CGIAR Advisory Services

CGIAR Research Program 2020 Reviews: Grain Legumes and Dryland Cereals

Authors: Jill Lenné and Guy Poulter

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All Annexes are provided in the Annex file

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Abbreviations

A4NH	Agriculture for Nutrition and Health CRP
AR	Annual report
ARC	Agricultural Research Council
ARI	Advanced research institute
AVISA	Accelerated Varietal Improvement and Seed Delivery of Cereals and Legumes in Africa
BCKVK	BC KrishiVigyanKendras
BGM	Botrytis grey mold
BMGF	Bill and Melinda Gates Foundation
BPAT	Breeding Program Assessment Tool
CCAFS	Climate Change Agri-food Systems CRP
CIRAD	Centre de Coopération International en Recherche Agronomique pour le Développement
CNG	Crop network group
CoA	Cluster of Activities
CRP	CGIAR Research Program
CSIRO	Commonwealth Scientific and Industrial Research Organization
DC	Dryland Cereals CRP
DS	Dryland Systems CRP
EiB	Excellence in Breeding Platform
ESA	Eastern and Southern Africa
FP	Flagship program
GEM	Genotype environment management
GL	Grain Legumes CRP
GLDC	Grain Legumes and Dryland Cereals CRP
HYPHEN	Drone-based imaging method
HPRC	Hybrid Parents Research Consortium
HTPG	High Throughput Genotyping Platform
IAC	Independent Advisory Committee
IAR	Institute for Agricultural Research
ICARDA	International Centre for Agricultural Research in Dry Areas
ICRAF	World Agroforestry Centre

ICRISAT	International Crops Research Institute for the Semi-arid Tropics
IDO	Intermediate Development Outcome
IF	Impact factor
IITA	International Institute for Tropical Agriculture
ILRI	International Livestock Research Institute
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
IP	Impact pathway
IPG	International public good
IRD	L' Institut de Recherche pour le Développement
ISI	International Scientific Index
ISPC	Independent Science and Partnership Council
MPAB	Markets, Partnerships and Agri-business cross-cutting theme
MS	Milestone
NARES	National agricultural research and extension system
NARS	National agricultural research system
NGO	Nongovernmental organization
NIRS	Near-infra-red spectroscopy
OICR	Outcome Impact Case Report
PABRA	Pan-African Bean Research Network
PAU	Punjab Agricultural University
PD	Program director
PIM	Policies, Institutions, and Markets CRP
PMU	Program Management Unit
POWB	Plan of work and budget
QoR4D	Quality of Research for Development
QTL	Quantitative trait locus
RGA	Rapid generation advance
RMC	Research Management Committee
RTB	Roots, Tubers and Bananas CRP
SA	South Asia
SDG	Sustainable Development Goal
SLO	System-Level Outcome

SLU	Swedish University of Agricultural Sciences
SMB	System Management Board
SNP	Single nucleotide polymorphism
SRF	Strateg and Results Framework
SRO	Subregional organization
SSA	Sub-Saharan Africa
ToC	Theory of change
TOR	Terms of reference
USAID	United States Agency for International Development
W1/W2	Window 1/Window 2
W3	Window 3
WUR	Wageningen University
XRF	X-ray fluorescence

Executive Summary

Background and Context

The main objective of the CGIAR Research Program Grain Legumes and Dryland Cereals (GLDC) is to increase the productivity, profitability, resilience, and marketability of nutritious grain legumes (chickpea, cowpea, pigeonpea, groundnut, lentil, soybean) and cereals (sorghum, pearl millet, finger millet) grown in semi-arid and sub-humid dryland agroecologies of Sub-Saharan Africa and South Asia. GLDC is led by ICRISAT in partnership with IITA, ICARDA, ICRAF, ILRI, Bioversity International, CIAT, IRD, CIRAD, CSIRO, and many nongovernmental organizations (NGOs), national agricultural research systems (NARSs), and private sector partners. It is structured on five flagship programs (FPs): FP1: Priority Setting and Impact Acceleration; FP2: Transforming Agri-food Systems (not funded); FP3: Integrated Farm and Household Management; FP4: Variety and Hybrid Development; and FP5: Pre-breeding and Trait Discovery. FP6: Common Bean was incorporated in November 2018 and approved by the CGIAR System Management Office (SMO) in January 2019.

Purpose and Scope of the CRP 2020 Review

The primary purpose of the review is to assess the extent to which the GLDC is delivering quality of science and demonstrating effectiveness in relation to its theories of change (ToCs) in the approved proposal. Its objectives are to fulfill CGIAR's obligations for accountability and donor support for international agricultural research; assess the effectiveness and evolution of research program's work; and provide an opportunity for GLDC to generate insights, including lessons for future CGIAR research modalities.

Review Questions

1. To what extent does the GLDC deliver quality of science, based on its work from 2018 to 2019?
2. What outputs and outcomes have been achieved, and what is the importance of those identified results?
3. To what extent is GLDC positioned to be effective in the future, seen from the perspectives of both scientists and end users of agricultural research (such as policymakers, practitioners, or market actors)?

Review Methods

The review used a combination of methods with reference to key GLDC and CGIAR documents and publications. Primary qualitative data were collected from 36 respondents. Quantitative data were obtained from bibliometric analyses, the CGIAR Dashboard, and physical outputs. Performance data were obtained from assessments of contributions to milestones, sub-IDOs, and IDOs. The analysis of impacts was implemented through a deep dive on selected seed systems OICRs and an analysis of agri-food systems.

Important Findings and Conclusions

The quality of science in GLDC is high. Priority setting is integral to all program activities; use of novel tools and technologies is modernizing the breeding programs for enhanced efficiencies; research in seed-system scaling is having impact; modeling and remote sensing are well integrated in crop systems management research; and many publications are in high-impact journals. This effort has generated recognized and measurable international public goods (IPGs).

GLDC has made notable progress in fully completing 30 of 57 milestones and delivering contributions to the sub-IDOs and IDOs in two years. The OICRs tell a compelling story, mainly on the adoption of GLDC-improved varieties and establishment of functional seed systems in several countries, in addition to measurable positive impacts on development targets. However, the lack of funding to FP2 has had a major impact on the nature of GLDC research and the extent of delivery on development impacts. It can be argued that generated GLDC technologies may have been more relevant to, and have had greater impact on, development targets had they taken wider agri-food systems issues into account.

Gender is mainstreamed across GLDC with notable achievements, and each FP has an appreciated bespoke strategy. Progress has been made in developing a youth strategy with partners. GLDC shows a clear commitment to capacity development, which contributes to its outputs and outcomes. The many PhD projects with national universities are noteworthy. Efforts to modernize capacity development activities through the Task Force need to be further supported. GLDC should take a program-wide view of its research contributions on adaptation to and mitigation of climate change. Internal partnerships could be strengthened by communities of practice. A multitude of strategic partnerships have contributed needed skills for increased effectiveness, but enhanced linkages with A4NH and Livestock CRPs are recommended.

