Improving productivity and alleviating bottlenecks in the value chain, will avail beans to consumers at lower cost. Furthermore, marketing of beans can contribute to farm income, and can induce adoption of production technology. In Ethiopia, a marketable product and a reliable market combined to improve crop management in Ethiopia and resulted in doubling of yields over a decade [16].

## 1.2. Objectives and targets (what, where, how)

Within the CGIAR framework of SLOs, IDOs, and Sub-IDOs, this flagship offers an ambitious and novel approach to improving bean productivity and usage. Within Africa this is based on solid experience and successful partnering of the [Pan-Africa Bean Research Alliance-PABRA network](#). Components of this approach include:

- Organizing efforts around production-to-consumption corridors with key actors in platforms that facilitate communication and planning with researchers
- Licensing of new varieties to attract more private seed companies
- Participation of the processing sector to develop uses of beans for industrial processing
- New methods to access genes of the *Phaseolus* genus to bring stability in the face of climate change
- Novel traits to increase genetic gain and yield potential
- Integrating nutrient-efficient cultivars with integrated fertility management
- Enhanced levels of dietary zinc in bean, as a complement to high iron

### Overview of expected outcomes

Based on its track record, CIAT will contribute to at least five outcomes, articulating these with the respective sub-IDOs (sub-Intermediate Development Goals). Sub-IDOs 1.3.1., 1.4.1., and 1.4.3. below find correspondence in GLDC in FPs 4 and 5, and sub-IDOs 1.3.4. and 2.1.1. in FP 3. Sub-IDO 1.3.1 below also has correspondence with FP 2. Detailed outcome narratives are provided in the following section, and milestones in [Annex 5](#).

1. Sub-IDO 1.4.3. *Enhanced genetic gain* on station and on farm with bean varieties that display greater yield potential.

2. Sub-IDO 1.3.4. *More efficient use of inputs* including fertilizer efficient varieties that maximize the return on investment.
3. Sub-IDO 1.4.1. *Reduced pre- and post-harvest yield losses, including those caused by climate change* with varieties that confront drought, excess rainfall, and/or higher temperatures, with accompanying biotic constraints.
4. *Diversified enterprise opportunities* through marketing of production and creation of new bean varieties and bean based products that enjoy market ready potential and meet consumer and food industry demands.
5. Sub-IDO 2.1.1. *Increased availability of nutrient-rich food* leading to improved food security and nutritional status through varieties that offer greater nutritional value and serve as raw products for processed foods.

### **Outcome narrative**

*Outcome 1: Enhanced genetic gain on station and on farm with bean varieties that display greater yield potential.*

Genetic gain in gene pools that have been subject to many cycles of selection will be gradual, since the important genes for yield (the “low hanging fruit”) already dominate in the gene pool, and, pending the identification of key yield genes through prebreeding, further gain will depend on accumulation of minor genes. This requires an agile and accurate system of phenotyping across a range of farmer-relevant environments. Phenotyping networks that link up communities of breeders in similar agroecologies and with similar grain type requirements can contribute to this end when all speak the same “breeding language” and use comparable methods. In Africa the PABRA regional programs are in an excellent position to build on existing relationships and hone these for more effective collaborative breeding, while in Central America, long term cooperation on two grain types (small red and small black beans) make a more coordinated early generation testing scheme a logical step to pursue a steady genetic gain on a regional basis. Genetic gain must address performance over a range of production environments, both stressed and favorable. While genetic gain for yield is often thought to be contrary to breeding for stress tolerance, research has demonstrated that traits for stress tolerance such as enhanced sink strength and better grain filling also contribute to yield increases under favorable conditions [1, 30]. Regional phenotyping networks will address this issue more amply. This activity is related to FP 4 of GLDC (CoA 4.3: Product testing and release).

*Outcome 2: More efficient use of inputs including fertilizer efficient varieties that maximize the return on investment.*

Closing the yield gap requires integrated soil fertility management (ISFM), combining the use of high-yielding, healthy planting materials with judicious use of plant nutrients (organic and inorganic and soil amendments). While this proposal does not contemplate the development of new ISFM or integrated crop management (ICM) techniques, it draws on other sources for these, for example, on the [Maize CRP](#) for practices of conservation agriculture, and promotes these through its partnership networks as a complement to genetic improvement. Soil treatments of lime and fertilizer at recommended rates are often too expensive for smallholder farmers, and fertilizer recovery from soil

by crops is typically very low. Inputs, either chemical or organic, applied at moderate levels that are within reach of farmers should be complemented by cultivars that make efficient use of inputs through improved uptake or through superior physiological use efficiency. Ample genetic variability is being tapped for tolerance to acid soils, and roots with longer root hairs will recover added nutrients for superior yields and better return on investment [7]. Preliminary data from Nicaragua suggest that enhanced nutrient efficiency can increase yields by as much as 400 kg ha<sup>-1</sup> over an elite cultivar [15], and a nutrient-efficient line is at the point of release in Mozambique. Interspecific lines yielded 34% more in low phosphorus trials and 49% more under aluminum stress trials than the elite check. This is related to FP's 3, 4 and 5 of GLDC. Breeding for soil constraints is not cited in GLDC, thus this research can offer lessons for the improvement of those other crops.

*Outcome 3: Reduced pre- and post-harvest yield losses, including those caused by climate change with varieties and ICM that confront drought, excess rainfall, and/or higher temperatures, with accompanying biotic constraints.*

CIAT and partners have demonstrated that improved bean cultivars can increase productivity among small bean producers. In the first 10 years of CIAT bean research in sub-Saharan Africa, farmers using CIAT-improved varieties increased bean productivity by 400 kg per hectare [22]. Genetic improvement work of CIAT and partners in Africa continued boosting bean yields in the region. By 2011, in Rwanda and Uganda, yield productivity was increased by 14% and 11%, respectively, by using CIAT-related improved bean varieties [25]. In spite of the important productivity increase, average yields in Africa are still half of average yields in other regions of the world [16], and yields will suffer severe reductions in the face of climate change [31]. Drought-tolerant varieties have been released in a dozen countries, and heat tolerance is now a major breeding objective [5]. Pest management has a role, for example, simple post-harvest technologies of seed storage such air-tight plastic bags (e.g., the Purdue Improved Crop Storage system) are a well-tested method. This outcome is related to FP's 4 and 5 of GLDC. Phenotyping for abiotic stress tolerance is backed up by studies of physiological mechanisms – an important point of interaction across legumes in GLDC.

*Outcome 4: Diversified enterprise opportunities through marketing of bean varieties that enjoy market-ready potential and meet consumer and food industry demands.*

Bean production in Central America and Africa is dominated by small-scale farmers who produce beans for both home consumption and for market. Some 86% of farmers in Nicaragua cite beans as their first or second most important source of income. An estimated 40% of production in Africa enters market channels, with the number of bean-growing households marketing beans ranging from 25% in Rwanda, DR Congo and Zimbabwe, to 76% in Ethiopia. Markets may be local, regional, or international, and Ethiopia has been especially successful in tapping international markets. It is estimated that using improved CIAT varieties increases the probability of being a net bean seller by 14% [40]. Climbing beans have grain with high commercial value, have the potential to triple yields of bush beans, and are an important opportunity for expanded market participation. Snap beans are finding wider acceptance, and beans also have potential as a raw material for processed products as the food industry seeks sources of vegetable protein. Even in Africa a budding food industry is



finding opportunities for bean-based convenience products such as weaning foods that cook in a matter of minutes. This outcome bears synergies with the proposed FP 2 of GLDC.

*Outcome 5: Increased availability of nutrient-rich food leading to improved food security and nutritional status through varieties that offer greater nutritional value and serve as raw products for processed foods.*

In 2011 it was documented that the use of CIAT related improved bean varieties reduced household food insecurity by 16% in Rwanda and 2% in Uganda, using a dietary diversity score as a measure of food security [25]. Beans were found to provide 24% of the daily requirement for protein for Ugandans [25]. Furthermore, CIAT together with HarvestPlus and other partners have promoted the adoption of high-iron bean (HIB) varieties in Rwanda since 2010. High-iron bean cultivars have been released in at least seven countries. By 2015, it was estimated that around 350,000 households are already growing HIB varieties. A recent rigorous study showed that consumption of beans had a positive effect on iron status of Rwandan women aged 18 to 27, but those who ate beans bred for high iron had a significantly higher hemoglobin levels [18] and better memory and attention span [28] than those who ate the standard beans. High iron and zinc is a breeding objective for four legumes in GLDC FP 4. Breeding for high iron has both opportunities and pitfalls, and the experience with common bean for high iron can well be of value to other legumes. GLDC's FP 3 proposes a comparable outcome of nutritional impact.

### **Expected impacts**

#### **SLO 1: Reduced poverty**

- At least 5% reduction in poverty prevalence among women and men headed households in target corridors
- Three million farmers are linked to profitable markets
- Twenty-five small-to-medium enterprises (SMEs) trade in bean products
- Six million households accessing seed (60% by women) of high yielding, nutritious, climate change resilient and market demanded bean varieties and ICM by 2022
- Ten thousand women participate in the development and delivery of climate smart technologies and information
- Farmers have access to heat tolerant varieties by 2023, thus expanding options of production in marginal environments

#### **SLO 2: Improved Food and Nutrition Security for Health**

- 5% reduction in food and nutrition insecure households in the targeted corridors
- Nine million households disaggregated by gender consuming nutritious bean and dry bean products

PRODUCTS	OUTCOME MILESTONES	LONG-TERM OUTCOME	SUB-IDO
Integrated regional system to evaluate large numbers of experimental lines	CIAT and national partners enhance data recovery from production environments and reducing time from line development to varietal release	<b>Outcome 1</b> Enhanced genetic gain on station and on farm with bean varieties that display greater yield potential	Enhanced genetic gain
A gene editing system	Bean-breeding community adopts an ideotype combining biomass accumulation and enhanced partitioning to grain		
Nurseries established with partners for multisite evaluation	Yield potential is enhanced in experimental conditions of managed stress and in conditions of farmer-managed production		
Transformable lines in commercial classes			
Improved varieties with enhanced yield under minimal inputs	Hard-to-reach smallholder farmers use ICM technologies that have been linked to seed delivery systems	<b>Outcome 2</b> More efficient use of inputs including fertilizer-efficient varieties that maximize the return on investment	More efficient use of inputs
New lines with increased performance for abiotic and biotic stress tolerance	Breeding programs incorporate systematic evaluation of root traits for tolerance to edaphic problems and for fertilizer recovery		
SNP markers for root penetration	ICM recommendations include the use of improved lines adapted to farmers' management of low fertility		
Varieties that confront drought, excess rainfall, and/or higher temperatures, with accompanying biotic constraints developed across various agro-ecologies and cropping systems	Seed enterprise deliver climate-smart varieties and complementary ICM technologies and information targeting hard-to-reach smallholder farmers	<b>Outcome 3</b> Reduced pre- and post-harvest yield losses, including those caused by climate change with varieties that confront drought, excess rainfall, and/or higher temperatures, with accompanying biotic constraints	Reduced pre- and post-harvest yield losses, including those caused by climate change
Climate-smart and environmentally friendly pre- and post-harvest integrated crop management (ICM) practices			
Climate advisories for bean production			
Improved market-demanded snap bean varieties resistant to multiple stresses developed and released			
QTL analysis of heat tolerance			
New bean varieties that enjoy market-ready potential and meet consumer and food industry	Multi-stakeholder bean business platforms use the corridor model to support trade	<b>Outcome 4</b> Diversified enterprise opportunities through creation, production and marketing of new bean varieties that enjoy market-ready potential and meet consumer and food industry demands	Diversified enterprise opportunities
First crosses specifically for high canning quality			
Contracts between market service providers and agribusinesses for production marketing			
Male and female entrepreneurs and farmers trained			
Varieties that offer greater nutritional value and serve as raw products for processed foods and seed supplied by partners	Partners develop and promote micronutrient-rich bean-based products	<b>Outcome 5</b> Increased availability of nutrient-rich food leading to improved food security and nutritional status through varieties that offer greater nutritional value and serve as raw products for processed foods	Increased availability of nutrient-rich food
Nutrition education and promotion tools	Partners in countries not addressed by HarvestPlus develop micronutrient-rich bean varieties with superior agronomic traits and supply seed		
A value chain for nutrient-rich beans	Using CIAT's recommendations, partners develop and promote one value chain for nutrient-rich beans		

**Fig. 1: Impact pathway overview**

### 1.3. Impact pathway and theory of change

#### Impact statement

Bean-based technologies that exploit the genetic diversity of the *Phaseolus* genus for dynamic markets and consumers, contribute to food and nutrition security, health, and the alleviation of poverty in Sub-Saharan Africa and Latin America.

#### Impact pathways

Impact pathways have evolved most effectively within the Pan-Africa Bean Research Alliance (PABRA), a consortium of 30 countries in sub-Saharan Africa with the facilitation and participation of CIAT. PABRA unites three sub-regional networks in East-Central, Southern and West-Central Africa. PABRA coordinates cross-country cooperation in the development and dissemination of bean technology, and promotes structures for the fulfillment of its mission. The [external review of the Grain Legumes CRP](#) (CGIAR Research Program), Phase 1, in which beans participated, noted that, within the context of seed dissemination,

“Linkage of participatory research to innovation platforms is creating positive impact (for example through the Pan-Africa Bean Research Alliance-PABRA). Such systems approaches are to be recommended across all seed enterprises. Different modalities for seed dissemination have been carried out effectively in an “action research” mode (e.g. marketing in small seed packets at low cost and permitting farmers to experiment with low risk; seed-for-grain models; standard private sector production; decentralized local production of Quality Declared Seed (QDS) with small NGOs and CBOs, value-chain development). This work has revolutionized the impact pathway and opened multiple channels to reach farmers, both outcomes of the effective partnerships within PABRA.”