GLDC is well managed with timely reporting. Some action points from the Independent Advisory Committee (IAC) meetings do not appear to have been followed up. The two separate funding streams (W1/W2 and W3/bilateral) and the limited time allocation to the program director (PD) have hampered his ability to direct GLDC, foster rich and productive interactions between FPs, and drive the program as a coherent and integrated portfolio.

The work of GLDC is critical to the hopes and aspirations of millions of poor people in semi-arid and sub-humid lands. The concepts, activities, and aspirations envisaged for the GLDC in the original proposal were well thought through and are just as appropriate for the future. For GLDC to clearly articulate its future contribution, it needs to further modify its theories of change and impact pathways to reflect its current operations without a functional FP2. It can then make realistic projections on the likelihood of ultimate delivery of outcomes.

Recommendations

- *Recommendation 1*: In spite of the disappointment of GLDC being terminated one year early, it is recommended that GLDC members continue to generate high-quality outputs with the drive and passion clearly evident from the first two years of operation.
- *Recommendation 2*: It is recommended that future research in seed systems take account of farmer demand for quality seed, farmers' choices to adopt improved varieties, market preferences, and key factors contributing to the establishment of sustainable seed systems.
- *Recommendation 3*: Although GLDC has made good progress in developing strong linkages with CRPs and Platforms for increased program effectiveness, it is recommended that links with A4NH

be strengthened to ensure that the biofortification targets relate to the nutritional objectives in target countries and with Livestock to fully address research and development needs in crop-livestock systems, the most common farming system in the semi-arid tropics.

- *Recommendation 4*: It is recommended that GLDC should as far as possible develop an enhanced systems approach that extends across the whole agri-food system for maximum development impact.
- *Recommendation 5*: It is recommended that the time allocation of the PD be increased to 40–50 percent to allow the PD to drive the program as a more coherent and integrated portfolio and to play a greater role in facilitating and guiding the direction of W3/bilateral funds under an agri-food systems program vision through enhanced dialogue with partner centers and funders. The Roots, Tubers, and Bananas CRP (RTB) offers a proven model.
- *Recommendation 6*: It is recommended that GLDC clearly articulate its true potential future contribution by modifying its ToC and impact pathways to reflect its current operations, allowing it to make realistic projections on the likelihood of ultimate delivery of outcomes.
- *Recommendation 7*: It is recommended that the System Management Board (SMB) and the SMO incorporate the concepts and thinking contained in the CGIAR Strategy and Results Framework (SRF), which are still relevant for transforming food systems for greater impact on the System-Level Outcomes (SLOs), into the forthcoming One CGIAR.
- *Recommendation 8:* It is recommended that the simple model in which each FP is entirely supported by one funder, as exemplified by FP2: HarvestPlus in A4NH and FP6: Common Bean in GLDC, be given serious consideration by the SMB and the SMO in the forthcoming One CGIAR.

1 Background to the CRP 2020 Review

1.1 Purpose and Audience of the Review

The primary purpose of the GLDC 2020 review is to assess the extent to which the research program is delivering quality of science and demonstrating effectiveness in relation to its theories of change (ToCs) in the approved proposal as the original ToC had not been updated to reflect the current GLDC's work. Within this primary purpose, the objectives of the independent review are to fulfill CGIAR's obligations for accountability regarding the use of public funds and donor support for international agricultural research; assess the effectiveness and evolution of the program's work under CRP 2017–2021; and provide an opportunity for GLDC to generate insights about their research contexts and program of work, including lessons for future CGIAR research modalities. The primary audience of the review is the CGIAR System Council. The GLDC review may also provide lessons that inform the transition to One CGIAR in 2022, based on the program-level findings. It is hoped that the review findings, conclusions, and recommendations will help GLDC refine the 2021 plans of work and budget (POWBs) to the extent feasible in the remaining program year, and inform future research modalities.

1.2 Overview of the CRP and Its Context in Research for Development

GLDC has experienced a difficult history. It was formed in 2016 through the merger of three Phase I CRPs: Grain Legumes, Dryland Cereals, and Dryland Systems. Prolonged revision and a difficult prioritization process resulted in late approval in 2017. GLDC was not initiated until 2018. Even then, one flagship program (FP2: Agri-Food Systems Transformation) was not approved or funded, which has affected the ability of GLDC to deliver on its outputs and outcomes. The implications of this are referred to throughout this report. The main objective of GLDC is to increase the productivity, profitability, resilience, and marketability of critical and nutritious grain legumes (chickpea, cowpea, pigeonpea, groundnut, lentil, soybean, and common bean) and cereals (sorghum, pearl millet, finger millet) grown in semi-arid and sub-humid dryland agroecologies of Sub-Saharan Africa (SSA) and South Asia (SA), where poverty, malnutrition, climate change, and soil degradation are most acute. Improved innovation capacities within the agri-food systems of key cereal and legume crops are expected to enable coherent and integrated research and development, production, and market and policy reforms that deliver resilience, inclusion, poverty reduction, nutritional security, environmental sustainability, and economic growth. GLDC is led by ICRISAT and has 9 core partners—IITA, ICARDA, ICRAF, ILRI, Bioversity International, CIAT (added in 2019), IRD, CIRAD, and CSIRO—as well as many NGO, NARS, and private sector partners. The program supports beneficiaries in 17 countries in SA and SSA to deliver improved rural livelihoods and nutrition by prioritizing demand-driven innovation to increase production and market opportunities along value chains. It is structured on five FPs: FP1: Priority Setting and Impact Acceleration; FP2: Transforming Agri-food Systems (not funded); FP3: Integrated Farm and Household Management; FP4: Variety and Hybrid Development; and FP5: Pre-breeding and Trait Discovery. FP6: Common Bean was added in November 2018 and approved by the SMO in January 2019, but it will not be integrated owing to the short time left in Phase II.

1.3 Scope of the Review

The review will cover the program of work of GLDC and the FPs during 2018–2019 and be guided by the CGIAR's quality of science and effectiveness criteria and the ToCs for GLDC and its FPs. Emphasis will be on the CRP's sphere of control—that is, the quality of inputs, activities and outputs, and influence. These are the short-term and intermediate outcomes that are expected to lead to a development impact. To the extent feasible, the review of GLDC effectiveness will assess the likelihood for achieving Intermediate Development Dutcomes (IDOs) and/or sub-IDOs, based on the performance in relation to the ToCs.

1.4 Review Questions

1. Quality of science: To what extent does the GLDC deliver quality of science, based on its work from 2018 to 2019?

1.1. To what extent does the GLDC benefit from sufficient high-quality inputs?

1.2. To what extent do the GLDC management processes ensure the quality of science, including credibility, legitimacy, relevance to next-stage users, and potential effectiveness, of the research and operations?

1.3. In what ways are the research outputs, such as germplasm, knowledge tools, and publications, of high quality?

2. Effectiveness: What outputs and outcomes have been achieved, and what is the importance of those identified results?

2.1. To what extent were planned outputs and outcomes achieved by 2019?

2.2. What is the importance of achieved outcomes, with reference to CGIAR IDOs and sub-IDOs, cross-cutting issues, and partners' objectives, with consideration for predictability of funding and legacy time frame for the CRP?

2.3. How have the program's management and governance supported GLDC's effectiveness in research?

2.4. To what extent have GLDC and its flagship programs made progress along the ToCs?

3. Future orientation: To what extent is GLDC positioned to be effective in the future, seen from the perspectives of scientists and of end users of agricultural research (such as policymakers, practitioners, or market actors)?

3.1. What programmatic evidence exists for future effectiveness within the life of the program (through 2021), considering the comparative advantages of GLDC and its FPs and drawing on GLDC's and its FPs' progression according to the ToCs?

1.5 Review Methods

The review used qualitative and quantitative methods. Program documents included annual reports (ARs) and POWBs, the approved GLDC proposal, evaluative documents such as reviews by the ISPC Consortium Office, publications, reports, and websites (Annex 2). Primary qualitative data were collected from 36 respondents (Annex 3). Quantitative data was obtained from bibliometric analysis of journal publications, ARs, POWBs, technical publications, CGIAR Dashboard (for confirmation purposes), and physical outputs (Annex 5h). Performance data were obtained from assessment of completion of milestones and

contribution to sub-IDOs and IDOs. The analysis of impacts was implemented through a deep dive on five seed systems OICRs and an analysis of agri-food systems/value chains.

1.6 Quality Assurance

Quality assurance was achieved through a mid-review check-in on analysis methods and final report expectations, preliminary findings, and the criteria and methodology to analyze OICRs.

1.7 Organization of the Review Team

The two-person review team divided the responsibilities based on the two main review criteria: quality of science was addressed by one member, and effectiveness was a shared responsibility. One member also took the main responsibility for qualitative data through interviews. Responsibility was shared for other parts of the review.

1.8 Limitations

The main limitation was the highly summarized nature of annual reports ("summaries of summaries"), which necessitated forensic analysis of other documents and frequent follow-up with FP leaders. A possible solution to this would be initial discussion of the TORs with CRP management to identify the most useful documents. The late inclusion of FP6: Common Bean in 2019 and the lack of milestones in the 2019 POWB limited its review. The inability to conduct face-to-face interviews with partners compromised feedback.

2 Findings

2.1 Quality of Science

2.1.1 Quality of Research Inputs

Skills and diversity of teams within GLDC: GLDC is implemented through a core partnership of seven centers and three advanced research institutes (ARIs). CSIRO and CIRAD/IRD bring additional skills and experience (agri-business, socioeconomics, systems expertise, crop improvement, and genomics/genetics) and committed funds and staff time. The skills and diversity of teams vary among FPs, determined by the activities of the FP and the GLDC crop/center involved. FP1 is implemented by economists and social scientists including gender specialists. FP4 involves breeders and seed systems experts, and FP5 involves molecular scientists with skills in genetics and genomics, both supported by pathologists, entomologist, physiologists, and statisticians. FP3 has a diverse skill base including pathologists, entomologists, agronomists, animal scientists, tree scientists, modelers, and systems scientists. The skill sets are appropriate for the activities planned in each FP. FP3 maintains a systems philosophy and approach; FP4 is involved in seed systems for a number of crops and countries; and FP1 works within a systems context in foresight, priority setting, enabling environments, and potential for scaling activities. However, integrated agri-food systems thinking across GLDC is limited, at least partly owing to the non-funding of FP2. An analysis was done of diversity by institute, geographical location, and gender of teams within each CoA and FP (Annex 5a). This is a reflection of Window 1/Window 2 (W1/W2) funding only and does not address the wider diversity of teams across the entire program. Most institutes listed are core partners. Again, diversity is somewhat determined by the activities of the FP and CoA, the main focus region, and the crop involved. **Overall, FP teams are appropriately diverse according to partner institutes, geographical locations, gender, and the needs of each FP and research activity.**

Skills and diversity of GLDC partnerships with other CGIAR partners: Partnerships with other CRPs are listed in Table 9 of the 2018 and 2019 ARs, although the latter also combines partnerships with other CGIAR Centers. In fact, there is confusion among FP leaders as to whether a partnership is with a center or a CRP, which detracts from the Phase II portfolio integration philosophy. FP1 works closely with PIM on IMPACT and whole farm modeling and with the CGIAR Collaborative Platform for Gender Research. FP3 partners with MAIZE; WHEAT; and Roots, Tubers, and Bananas (RTB) on the development of Sustainable Intensification Indicators and Framework and on combining farm-level models with agent-based models to assess trade-offs and synergies across scales. It partners with ILRI on a USAID-funded crop-livestock value chain project in West Africa. FP3 also partners with CCAFS on remote sensing, modeling, and management practices, but this is not highlighted in the ARs. FP4 and FP5 work with the Excellence in Breeding Platform (EiB) for modernizing plant breeding through innovation in product profiles, phenotyping, genotyping, and drones (EiB, 2020) and with the Genebank Platform to access novel crop diversity. FP4 partners with the Big Data Platform on the Digital Seed Road Map to support seed systems activities and with ILRI on improving fodder quality of sorghum, pearl millet, and groundnut. FP4 also partners with A4NH for biofortification of pearl millet and sorghum. The importance and significance of these partnerships are addressed in Section 2.4.5.

Skills and diversity of GLDC partnerships with external partners: Both the 2018 and 2019 ARs highlight key partnerships for specific activities that complement those described above. Examples include a synthesis of impact studies and scaling approaches with the University of Wisconsin; testing of soybeans

to identify high-yielding drought- and disease-tolerant varieties for agroecologies across Africa, including Mozambique, with the Soybean Innovation Lab and Syngenta Foundation; research on sustainable intensification framework and sustainability assessment between ICRISAT, ICARDA, WUR, and SLU and NARES in SSA and SA; testing and delivery of CRP-GLDC crops with crop network groups (CNGs), ADVANTA Seeds, and Syngenta Foundation and enhanced engagement with seed companies through ICRISAT-HPRC and food industries in Asia and ESA; SNP genotyping with Intertek and drone-based imaging indices with HIPHEN; access to cutting-edge technologies like gene editing and training in sorghum and pearl millet from Corteva AgriScience; and help from private and public sector partners to develop rapid generation technology in sorghum and pearl millet for accelerated varietal delivery in AVISA. Finally, many publications documented in the bibliometric analyses (Annexes 5b, 5c) also demonstrate skills and diversity in external partnerships. **The skills and diversity of the above partnerships add value and enhance the ability of GLDC to address its objectives throughout the program.**

Availability of funding: The limited nature of W1/W2 funding, much of which is used to pay the salaries of scientists, has no doubt compromised the scientific inputs to research in all FPs. The most serious gap is the lack of agri-business research skills created by unfunded FP2. Some FPs—e.g., FP5 for the development of tools and technologies—have addressed the lack of sufficient scientific personnel by using PhD students. The availability of Window 3 (W3)/bilateral funds is largely determined by the funders who have their own priorities.