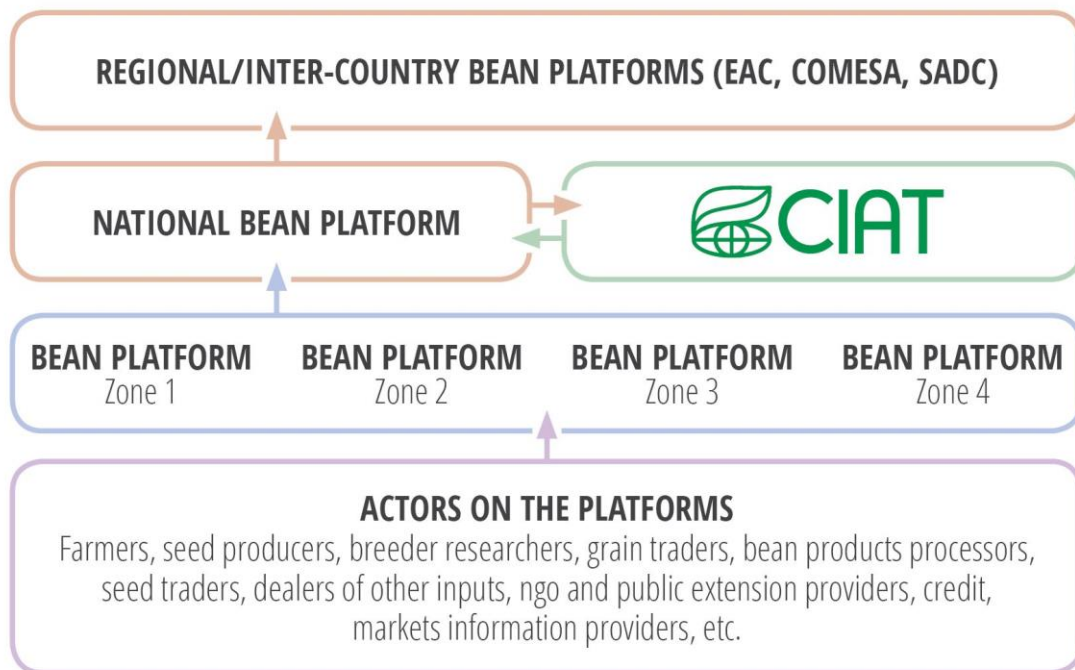
Platforms so developed are not limited to seed dissemination strategies, but are extended to sharing other technologies such as crop management practices. These platforms permitted PABRA to reach 16 million households with improved bean varieties, bean products, and crop management practices in the last 5 years (see “Lessons” below). The role of CIAT (beyond research) has been two-fold:

- To support national programs (typically a branch of the Ministries of Agriculture) in facilitating platforms of bean value chain actors for communication between suppliers and demanders of technology, especially but not exclusively bean seed. Face-to-face meetings are held every 6 months or on a yearly basis. Regularity is a key to success. Participants include researchers, extension agents, farmers groups, private seed producers, and occasionally non-traditional participants such as traders, credit providers or representatives of the food industry. Memoranda of understanding result from an organic process between actors without the necessity of continual coordination by either PABRA or the national program.
- In pursuit of the above, CIAT has invested staff time in this function, to draw in partners and prospective participants along the value chain and to evaluate models that enhance effective and faster reach of technologies. CIAT’s success is largely thanks to investing in this “bridge-building” function.

This scheme is diagrammed below in Figure 2, where the role of CIAT is supportive but not antagonistic in the long run, and where the *relations* among the actors in the platforms is the key to success. A pathway diagram is symbolic of a process with various successive steps, and it is the interaction between the actors at each successive step that must be nurtured over time, as mutual confidence grows among actors, as knowledge of available technology is shared, and as feedback informs on the nature and magnitude of the demand for that technology. To date these platforms have been organized on a national or sub-national level with substantial success, but now this experience is being applied to production-to-consumption corridors, described in detail in Cluster of Activities 5 below, in such a way that will bring the public and private sectors together over a larger geographic area in a long-term, systematic dialogue. The flagship will capitalize on the Monitoring, Evaluation and Learning (MEL) tools available at CIAT, including the online platform CIAT-MARLO (Managing Agriculture Research Learning & Outcomes) which offers interoperability between center OCS tools and CRP reporting. This tool, combined with support from MEL staff, will facilitate periodic monitoring of progress towards flagship outputs and outcomes.

**Theory of change**

Our theory of change is based on our experience with national partners in convening and coordinating innovation platforms. Being convened by the national partner, platforms have the potential for sustainability without the perpetual accompaniment of CIAT. To date such platforms have focused most frequently on seed based technology, in a context of diverse markets (grain for local use; grain for different regional markets; grain for international markets; snap beans).



**Figure 2: Supportive role of CIAT in building relationships between diverse actors**

Thus each innovation platform must attend to its specific demands and issues. For example, international markets for white navy beans from Ethiopia have high and more explicit quality demands that must be communicated through the value chain, even to farmers.

The case of Ethiopia and white navy beans reflects a second dimension of our theory of change: market-pull transformation. Bean yields in Ethiopia were comparable to those in other African countries, and were well below a ton per hectare. Through an innovation platform of researchers, farmer cooperatives, extension agents, traders and exporters, farmers gained confidence in a stable market, and were informed about improved agronomic practices and market requirements. This led to the adoption of technology including fertilizer, weeding and new varieties, with the confidence of obtaining a return on their investment. While options for dynamic international markets may be few, the regional African market is in fact much larger and has great potential for development. The large deficit in bean suggests a major market opportunity that can induce changes in productivity.

A third aspect of the innovation platforms is that they grow organically. As noted above, the navy bean trade in Ethiopia existed prior to the innovation platform, but the platform facilitated more dynamic relationships among the actors. The organic nature of the evolving relationships is evidenced by the bilateral agreements which often result, without the need to engineer these by either CIAT or the national program. A similar experience emerged in Central America with the so-called “learning alliances” but without the necessary regularity and coordination for continued growth.

## 1.4. Science quality

The Bean Program communicates its research outputs regularly through peer-reviewed journal articles, and has a solid history of publications in the areas of genetics, genetic resources, applied breeding, stress physiology and seed systems. Many of these publications appear in the reference list at the end of this text, while a complete list of recent publications (2013–2017) is available at this <http://bit.ly/2BgMT82>. This knowledge has been translated into products by the release of more than 500 varieties in Latin America and more than 400 varieties in Africa, and in cultivars that respond to an emerging research agenda including climate change and nutritional demands.

## 1.5. Building on successes and lessons; Unintended consequences

Economic and impact assessment analyses show that the adoption of CIAT-related varieties, either directly with lines generated by CIAT or through breeding with CIAT germplasm, has created impact between Latin America and Africa estimated at **US\$17.4 billion**, with a return on investment of **US\$3.22** for every dollar invested, calculated on the combined research expenditure of CIAT and partners [14]. Indeed, of a total research investment estimated at US\$5.3 billion, CIAT’s portion is only about 12% but potentiates the investment made by national partners. In recent history between 2012 and 2016 the Bean Program and partners in Africa are estimated to have reached 16.7 million users of bean technology, including 11 million who accessed new varieties (of whom 51% were women), 3.8 million who accessed crop management practices (55% women), and 1.9 million who received bean products (45% women). The bean corridor approach will allow us to scale up and build on these successes. Important lessons in recent years emerge both from CIAT’s work and the wider research and development community, and bear repeating.