2.1.2 Quality of Process (including Partnerships)

Effectiveness of the proposed partnership strategy: GLDC is implemented through a multitude of internal (e.g., CGIAR and ARIs) and external partnerships (e.g., regional fora and subregional organizations [SROs], NARES, NGOs, ARIs, farmer producer organizations [FPOs], and private sector companies). External partners complement the skills of the internal partners and broaden the diversity of teams. Most external partnerships are supported by projects funded through W3/bilateral funds. Some are supported by the Innovation Fund. New partners are sought depending on the needs of the project. Many external partners are long-standing from pre-CRP and Phase I CRP periods. The approach is to use the skills available within GLDC and seek partners for complementary skills. Overall this strategy appears to be effective in terms of generating outputs that contribute to sub-IDOs and IDOs.

However, GLDC has not explicitly analyzed its comparative advantage with regard to alternative suppliers. This could hamper its choices of the most valuable partners to meet its objectives. That said, the centers collaborating in GLDC have a long history of productive and well-regarded external partnerships. This provides GLDC with credibility to attract new partners who can contribute necessary skills where GLDC does not have a comparative advantage—e.g., development NGOs, agri-businesses partners, and scaling partners. GLDC acknowledges that scaling out innovations depends on forming good partnerships with these groups, and the effectiveness of this strategy is clear from the achievements in seed systems (see "deep dive on seed systems" in section 2.2.2). **However, the lack of funding for FP2 has seriously compromised the forming of partnerships for scaling out innovations in agri-food system development.**

Managing partnerships and conflicts of interest: The transition from Phase I to Phase II CRP development involved the merger of three CRPs: GL, DC, and DS. The process was difficult and prolonged and required external input for resolution. Several dryland crops were dropped from the portfolio based on economic and agroecological priorities, and there was a perceived lack of transparency in some interactions with ICRISAT. As a result some core center partners are less than content. **Although such conflicts of**

interest take time to resolve, not enough attention seems to have been given to this. Underlying feelings of resentment should be addressed.

GLDC has cross-checked its priorities with the strategies and priorities of SROs and regional fora as SROs are important in scaling out benefits from GLDC interventions within similar agroecological zones to neighboring countries. Mixed feedback was received from discussions with FP leaders and core partners on the level of involvement of NARS partners during project development and implementation. **The overall assessment was that more effort should be made to take full account of external partner equity and activities.**

Research transparency and procedures: Management of the research processes in GLDC occurs at two levels: program direction and management, and FP/CoA levels. The main input from the PD is through approximately bimonthly Research Management Committee (RMC) meetings, the Annual Review Meeting, and interactions with FP leaders (see section 2.2.3). The Annual Review Meeting is the most important interaction for FPs in the research process, as priorities and work plans are set for the following year. Decisions are made on dropping or enhancing activities based on the likelihood of achieving outputs, delivering milestones, and contributing to sub-IDOs. Budget allocations to activities are also made. **Although some concerns were raised about the early processes used, there was general consensus across FP and CoA leaders that the current system is fair and transparent.** Mentoring and training of junior researchers is an integral part of GLDC, mainly through the involvement of PhD and MSc students in research projects. Although few of them are likely to become partner center staff, the capacity built enables national systems to grow and prosper. Internal reviews of staff performance are done at the center level and not through GLDC.

2.1.3 Quality of Outputs

Quantum and quality of research publications (Annex 5b, 5c): The quantum and quality of research publications were analyzed using the QoR4D Framework for scientific credibility (ISI journal IF, number of citations, altmetrics, and h-index); legitimacy (acknowledgement of coauthors); and relevance (significance of research and international public goods [IPG] rating) for publication lists provided by GLDC for 2017–2018 and 2019. The two groups of publications were analyzed as two separate pools owing to bias against more recently published papers if combined. During 2017–2018, GLDC produced 252 peer-reviewed publications, of which 62 percent were in International Scientific Indexed (ISI) journals and 63 percent were open access (Table 6, AR 2018). Sixty-six papers published in 2017/2018 from GLDC research generated at least 5 citations (Annex 5b). Twenty-four papers attracted 20 or more citations; some attracted more than 50 citations. Altmetric scores on highly cited papers showed significant interest. Generally, journals with higher impact factors (IFs) are molecular breeding, genetics, and plant breeding journals, where scientists in FP4 and FP5 publish. Journals that cover disciplines relevant to FP3 tend to be lower-IF journals with some exceptions, such as remote-sensing journals and agronomy journals such as *Field Crops Research*, while papers from FP1 in economics and social science journals generally have lower Ifs, with the exception of *Food Policy* and *World Development*. In 2019, GLDC produced 80 peer-reviewed publications, of which 85 percent were in ISI journals and 75 percent were open access (Table 6, AR 2019). Forty-one papers published in 2019 from GLDC research were sampled based on a combination of citations/almetrics and journal IFs (Annex 5c). Sixteen papers attracted acceptable levels of citations/altmetrics for their ages. **External recognition of GLDC publications is clear from the number of citations, altmetrics, and h-indices of the first authors reaching high scientific and academic quality standards.**

The h-indices of first authors indicate good international peer recognition through citations. This metric measures both quality and quantity of publications. An h-index of 20 or more is good, 40 excellent, and 60 outstanding (see *https://bitesizebio.com › does-your-h-index-measure-up*). Annexes 5b and 5c show a notable number of first authors with h-indices greater than 20 (17 and 12 publications in 2017–2018 and 2019, respectively) and some higher with h-indices more than 30 (13 and 8 publications in 2017–2018 and 2019, respectively). Coauthorship of publications is also impressive for both 2017–2018 and 2019 (Annexes 5b, 5c). Within the limitations of a desk review, it was not possible to do an in-depth analysis of fairness, ethics, co-design, mutual understanding, and commitment. Legitimacy was therefore assessed by the diversity of partners, including CGIAR Centers, ARIs, universities, and NARSs, that made a notable contribution to the research that generated the publications. In 2017–2018, 77% publications were coauthored by a GLDC partner center and at least two other institutes, and only 7 publications were authored by one center alone. In 2019, 63% publications were coauthored by a GLDC partner center and at least two other institutes, and only 3 were authored by one center alone. Although both the significance of the research and the IPG value presented in the publications were evaluated subjectively, the findings make a useful contribution to the assessment of the overall quality of outputs. Significance denotes the importance and usefulness of the research findings to the problem to be solved and the comparative advantage of the team, while IPGs denote the wider value of and access to the output. In 2017–2018, 76% and in 2019, 88% publications were rated as of good to high significance. In 2017-2018, 68% and in 2019, 78% of publications were rated as making a significant contribution to IPGs.