*Importance of beans as nutrition- and health-promoting agents:* Besides reducing risk of chronic diseases, beans are also an important source of iron and zinc. The Bean Program has participated in HarvestPlus since 1994, and beans bred for high iron are one of its banner successes, improving hemoglobin status [18], and showing a positive effect on memory and cognitive ability [28].

*Exploiting the potential of bean biodiversity:* Sister species in the center of origin in Latin America evolved in extreme environments and are invaluable sources to address challenges of drought, high temperatures, excess rainfall, resistance to certain diseases, and edaphic constraints (phosphorus, aluminum [11, 12]). These species may also contribute genes for yield potential and nutritional quality. Improved methods for tapping the diversity of these species have been developed [2] and are being complemented with genomic analysis.

*Relationships with development partners:* In reference to the suggested impact pathway, a key to creating impact has been to dedicate staff time explicitly to building relationships with development partners. Too often the interaction with these partners is sporadic and limited to the scope of short-term projects. Impact needs to be someone's "day job" and their primary responsibility. CIAT staff working in PABRA (see below) have assumed this task, essentially facilitating linkages between the suppliers of technology with the demand for technology through platforms, while exploring novel institutional relationships, such as the licensing of bean varieties to private companies (see text box).

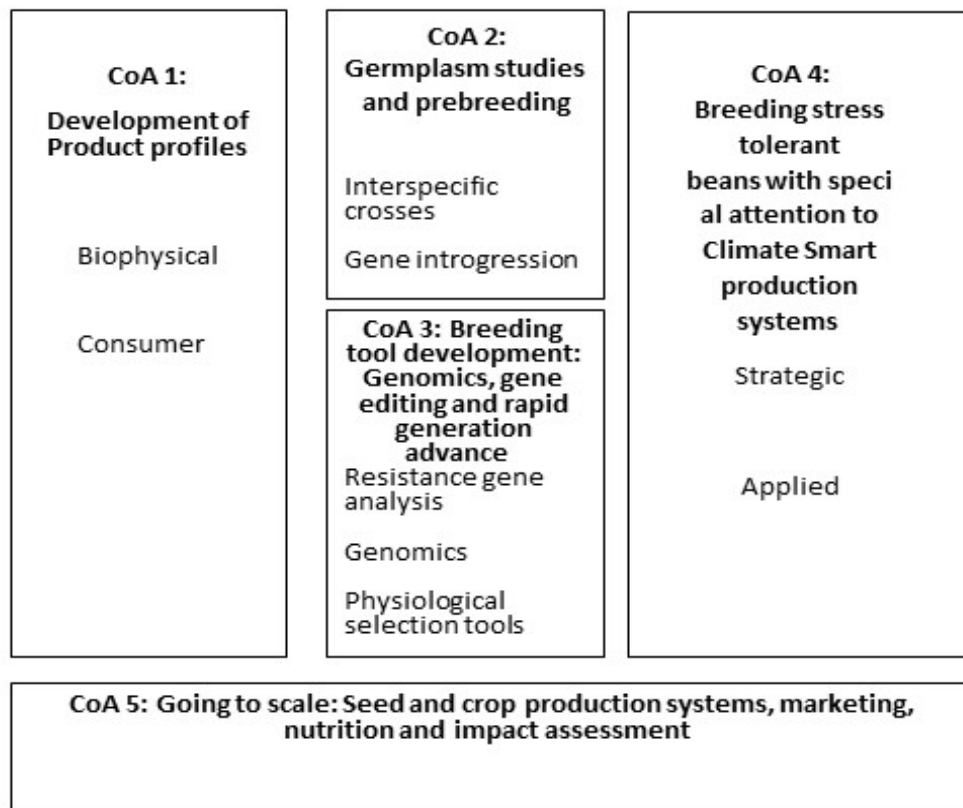
*Dramatic success stories:* Climbing beans have raised yields dramatically in Rwanda, and where previously hunger loomed large, now beans are exported. A second success story illustrates the potential of markets to motivate improved crop management practices. Above we cited the case of Ethiopia where an assured market and training led to farmer investment in crop management and quality control, resulting in a doubling of yields over a 10-year period [16].

*Possible unintended consequences:* Increased productivity always runs the risk of glut and low prices. While in the broader scheme there is ample deficit in both continents that can absorb production, gluts can and do occur locally and at harvest time. Here the role of markets and market access at the appropriate moment take on importance, together with the issue of storage capacity to be able to sell at a favorable time – a capacity that can be addressed through the efforts of market corridor platforms. Yet another unintended consequence may lie in the promotion of trade. Will poor consumers find themselves in competition with regional and international markets, with less access to beans as a staple food, and with negative health consequences? CoA 5 will address this.

Bubayi Seed Company, a family-run seed business in Western Kenya, initially dealt in maize seed but saw an opportunity to provide seeds of other crops – especially beans – albeit with great uncertainty. Many seed companies shy away from the bean seed business because of non-repeated purchases and low profitability. However, Bubayi opted to take the risk, buoyed by the fact that farmers needed access to bean seed that was unavailable in agro-dealers' shops. In 2015, Bubayi and the Kenya Agriculture and Livestock Research Organization (KALRO) entered into a bean variety licensing arrangement supported by the Syngenta Foundation for Sustainable Agriculture and CIAT. Varietal licensing greatly encouraged them, and since 2014, Bubayi bean seed production has grown from 6.1 tons of certified seed to more than 160 tons. This model of public-private partnership bodes well for engaging more private companies in a budding market.

## 1.6. Overview of clusters of activities (CoA)

The activities in this flagship will be organized into five clusters. Clusters 1-4 include the development of product profiles, prebreeding, and breeding. Scaling activities will be implemented continuously based on strategies that have been devised already in PABRA, HarvestPlus and Grain Legumes programs. The below illustrates the five clusters and detailed descriptions are provided in the following section of this proposal. Links of clusters to sub-IDO's are represented in [Annex 6](#).



**Figure 3: Overview of Clusters of Activities**

### Clusters of activities (CoA) narrative

#### *CoA 1: Product Profiles developed through environmental and social characterization*

A priority setting exercise in 2012 identified climate change, soil constraints, and biotic limitations as key targets for genetic improvement in recent years. That analysis will be refined using statistical analysis of climate and soil data as components of product profiles, to develop a concept of Typical Production Environments (TPE). One effort in this regard employed the MaxEnt model (maximum entropy) to characterize environments for the cultivation of climbing beans [19], in which temperature, soil pH and cation exchange capacity (CEC) emerged as determining factors. The MaxEnt method will likewise evaluate the effects of climate change over time, by mid-century and

end-of-century. Data on health parameters, especially anemia and stunting, will be incorporated where possible, although these data often are available only on the national level ([Annex 3](#)). Zinc is emerging as an even higher priority than iron in some countries, and targets must be refined with HarvestPlus. The geographic distribution, character and magnitude of demand (including gender disaggregation) must be estimated as population growth and urbanization transform food habits and consumption. Gender differentiation of trait preferences has been practiced in the Bean Program for many years, but is subject to the dynamics of a changing environment. Varietal development is being aligned with the concept of demand-led breeding (DBL) in dialog with CoA 5 below, whereby local, regional, and international markets and value chains are characterized around production-to-market corridors. Ex ante analysis will seek to foresee demand and traits preferred by different types of consumers (men, women, poor or rich). The surprising receptivity to easy-to-cook infant foods even by rural women suggests that the processed food market merits study. These activities contribute to refining the product profiles for different production regions as facilitated by Module 1 of EiB, to sharpen the focus for flagship Outcomes 1 to 5, and to enhance likelihood of adoption. GLDC houses these activities in CoA 1.1., 1.2, and 4.1.