Analysis of publications by journal IF: IFs of 3+ are considered good. The analysis was done on the 220 publications from 2017–2019. Forty-eight percent of GLDC publications are in good to excellent journals, including very high IF journals (Table 1).

Table 1. Analysis of publications by journal impact factor (IF), 2017–2019

Journal IF	% publications (220)	Examples of journals
IF = 4+	34.5	Nature Biotechnology, IF 35.7 Nature Genetics, IF 27 Trends in Plant Science, IF 14 Molecular Plant IF, 10.8 Plant Physiology, IF 5.9 Journal Experimental Botany, IF 5.3 Science Reports, IF 4.5 Frontiers in Plant Science, IF 4.3 Int. Journal Digital Earth, IF 4 Ecological Applications, IF 4.4 Remote Sensing, IF 4.1
IF = 3–3.9	13.5	Field Crops Research, IF 3.9 Theoretical Applied Genetics, IF 3.9 World Development, IF 3.9 Food Policy, IF 3.8 Land Use Policy IF 3.8
IF = 2–2.9	16.0	PLoS One, IF 2.8 G3 Gene, IF 2.6 Functional Plant Biology, IF 2.5 Agricultural Economics, IF 2.5 J. Science Food and Agriculture, 2.4 Climate and Development IF, 2.4
IF = 1–1.9	25.0	Molecular Breeding, IF 1.9 America J. Economics, IF 1.8 Euphytica, IF 1.6 Crop Science, IF 1.6 J. Agricultural Economics, IF 1.5 Plant Breeding, IF 1.3 Int. J. Agricultural Sustainability, IF 1.3
IF < 1	11.0	Int. Food and Agri-business Review, IF 0.9 Plant Health and Nutrition, 0.8

Note: 2019 data include publications from FP6: Common Bean.

Most of these papers are crop molecular prebreeding studies and molecular/breeding technology development studies (FP4 and FP5) as well as some remote-sensing studies (FP3) and technology adoption studies (FP1). Thirty-six percent of GLDC publications were in lower-ranked journals (IF <2). When analyzing journal IFs, it is important to acknowledge that different journal disciplinary groups attract different IF ranges. Journals with higher IFs are molecular breeding, genetics, and plant breeding journals where scientists in FP4 and FP5 are likely to publish. Some journals, which cover disciplines relevant to FP3 (e.g., remote sensing and agronomy) and FP1 (e.g., food and land use policy and world development) are in higher-impact journals within their disciplinary groupings. In both years, publications from FP4 and FP5 and ICRISAT are the dominant publications in the higher-impact journals, with good contributions from IITA, ICARDA, and ICRAF. Analysis of the most productive authors (Annex 5d) complements the above findings: all but one are from ICRISAT, many with h-indices greater than 30, and all work in FP4 and FP5 except for one in FP3.

Review of selected research publications from GLDC annual reports. Seventeen publications were selected from those highlighted in the 2018 and 2019 ARs (Annex 5e). These were evaluated for methodological rigor, originality, referencing, IPG value, quality of publication (IF), coauthorship, and overall quality. In all cases, methodological rigor was good to excellent (see Annex 4). Originality varied with the type of

publication—many original research articles were rated highly based on presentation of new findings or novel innovative perspectives; review papers were generally rated lower. For all publications, referencing was good to excellent. Most publications were assessed to be of broader to significant applicability for IPGs. Selected publication venues were appropriate for the research topic although the quality of journals based on IF varied widely. Most molecular breeding/genetics papers were in high-IF journals (e.g., *Nature Genetics*); a paper on analysis of cropping systems was published in the high-IF journal *Field Crops Research,* while several socioeconomic papers were published in high-IF journals (e.g., *Food Policy*, *World Development*). Coauthorship showed recognition of the contribution of the research team in most cases although five papers suggested lack of recognition of partner contributions. Overall, the quality of the 17 selected publications from the GLDC ARs was good to high. This was partly supported by citations and altmetrics.

Quality and quantum of technical publications and communication (technical notes, working papers, newsletters, manuals, guidelines): An assessment was also made of selected technical publications referenced in OICRs and other venues. Annex 5f presents the quality and relevance to next-stage users and potential for capacity building. Technical publications including research reports, project reports, working papers, conference papers, book chapters, and a leaflet were of good to high quality and suitable and usable by next-stage users. Some had significant embedded capacity development, and one generated two PhDs. Assessment of communication tools is also given in Annex 5g.

Development of physical products including varieties, digital innovations, methodologies, tools, services (Annex 5h): Science quality of physical products is embodied in the principles of scientific method. Of the various criteria used to assess quality, the credibility of usefulness was used in this case. Examples are given for each FP; a comprehensive list is provided in Annex 5h.

The efforts by FP1 in generating 10 expert reports addressing prioritization and lessons learned from Phase I predecessor CRPs are recognized as a condition for approval of GLDC and as an enabling factor for its implementation. Several of these studies provided excellent guidance for the development of the approved GLDC proposal (Orr et al., 2017a, b). During 2018–2019, the IMPACT model for foresight modeling and *ex ante* analysis for priority setting was updated in collaboration with PIM. FP1 also led the development of product profiles for prioritization of early-maturing, enhanced nutritional, drought-tolerant varieties and hybrids with resistance to pests and diseases based on end-user preferences to inform the breeding programs (FP4 and FP5). These physical products are considered to have potential and demonstrated broader applicability as IPGs.

FP3 is the most complex of GLDC's FPs as it involves research on pests and diseases, mitigation of climate stresses, natural resource management, livestock, trees, remote sensing, and modeling. Modeling and remote-sensing tools were developed to assess trade-offs and co-design farming systems for resilience and income generation, and crop system modeling tools were generated as a decision support tool to optimize G x E x M for integration in breeding programs in India. These have potentially broader applicability as IPGs. Remote sensing was used for risk area maps for chickpea and pigeon pea diseases with CCAFS. Of note, 115 sustainable intensification indicators, a platform, and a framework were developed in Burkina Faso, India, and Niger, which other CRPs are adapting for their use, demonstrating broader applicability as IPGs.

FP4 carried out a comprehensive prioritization exercise for target traits where more than 100 target traits were reduced to a manageable number of must-have traits, which was critical to the approval of GLDC. The significant effort to modernize crop breeding in GLDC through use of the Plant Breeding Program Assessment Tool (BPAT) and collaboration with EiB improved mechanization and digitization, breeding operations, and phenotyping to achieve greater accuracy and throughput at reduced cost. During 2018–

2019, 99 improved varieties of sorghum, pearl millet, finger millet, chickpea, pigeonpea, groundnut, lentil, and cowpea were commercialized in 16 countries in SSA and SA. Must-have traits were mainstreamed, including drought and heat tolerance, biofortification, and resistance and tolerance to diseases and pests based on product profiles developed by FP1. Single nucleotide polymorphism (SNP) markers developed by FP5 were deployed for early generation selection through the High Throughput Genotyping facility (HTPG) in ICRISAT, India. Speed breeding protocols (rapid generation advance [RGA]) have been deployed in chickpea, lentil, and groundnut to enhance the rate of genetic gain by increasing the number of cycles per year. Significant impact was realized through successful development of functional and sustainable seed systems in several countries, as described in nine OICRs (five covered by deep dive seed systems in section 2.2.2). CNGs were established for five GLDC crops with small and medium seed companies to more effectively integrate key stakeholders in varietal development and seed production. The successful model of the Hybrid Parents Research Consortium (HPRC) in Asia was expanded to deliver improved cultivars of sorghum in the ESA region. Gender issues were well integrated in priority trait targets and seed systems. All showed broader applicability of IPGs generated.

Most of FP5's prebreeding and trait discovery outputs feed into FP4, enhancing the effectiveness and efficiency of varietal and hybrid development. Hence although FP5 generates IPGs itself, it also generates further IPGs through the use of its tools and technologies in FP4. Significant progress was made in modernizing prebreeding and trait discovery approaches and methods in partnership with the EiB Platform. During 2018–2019, release of the first molecular-bred varieties was a key achievement of both FP5 and FP4. Marker development/deployment resulted in the generation of more than 700 K marker data points combined in all GLDC crops through the HTPG Platform for identifying quantitative trait loci (QTLs) for the breeding activities, while SNP panels for quality control were developed and partially validated in pearl millet, groundnut, and chickpea, all for use by FP4. Standardized protocols were developed, proof-of-concept in genome editing was established, and second-generation transformation was achieved with QuickCrop in collaboration with Corteva Agriscience. Finally, development of demand-led breeding approaches to generate varieties with better attributes reflecting the needs of end users, especially women, were established with the gender cross-cutting theme. All showed broader applicability of IPGs generated (Annex 5i).

2.2 Effectiveness

2.2.1 Achievement of Planned Outputs and Outcomes

Outputs are assessed by the systematic review of the milestones (MSs) in two ways. First, the proportion of MSs that were completed, extended, or canceled by FP in the period 2018–2019 are presented in Table 2 and graphically in Annex 5j.

Table 2. Percentages of Milestones Completed, Extended, or Canceled, by Flagship (2018–2019)

	# MS	Completed	Extended	Canceled	Total (%)
CRP	57	52.6%	29.9%	17.5%	100%
FP1	16	43.8%	56.2%	0%	100%
FP3	15	40%	40%	20%	100%
FP4	20	55%	10%	35%	100%
FP5	6	100%	0%	0%	100%

Note: Milestones that were added during the year, after the POWB had been finalized, are included in the totals and proportions above; percentages are rounded to one decimal point.

Second, a qualitative assessment of the MSs from the 2019 POWB was made and is presented as an annotated Table in Annex 5i showing whether individual MSs have been completed, together with a short qualitative assessment of the research.

Outcomes are assessed by the extent to which achievement of outputs (i.e., MSs) has impacted the GLDC Intermediate Research Outcome—i.e., whether ***farmers, value chain participants, and policymakers increase GLDC productivity and food nutrition in target agri-food systems***. This then relates to the GLDC ToC.

The GLDC ToC argues that ***"household-level outcomes of food security, resilience and poverty reduction depend on the ability of smallholder farmers and other actors to tackle system-level change in agri-food system regimes."*** The proposal states that for GLDC to support smallholders in overcoming challenges and capturing opportunities, **research on *crop improvement and farming systems is necessary but not sufficient***. It further claims **that *socioeconomic science, contemporary development practice, and scaling partners must be integrated* to support GLDC *beneficiaries and stakeholders.* The aim is *to unlock opportunities in the context of their differing innovation capacities and agri-food system regimes***.

The ToC is translated into a twin track impact pathway (IP):

- **The integrative solutions pathway** results in household-level outcomes by developing integrated technological, institutional, and policy solutions with key partners. The IDO for this pathway is expanded and resilient production, value addition, trading, and consumption of GLDCs in target countries.
- **The scaling and sustaining pathway** leads to implementation of five mechanisms for working with change agents to address agri-food system barriers and secure sustainable outcomes. The IDO for this pathway is improved capacity and inclusivity of agri-food system stakeholders to

collaboratively develop innovations that respond to the needs of woman, men, and youth in GLDC-based livelihoods and value chain developments.

Progress along the ToC and IPs are considered in the section below on achievements of outputs and outcomes, and in more detail in section 2.2.4 ("Progress along ToC").

Progress: Outputs and Outcomes at Program and Flagship Levels: Table 2 shows that during 2018–2019, GLDC aimed to achieve 57 MSs, of which just over half were formally recorded as completed. This apparently high rate of non-achievement was largely due to re-formulating of work objectives (and hence MSs) as the new program settled down with 29.9 percent of MSs extended, rolling over to 2020 and 2021 because of reduced funding or personnel availability and 17.5 percent known to be canceled. Table 2 also shows the overall achievement of MSs at the FP level. Further details of progress at the FP level are provided in the sections below.

FP1 is based on the premise that dryland agriculture is characterized by low adoption rates, poor market access, inefficient value chains, weak social institutions, social inequity, high risks, and degraded natural resources. Good progress has been made on the IP for FP1 that seeks to ensure that GLDC research is demand-driven, outcome-focused, inclusive, and scalable, and has a high potential for impact contributing to the Strategy and Results Framework (SRF) and the SDGs. The outputs have been strong on *ex ante* economic, poverty, and nutritional analyses ***(MS: Ex ante evaluation of GLDC research and technology options was completed, and working papers were published on the potential poverty and nutrition security impacts to guide priority setting).*** Work is in progress on varietal attributes, product profiles, and consumer demand. Groundbreaking work has been completed on aspirations of farming households ***(MS: Diversity of farm household preferences vis-à-vis market demand by context was outlined in view of research in GLDC).*** There appears to be a lack of coherence between activities on identifying research priorities on the basis of economic, poverty, and other criteria, and the activities on adoption and scaling mechanisms. Although progress on value chains, markets, and drivers of adoption is not as extensive as originally envisaged ***(MS: Evaluation documenting the strengths, shortcomings, and key lessons learned on GLDC scaling approaches and impacts was delayed until 2020***), some good progress has been made on drivers of adoption from the farmer side (aspirations) to the consumer side (urban food demand). The combination of these is embracing the agri-food systems perspective and has direct implications for improvements of the functioning of the system for GLDC crops. Overall, in 2018–2019 of the 16 MSs planned, 43.75 percent were completed, 56.25 percent were extended, and none were canceled.