#### *CoA 2: Germplasm studies, trait discovery and prebreeding*

Faced with extreme climates of the future, prebreeding with sister *Phaseolus* species offers superior adaptation to such environments (Outcome 3), to complement the mainstream breeding program. *P. coccineus* and *P. dumosus* evolved in humid environments, while *P. acutifolius* evolved in hot, desert-like regimes. Interspecific variability is a key to accelerating genetic gain (Outcome 1). Our experience with breeding for abiotic stress sheds light on the role of photosynthate transport to grain in both stressed and unstressed environments [1]. *P. acutifolius* is especially efficient in this regard and can serve as a genetic model for yield improvement [30]. *P. acutifolius* offers tolerance to drought, heat (at least 28° C night temperatures), and some pathogens and insects (Outcome 3). Lines derived from tepary bean (*P. acutifolius*) showed 468% increase over the common bean parent under heat stress and 12% increase over the best elite line. In the past breeders made little use of this species due to the need culture young embryos in the laboratory. The recent discovery of interspecific bridging genotypes that are cross fertile with both species opens vast new opportunities for breeding of common bean [2]. *P. acutifolius* accessions from the genebank will be examined more extensively to determine what other traits they may offer. *P. coccineus* has ample genetic diversity that has never been characterized. This species has unique root traits which if transferred to common bean, could improve access to soil water and nutrients [7, 11, 12] and improve recovery of fertilizer (Outcome 2). Superior interspecific lines are already moving into the mainstream breeding program while others are being developed. Understanding the genetic systems of these species will permit designing common beans through gene editing or genetic transformation when these methodologies are perfected [27]. In GLDC these activities are found in CoA 5.1 and 5.2.

#### *CoA 3: Enabling technologies: Genomics, gene editing and rapid generation advance*

Markers for key disease resistance genes have been tagged with SNP in years past, and this work continues (Outcome 3). In-house capacity exists for selection of SNP by the melting temperature differential technique, but prospects of high volume, low cost outsourcing of genotyping are being

explored. Increasingly the sequencing of key genotypes is contributing to the identification of unique, linked polymorphic loci [26]. Traits derived from interspecific crosses offer higher probability of unique polymorphisms in relation to *P. vulgaris*; thus sister species should be sequenced strategically, for example, to reveal markers for heat tolerance from tepary bean (Outcome 3) and root traits from *P. coccineus* (Outcome 2). RILs segregating for iron concentration have been phenotyped and are ready for genotyping and marker development (Outcome 5). Prospects for gene editing are good, as the obstacle of recovering plants from tissue culture has now been overcome [27]. Rapid cycling of generations combined with reliable selection criteria in each generation will lead to faster genetic gain as favorable alleles are recombined in each cycle (Outcome 1). This will be especially useful in climbing beans that have a long growth cycle of 4-to-6 months or longer. Novel phenotyping tools, for example, to evaluate photosynthetic traits or in situ root distribution in soil, will be explored. In GLDC this CoA corresponds to CoA 5.3.

#### *CoA 4: Breeding pipelines for stress-tolerant, market-ready beans*

Common bean breeding must meet specific grain characteristics of color, size and shape. We will improve the current networks of NARS partners in PABRA, Central America, and CIAT into efficient professional breeding networks around commercial classes of bean, working under the same system, methodology and following the same metrics. We have taken steps in this direction with the implementation of the bean trait dictionary. Involving partners from breeding to dissemination and market studies will ensure optimal goal setting. New germplasm developed at CIAT stations in Colombia and Africa will be shared with NARS partners in regional communities of breeders, and built around regional nurseries of several hundred lines planted in 10–12 sites per region, to obtain adaptation data early in the testing and release process, and to facilitate rapid release and use of lines (Outcome 1). These yield trials will facilitate documenting genetic gain in a farmer production context. A stage gate system will be adopted by the breeding network for information flow, transparency, quality assurance and optimal budget allocation. Organized data feedback from NARS will permit exploring genomic prediction for breeding at a distance. Bean breeding has long highlighted relieving biotic constraints (fungal and viral pathogens) and selection of several important resistance genes is now facilitated with SNP. Several grain types and most production constraints are similar in Latin America and in Africa, with major exceptions of gemini viruses in Latin America, and the bean stem maggot (*Ophiomyia* sp.) in Africa. Climate change will alter patterns of insects and diseases, and brings abiotic constraints to the forefront, especially drought and heat stress [5], requiring creative approaches to stress physiology. If photosynthetic traits measured by the [MultispeQ](#) prove to be related to yield, data can be compiled in real time over entire regions in the [PhotosynQ](#) cloud database. Several drought tolerant varieties have been released already, while breeding for heat tolerance is more recent (Outcome 3). Stress tolerant lines are components of climate smart agriculture (CSA) in CoA 5. Lines derived for adaptation to infertile soils and nutrient uptake are being incorporated into the mainstream breeding programs (Outcome 2), to be combined with integrated crop management (ICM) practices in CoA 5. Market demands of grain types, industrial traits (e.g., canning quality), and consumer preferred traits (cooking time, taste) [4] must be included in phenotyping platforms. Market traits have dominated criteria for release of varieties in

Latin America for two decades, and Africa is moving in this direction rapidly. Breeding for improved micronutrient concentration (iron and zinc) is developed in HarvestPlus under the Agriculture for Nutrition and Health (A4NH) CRP and mainstreamed in this flagship [9, 10] (Outcome 5), while biofortified lines are distributed to countries beyond the HarvestPlus mandate. Climbing and semi-climbing beans with viral and fungal resistance will offer farmers high yield with excellent commercial value (Outcome 1). The creation of new varieties must be supported by phenotyping with auxiliary disciplines of physiology, pathology, entomology and virology that will elucidate mechanisms of stress tolerance to develop selection criteria for the breeding program. These activities correspond to GLDC CoA 4.1 and 4.2.

*CoA 5: Going to scale: Seed and crop production systems, marketing, nutrition and impact assessment*

Seed dissemination: Scaling up of seed-based technologies resolves to seed dissemination strategies, including seed production, distribution including marketing, and messaging. Especially for legume seed, multiple strategies have been devised, tested and implemented as alternatives to high cost certified seed, with significant efforts under the Tropical Legumes II and III projects, in collaboration with PABRA which led the seed component of those projects. A major key to success has been the innovation platforms engaging multiple actors, many of whom are self-financed and are anxious to access new varieties. Demand for seed is better channeled from producers to seed enterprises who use this information to respond appropriately to supply the quantities required (Outcomes 1 to 5). As cited above, the phase I external review of the Grain Legume CRP noted several strategies including “marketing in small seed packets at low cost and permitting farmers to experiment with low risk; seed-for-grain models; standard private sector production; decentralized local production of Quality Declared Seed (QDS) with small NGOs and CBOs, value-chain development”. To this list can now be added a wider involvement of the private sector in production and marketing, in novel legal arrangements for production of large amounts of breeder and foundation seed, or in licensing of new varieties. In Central America seed dissemination works through multiple mechanisms: through public extension services (all countries), local community seed banks (Nicaragua), and more than 100 local farmer research committees (Honduras). Participation of the private sector here is scant but is being explored. This CoA corresponds to GLDC CoA 4.4.

Crop management practices: Integrated soil fertility and pest and disease management practices must accompany scaling up of bean varieties across the diverse production environments, including judicious use of organic, inorganic and foliar fertilizers, integrated pest and disease management options such as seed dressing. Site-specific fertilizer recommendations with emphasis on balanced plant nutrition and micronutrients will contribute to more nutritious grain (for example, to increase zinc concentration in grain). The adaptation of simple-to-use post-harvest labor saving technologies like bean threshers (e.g. in Ethiopia and Tanzania) is increasingly important as youth migrate and farm labor becomes scarce. This is a long-term reality in Central America and is occurring already in parts of Africa. Promotion of climate smart agriculture practices that improve water and nutrient use efficiency such as conservation agriculture require attention. Climate risk assessments will provide accurate and timely climate information to inform farm decision making and operations. CIAT and



partners have carried out climate-smart agriculture (CSA) profiles in nine countries in Latin America and the Caribbean and seven countries in Africa (Kenya, Rwanda, Senegal, Mozambique, Tanzania, Zambia and Uganda) and downscaled Climate Risk profiles at sub-national level in 31 counties in Kenya. While these activities are not research per se, they bear relation to GLDC CoA 3.2.

Regional corridors: PABRA is restructuring interventions around a regional corridor approach.

Ongoing analyses reveal existence of corridors of unstructured major flows of beans between areas of production and consumption, connected by poorly organized distribution networks. Eight such corridors have been defined ([Annex 7](#)), and characterization of major corridors in Eastern, Southern and Western Africa is well advanced. What is unique about this current approach is the detailed quantification of these flows, and the information on service providers such as sources of credit, insurance, and ICT. Efforts are aligned and focused on enhancing the efficiency of the three interlinked component corridor “hubs”: the production, distribution, and consumption hubs. Production hubs are defined as sites or regions where large volumes of beans are or can be produced in response to market needs by: targeting varietal development and dissemination of market demanded varieties. Also by, improving productivity and production through good agricultural practices (GAPs) including CSA and ICM, developing and sustaining seed systems, and strengthening the capacity of farmer producers units for collective marketing. Distribution hubs include product aggregation centers, distribution centers, warehouses, storage points, or commodity exchanges, for distributing beans to consumers. Consumption hubs are the major market outlets in rural, peri-urban and urban areas (within or outside of the production areas) and involve processing units, supermarkets, and bean dealers.

Engagement with the private sector in the corridors is operationalized in bean business platforms that are built around lead firms in the seed and grain businesses. Platforms based on lead firms enjoy better coherence and sustainability, and facilitate market channels into which smallholder farmers can link. The experience of Ethiopia whereby smallholder farmers doubled their yields in response to market pull can be replicated through this approach. Recent platforms have been established in Southern Tanzania for sugar bean, and for precooked beans (including biofortified beans) in Rwanda. The corridors will systematize this experience and help to create market-driven, rural agricultural transformation by linking all members of the bean value chain across the corridor while stimulating, developing and intensifying use of support services such as credit, insurance, and ICT among others.

A corridor perspective sets the context for CoA 1 above and permits defining product profiles in a specific regional context. Markets are increasingly reflecting what consumers want and are determining what farmers will grow. This has been a reality in Central America for nearly two decades where the market demands small red beans of a specific pinkish tone, while in East Africa, large red-mottled beans are produced in Uganda, Rwanda, Tanzania and some parts of Kenya, and flow to the market in Nairobi. Focusing interventions around corridors as an integrated unit likewise offers a context to enhance gender sensitivity of value chains (encouraging women as producers and buyers, etc.; Outcome 4), and to evaluate impact of interventions. Nutritional outcomes (e.g., of biofortified beans) similarly are scaled by tapping into the volumes of grain moving through the corridor (Outcome 5). Bean-based products (flours, porridge) are being developed and

commercialized within the consumption hub to create new markets for nutritious food options (Outcomes 1 and 5). These activities are comparable to GLDC CoA 2.1.

Governments in net exporting countries have embraced the opportunity to commercialize bean and have classified bean as a tradable commodity for further promotion. How will this impact on the production and domestic consumption, especially of the poorer households who are sometimes net buyers but now have to compete with consumers in regional/international market? Will this increase malnutrition and create a heavy health burden on these governments, or will returns to trade have positive social gains? A previous study examined this in Rwanda, and this will be studied further within CoA 5.

## **1.7. Partnerships: Jointly funded collaboration**

*Networks with national partners:* CIAT has a long history of creating regional networks with partners, first in Central America, and later in the Great Lakes region, and in Eastern and Southern Africa. The Central American network has not functioned formally since the early 1990s, but governments of the region maintain formal programs of collaboration and a spirit of cooperation. Collegial relations among researchers facilitate interchange of germplasm and results across countries with similar agroecologies and grain preferences. CIAT works closely with the Pan-American School (Zamorano) in Honduras which plays an important role in coordinating regional trials. An annual meeting of agronomists (the Central American Cooperative Program for the Improvement of Crops and Animals –PCCMCA by its Spanish acronym) facilitates coordination of activities.

The Pan-African Bean Research Alliance (PABRA) is a self-governing consortium facilitated by CIAT that coordinates cooperation among 30 countries and 3 regional networks. Annual meetings permit information sharing and joint decision making on priorities and governance. An [external review of PABRA](#) stated that:

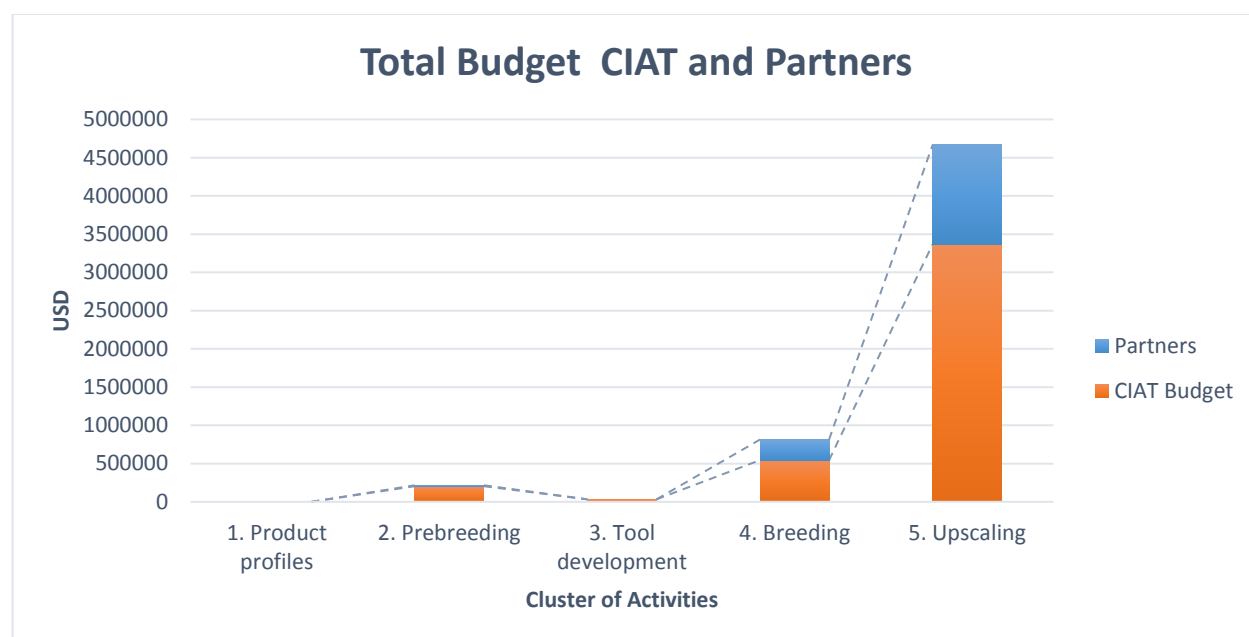
“PABRA represents a model for how a continent-wide crop network can function for the benefit of smallholder farmers. The efficiency and effectiveness of PABRA are demonstrated by the potential for communication and cooperation in bean research and allied areas among 30 African nations. PABRA is becoming increasingly relevant with changes in African agriculture and market development across the continent.” [32]

Regarding CIAT’s role in relation to PABRA, the review states:

“PABRA has benefited enormously from its partnership with CIAT, and CIAT’s support has kept up with changing circumstances in the member countries of the network. The PABRA network, in essence a multifaceted partnership, contains some strong countries whose bean production is being commercialized or is at the point of being so. It also includes countries that are aiming to supply domestic, regional, sub-regional and international markets... If CIAT were not available as a partner in PABRA it is likely that only few countries could continue to develop their bean breeding, bean production and related activities...CIAT is a mainstay of the PABRA network and will continue to be so into the future.” [32]

Three CIAT breeders within PABRA have a role of breeding for locally important traits and distributing germplasm through regional trials while mentoring national programs in their own breeding programs. They also coordinate introduction of germplasm from CIAT-Colombia from the two breeders there. CIAT scientists interact with their peers working on other legumes through the Tropical Legumes III project, funded by the Bill & Melinda Gates Foundation and led by ICRISAT. PABRA leads the seed component of this project, whereby successful experiences in seed dissemination have been shared and applied to other legumes of GLDC, illustrating the benefits of cross-legume cooperation to be nurtured by this flagship.

The current 2018 Bean Program budget for CIAT activities and for national partners is represented by Cluster of Activity in Figure 3 with the respective portions. Budgets for 2018 to 2022 by Clusters of Activities are presented in [Annex 8](#). CoA 1 and CoA 3 are currently not funded but discussions are underway to obtain bilateral funding.



**Figure 3: Assured funding for 2018 by Clusters of Activities, for CIAT and for partners.**

*Upstream partners:* The largest bean research community in the developed world is that of the United States, where the genome sequence of common bean was developed. A joint project focusing on breeding for abiotic stress tolerance is funded through the United States Agency for International Development (USAID) and is administered by Pennsylvania State University. Which facilitates interaction with colleagues in three stations of USDA, the University of Puerto Rico, North Dakota State University and Zamorano (Honduras), and in Mozambique, on topics as diverse as stress physiology, breeding and genomics. Cooperation with Michigan State University has focused on soil pathogens, on processing characteristics of bean, and on photosynthesis research, and with UC Davis on physiology. CIAT’s role includes the provision of unique germplasm resources, and physiological

studies in tropical environments. We anticipate opportunities to develop cooperation on nutritional and health with partners such as Michigan State University, Colorado State University, Washington University, or potentially through them, with the National Institute of Health (NIH). Cooperation is on-going with institutions in the UK: with Reading, Rothamstead and Leeds Universities.

*CRP linkages:* While links to CRPs are typically conceptualized at the level of the CRP per se, the unusual context of this flagship requires maintaining strong linkages to the A4NH CRP and the HarvestPlus program on biofortification, where beans have been one of the foremost cases of success. Regarding production systems, bean has the closest affinity with the Maize CRP, with which we have collaborated in East Africa and in the [MASAGRO program](#) in Mexico. Beans have been shown to benefit in particular from conservation agriculture that [CIMMYT](#) (under the SIMLESA collaborative project) has promoted widely. The [CCAFS](#) (Climate Change, Agriculture and Food Security) CRP, is housed in CIAT and conversations are ongoing around the analysis of future climate scenarios and implications for common bean production.

## 1.8. Climate change

While drought tolerance has long been a priority in the breeding program and has resulted in the release of more than 20 tolerant varieties, interaction with CIAT experts in agroecology has consistently indicated that heat stress will be a major limitation in many bean-growing areas [31]. Continuing collaboration with climate experts will serve to identify the most adequate selection sites that will mimic future stress environments, and to target traits for climate resilience more effectively. As mentioned above, climate-smart agriculture (CSA) profiles and downscaled Climate Risk profiles have been developed in collaboration with CCAFS.

## 1.9. Gender

Empowering women is a central value of CGIAR and holds a special significance for a crop like beans that is widely cited as a women's crop in Africa. This implies both a responsibility and an opportunity to exploit the potential of the crop to benefit women, and through women their children and their families. It is truism that income in the hands of mothers brings greater social benefits, thus studies of socio-economic impact must be measured with a gender lens. An extensive survey in several regions of Uganda showed that although men are heavily involved, women continue to be active even in marketing of beans, and exert influence on use of income in the household ([Annex 9](#)). Nonetheless, as beans gain in commercial value, men are becoming more involved in cultivation and marketing [23]. This situation merits monitoring and even active intervention, in the capacity building of women to engage with evolving markets and in fora for exposure to technology, and indeed, to maintain their input into the technology development process. Participation in technology development has been channeled in many cases through exercises of participatory varietal selection. Such exercises contribute to the immediate process of choosing lines to advance in the evaluation procedure, but data compiled in the exercise in turn need to influence setting of breeding objectives, considering trait preferences by gender and including these in product profiles. This dimension formed a part of the breeding program early on in its development in the 1990s [34, 35] and has been updated on occasion since then [29]. Gender analysis of preferred traits have sometimes shown differential preferences (for example, women citing cooking time as important), while other studies

show little difference between men and women. Most importantly, gender disaggregated participatory evaluation of germplasm has been incorporated routinely into collaborative work with national research institutions, of whom more than half use gender disaggregated evaluations as their standard operating procedure (Figure 4 below). The context of the production-to-consumption corridors will bring new implications for trait preferences, as markets set standards for new varieties, and as farmers grow for markets, some of which might be quite distant. This will require monitoring of impact of new commercial relations on gender roles in bean production and marketing, and in those distant centers of consumption where women purchase and prepare beans as food, to ensure that women and youth benefit from this model.