FP2 was not funded by W1/W2 funds. Projects funded by W3/bilateral funds mapped to FP2 were continued to be reported in 2018 as there was still hope of obtaining funding, but not in 2019. Lack of W1/W2 funding to FP2 reduced its ability to leverage funds from agri-business partners and to address integration with other FPs as originally planned. In 2019 the cross-cutting theme Markets and Partnerships in Agri-Business (MPAB) was supported by $250k. Some activities have been initiated, and it is hoped that bilateral funding will be invested by 2021. The originally proposed ***focus*** on GLDC agri-food systems is hardly observable. Related activities have continued as planned under ICRISAT's Agri-business Innovation Platform. Availability of planned funding for FP2 would have strengthened GLDC's coherence, adding value to cross-CRP integration.

FP3 planned to work in close cooperation with partners to a) design, test, and scale improved crop-tree-livestock management options; b) increase the productivity, agro-biodiversity, and climate resilience in farming systems; c) manage and conserve the natural resource base; and d) work with FP1/FP2 in the use of an Innovation Platform approach for value chain enhancement. Thus, FP3 sought to understand how farming systems can accommodate GLDC crops in response to growing market demand and

contribute to a range of ambitious development outcomes. A series of participatory field studies designed to optimize aspects of the integrated farm management of GLDC crops were undertaken in India and nine African countries (***MS: Farm-household typologies were characterized, and participatory field trials under smallholder conditions in different cropping systems were evaluated for common and type-specific determinants of adoption of innovations, intensification, and diversification***). Their results are being used to develop trade-off analysis/household models to contribute to equitable enhancement of livelihoods of poor farmers ***(MS: Ex post impacts of innovation practices on crop production efficiency and household livelihoods were measured).*** These are useful studies leading to a greater understanding of farm-level issues as listed in the FP3 plan as summarized above. They appear to be conventional studies focusing on factors such as "economic returns," "benefit-cost ratios," and "means to optimize genotype x environment x management." There is little sense, however, that the wider aspirational issues, such as the agri-food system or contemporary development practice (with the exception of gender), feature in the FP's strategic thinking (as discussed below in relation to the CGIAR SRF). FP1's study on farmers' aspirations would surely be relevant here. Regarding progress on the FP3 IP, the outputs noted above all potentially contribute to the higher-level objectives listed in the IP. Overall, in 2018–2019, of 15 MSs planned, 40 percent were completed, 40 percent were extended, and 20 percent were canceled.

FP4 is the mainstay of GLDC crop improvement research. It is premised on the concept that resilient varieties and hybrids, together with enhanced access through strengthened seed systems, will contribute to inclusive livelihood opportunities for smallholder agriculture and improved economies. FP4 contributes through higher productivity, market-oriented products, and entrepreneurship. FP4 has prioritized four trait clusters: a) productivity improvement that targets genetic gain, grain yield, and resilience traits; b) resource-use efficient and crop architecture traits; c) traits demanded by markets; and d) traits that support agri-food system performance. Is there evidence to support the achievement of these goals? As with FP3 above, substantial studies, especially on seed systems, have been completed that impact targets designed to improve the livelihoods of poor people (***MS: New suite of resilient varieties was released by NARS partners [Phase 1 investments start being released]***). Seed system studies are at the heart of the CGIAR's comparative advantage in agricultural research for development, and all the indications are that the FP has been productive, particularly in the first and second set of the prioritized clusters listed above. Breeding to biofortify GLDC crops to boost their content of essential micronutrients features prominently, directed by product profiles from FP1 (***MS: New varieties with enhanced nutrient levels (Fe, Zn, oil, protein, high oleic) were developed***). Further, excellent work has been completed to develop and commercialize high-oleic groundnuts (***MS: delivered—see above***). Further information is needed on wider consumer/market acceptance issues (e.g., cooking, storage, organoleptic factors) that have a major impact on the acceptance of new varieties in the wider agri-food chain. The FP has made good progress toward the sub-IDOs in its IP on productive and profitable varieties. The absence of FP2 limits the impact of FP4 to the left-hand side of the IP (farm households). Overall in 2018–2019, of the 20 MSs planned, 55 percent were completed, 10 percent were extended, and 35 percent were canceled.

FP5 focuses on exploiting untapped genetic resources of wild relatives of GLDC crops by developing and using cutting-edge tools and techniques for trait discovery and accelerating realized genetic gains. More specifically, the key objectives are: a) to widen the genetic base of GLDC crops; b) to provide an extensive tool kit of modern techniques for efficient breeding of GLDC crops. These activities are designed to Increase the productivity of GLDC crops on the premise that increased agricultural productivity contributes to improved food and nutritional security and reduced poverty in smallholder farming communities. Since most of the FP5 activities feed into FP4, FP5's contributions to GLDC's overall

impact on SDGs and SLOs are represented by FP4. FP5 has been very active. The volume and quality of its output are high, and several success stories recorded for FP4 relate to work done by FP5. Thus, FP5 appears on top of its game in terms of utilizing the latest technical tools to provide GLDC varieties with appropriate characteristics***.*** The links with FP1 and FP4 help develop the list of desirable characteristics for FP5 to prioritize. However, FP5 still talks predominantly **about breeding of new varieties, targeted to achieve higher productivity and quality produce in farmers' fields**. While productivity and quality are necessary, other factors must also be considered to meet the full range of outcomes required if wider contemporary development ambitions are to be fulfilled. FP5 has been active in training courses, PhD projects, expert consultations, and workshops and is commended for this. FP5 IP lists 2 IDOs. First, it has increased productivity based on collaboration with FP4, which has been strong and productive. Second, in terms of capacity developed, FP5 has also been highly productive. Capacity building is a CGIAR SLO in its own right. (***For 2019, 3 MS were delivered: a) development/refinement of technologies for overcoming barriers to wide crosses for 1 crop; b) precision phenotyping for key traits for these collections and genotyping to identify novel alleles for 2 traits in 2 crops that have limited variability in breeding populations; and c) network of precision phenotyping sites established across GLDC crops to provide unique and relevant testing locations for key traits.)*** Overall in 2018–2019, of the 6 MSs planned, 100 percent were completed.