These same criteria of product evaluation must be incorporated into the development of non-germplasm products such as bean flours or other processed bean products, as interaction with the food sector grows. In their role as caregivers, mothers are also the so-called “gate-keepers” who decide what their children will eat. Weaning foods or other products targeted to improve the health of children will not have the desired effect if the products are not first approved by the mothers. Beans are an especially nutritious option for improving the growth and health of children, but fulfilling this potential will depend on engaging with mothers.



**Figure 4: Left: Farmers in Kenya prepare to rate breeding lines using colored strings to mark preferences. Right: Gender disaggregated data are extracted from string colors.**

Gender consciousness is reflected in the gender balance in the Bean Program, where 40% of scientific staff are women, serving in a range of disciplines: breeding, economics, nutrition and food science, monitoring and evaluation, and gender analysis per se. A full time gender expert based in East Africa who assures rigor in issues of gender analysis will be in a position to cooperate with the gender expert of GLDC.

## 1.10. Capacity development

CGIAR suggests ten areas of intervention that develop capacities in agricultural research for development (see full list: [goo.gl/Lk4y7z](http://goo.gl/Lk4y7z)) of which two are especially relevant for this proposal:



- Develop CRPs and centers’ partnering capacity and strengthening institutions: As stated by the [CGIAR capacity development framework](#), it is important to “face the challenge to move from research partnerships to broader, strategic and effective multi-stakeholder partnerships [...]. This includes partnerships with local organizations, NGOs and institutions adept at developing capacity, particularly for producers and other stakeholders. The PABRA structure provides a model for cross-country, cross-institutional learning and empowerment whereby results and experiences can be shared in short order. A key challenge already faced by PABRA is to innovate in public-private partnerships to deliver products at scale.
- Develop future research leaders: Efforts are on-going to enhance and modernize breeding programs of the international centers. The Excellence in Breeding platform will offer updated knowledge on techniques and data analysis, among other services. The Breeding Performance Assessment Tool (BPAT) will facilitate a program-by-program analysis of strengths and weaknesses to guide this process. The Bean Program is actively engaged in this analysis and the broader process. Considerable effort has been dedicated to formal post-graduate training of national program staff. In the past 20 years, PABRA alone has trained 86,880 people, a third of which women. While this should continue, a greater effort should be made to create capacity at the level of field and laboratory technicians. Cooperation with GLDC in this area should be pursued. Breeding programs everywhere depend on well trained technicians who bear the brunt of day-to-day operations.

This flagship will address the following Cap Dev sub-DOs as stated by the CGIAR strategy:

- Enhanced capacity to deal with climate risk and extremes
- Improved capacity of women and young people to participate in decision making
- Increased capacity of beneficiaries to adopt research outputs
- Enhanced individual capacity in partner and research organizations through training and exchange
- Increased capacity for innovation in partner research organizations

## 1.11. Intellectual asset and open access management

CIAT abides by the [CGIAR Principles on the Management of Intellectual Assets](#) (CGIAR IA Principles) and their Implementation Guidelines. Results and outputs of research and development activities of this flagship are international public goods and will be disseminated widely to maximize impact for farmers and consumers in target countries. CIAT will manage its intellectual assets with integrity, fairness, equity and accountability.

In keeping with the [CGIAR Open Access and Data Management Policy](#) (OADM), research data, tools, and associated information generated under Bean flagship will be made open via FAIR principles (Findable, Accessible, Interoperable, Re-usable) to enhance innovation, impact, and uptake. [CGIAR Big Data Platform](#) framework, principles and tools will be used for timely dissemination of data related products including final versions of its data products openly and freely accessible for use and reuse by others through [CIAT Dataverse](#). In addition, the flagship will use other specialized and shared databases such as the Breeding Management System (BMS) to make available its results to the global research and development community. For example, CIAT

established a trait dictionary that serves as the “lingua franca” of bean research. Pedigrees are maintained in the IPHIS program (a *Phaseolus* adaptation of the International Crop Information System-ICIS) and are web accessible. Internally CIAT has developed software for managing seed inventories. More effective management of phenotypic data is high priority for improvement in the near future.

## **1.12. Flagship management**

The Directors of CIAT and GLDC, in consultation with the System Management Office, agreed that GLDC will host the flagship on common bean, building residual synergies with other legumes, while respecting the overall dryland systems focus of the CRP. The management principles of the hosting relationship will be:

- CIAT will be accountable for financial and research performance monitoring.
- The flagship will be individually managed by the Flagship Leader: CIAT’s Bean Program leader (currently Stephen Beebe)
- The flagship will use CIAT’s Monitoring, Evaluation and reporting system –MARLO, a platform that is used by 8 other CRPs. CIAT-MARLO is comparable with the MEL system used by GLDC. MARLO is undergoing a process of interoperability with the MEL, which will allow the CRP director access to key monitoring information. A report will be rendered to GLDC management once a year.
- The flagship leader will provide information and technical input to the Research Management Committee (RMC) and the Independent Advisory Committee (ISC), as needed. And serve as a channel to receive similar information from other legume crops.

### 1.13. Budget summary

	2018	2019	2020	2021	2022	Total
<b>Funding needed</b>						
W1+W2						
W3	4,088,883	4,293,327	4,507,993	4,733,393	4,970,062	22,593,658
Bilateral	6,825,329	7,166,595	7,524,925	7,901,171	8,296,230	37,714,250
Other sources						
Total	10,914,212	11,459,922	12,032,918	12,634,564	13,266,292	60,307,908
<b>Funding secured</b>						
W1+W2						
W3	1,458,523					1,458,523
Bilateral	4,081,724	3,901,940	1,673,498	1,623,047		11,280,209
Other sources						
Total	5,540,247	3,901,940	1,673,498	1,623,047	0	12,738,732
<b>Funding gap</b>						
W1+W2						
W3	2,630,360	4,293,327	4,507,993	4,733,393	4,970,062	21,135,135
Bilateral	2,743,605	3,264,655	5,851,427	6,278,124	8,296,230	26,434,041
Other sources						
Total	5,373,965	7,557,982	10,359,420	11,011,517	13,266,292	47,569,176
<b>Line items</b>						
Personnel	3,854,964	4,047,712	4,250,098	4,462,603	4,685,733	21,301,110
Travel	727,581	763,960	802,158	842,266	884,379	4,020,344
Capital equipment	72,399	76,019	79,820	83,811	88,001	400,050
Other supplies and services	2,591,679	2,721,263	2,857,326	3,000,192	3,150,202	14,320,662
CGIAR collaborations	-	-	-	-	-	-
Non-CGIAR collaborations	2,586,000	2,715,300	2,851,065	2,993,618	3,143,299	14,289,282
Indirect costs	1,081,589	1,135,668	1,192,451	1,252,074	1,314,678	5,976,459
Total	10,914,212	11,459,922	12,032,918	12,634,564	13,266,292	60,307,907
	2018	2019	2020	2021	2022	Total



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