FP6 was added to the GLDC 2019 but was not and will not be integrated into the main program owing to time constraints. FP6 has a distinctive value chain approach in SSA and is founded on a mature network: the Pan-African Bean Research Alliance (PABRA). It has performed well and has the potential to generate significant benefits for poor people. The value chain approach also has considerable potential for cross-FP learning within GLDC activities. Of note, FP4 is assessing PABRA as a model for the development of crop network groups.

Strategy and Results Framework (SRF): GLDC was developed as a second-generation CRP in the light of the CGIAR 2016–2030 SRF, which lists the System's aspiration in Phase II CRPs to ***"do things differently."*** Thus, in addition to assessing GLDC's achievement of its planned MS outputs and related outcomes (see above), an additional assessment is made in Table 3 on how GLDC has fared with the "***things***" it set for itself "***to do differently,***" as described in the SRF and reinterpreted in the original GLDC proposal. In this regard, the SRF stresses that establishing new research building on existing CGIAR strengths is relatively easy, but ***doing things differently***, such as by adopting an agri-food systems approach, is more difficult. The report returns to these issues in later sections.

Table 3. Have the aspirational issues of GLDC as a Phase II CRP been accomplished?

	Individual flagship program							CRP
Aspirational issue	FP1	MPAB	FP3	FP4	FP5	FP6	GLDC	Aspirational issue
Coherent and integrated portfolio	Yes	No	Partly	Yes	Yes	Yes	Partly	Coherent and integrated portfolio
Crop improvement/ farming systems	Yes	No	Yes	Yes	Yes	Partly	Yes	Crop improvement/ farming systems
Working with agri-food supply chain	Partly	Partly	Partly	Partly	No	Yes	Small part	Working with agri-food supply chain
Socioeconomics, contemporary development practice, and scaling partners integrated	Yes	Partly	Partly	Partly	No*	Yes	Partly	Socioeconomics, contemporary development practice, and scaling partners integrated
Equitable gender access	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Equitable gender access
Aspirational issue	FP1	MPAB	FP3	FP4	FP5	FP6	GLDC	Aspirational issue

*FP5 partly addresses this aspirational issue through FP4.

2.2.2 Demonstrated Importance of Outcomes (Deep Dive on Selected OICRs)

One deep dive was conducted on five OICRs on seed systems, and a second was done on the role of agri-food supply/value chains and wider development issues in the context of GLDC (Annex 6a, b).

Deep dive on seed systems: From the OICRs included in the 2018 and 2019 ARs, five on seeds systems (four on grain legumes and one on dryland cereals) were selected for a deep dive (Annex 6a) through a combined analysis. The data was derived from ARs, publications generated by the OIRCs, and feedback from interviews with GLDC scientists involved in the projects as well as the Bill and Melinda Gates Foundation, which funds much of this research. The existence of viable and sustainable seed systems supported by institutions, markets, and policies is fundamental to addressing farmers' access to quality seed and consumers' access to quality grain. In this context, the OICRs on seed systems contribute directly to three of GLDC's IDOs—improved diets for poor and vulnerable people; increased incomes and employment; and increased productivity—and indirectly to increased resilience of the poor to climate change and other shocks through improved varieties with drought and heat tolerance. All five OICRs documented at least some of the following measurable outcomes: increased adoption of improved varieties; increased area planted; increased productivity; increased income to farmers; good market access and growth; increased welfare and reduced poverty incidence; and significant economic benefits (Annex 6a). Engagement with cross-cutting issues was demonstrated in all, including attention to gender-preferred traits and commitment to participation of women as seed producers and users; targeted capacity building of different seed-producing models; acknowledgment of the role of grain legumes as environmentally friendly technology (drought tolerant; nitrogen fixing) for poverty reduction; and intensive engagement with partners including NARES, the private sector, and key institutions such as

national seed regulation bodies and, for chickpea in Ethiopia, the Ethiopian Commodity Exchange (Annex 6a). Also of note, the multistakeholder platform EthioPEA Alliance was crucial in developing the chickpea value chain, including farmers, seed producers, extension agents, and quality control actors, and export grain aggregators in Ethiopia. Owing to the time lag in developing improved varieties, it is inevitable that all of these OICRs involved research preceding the current CRP cycle with maturity levels 2 and 3.

Successful adoption of innovations depends not just on the right technologies but also on functional institutions, markets, and policies—the enabling environment (Annex 6a: Orr, 2018). These five OICRs clearly show that identifying market demand correctly, working with innovative institutions/models to overcome constraints in production and delivery of improved seed, and the existence of conducive policies to support seed systems are integral to their success in the context of GLDC's work. It is also fortunate that predictable funding largely through bilateral projects was available to support the work, and reliance on reducing W1/W2 funding was unnecessary.

Importantly, lessons were learned from these OICRs which can now inform future seed systems research, including the value of small seed packets to reach many farmers; building on past projects such as Tropical Legumes I, II, and III; the value of innovative partnerships; and the importance of a functional extension service for grain legumes and the private sector for cereal hybrids. In addition, the analysis of these studies identified a number of areas that require further research. These included the need **to better understand farmer demand for quality seed** (Annex 6a: Almekinders et al., 2019); **to improve understanding of why and under what circumstances farmers decide to adopt improved varieties** (Annex 6a: Glover et al., 2019); **to better understand market preferences** (a reflection of unfunded FP2); **to have models for scaling up technologies for delivery**; and **to better understand the key factors contributing to the establishment of sustainable seed systems.**

Deep dive on agri-food supply/value chains: GLDC's OICRs for 2018 and 2019 are limited in scope and almost entirely focus on the impact of breeding improved varieties and establishing functional seed systems. The CGIAR 2016 SRF and the original ToC/IPs in GLDC (see section 2.2.1) aspired to a rather broader agenda, arguing that while crop improvement/farming systems research is necessary, it is insufficient to fully meet the CGIAR higher-level development outcomes. It was argued that in the new generation of CGIAR CRPs it is important, *inter alia*, a) to consider the agri-food-system as a whole and particularly agri-food supply and value chains, and b) to integrate socioeconomic science, contemporary development practice, and scaling partners. Thus, the second deep dive focused on the extent to which these aspirational issues a) were included in the planned activities, b) were undertaken in practice, and c) impacted the achievement of outputs of the program, including the impact on higher-level development objectives (see Annex 6b for a full report).

The original thinking as incorporated in the GLDC ToC and IPs states that in ***Pathway One****,* GLDC research will lead to ***household-level*** outcomes, whereas in ***Pathway Two***, GLDC will implement five mechanisms for working with ***change agents to address agri-food system barriers*** and secure sustainable outcomes. Thus, in broad terms, this second deep dive will consider ***Impact Pathway Two,*** which, as defined in the proposal, is dependent on the program ***delivering outputs concerning agri-food supply/value chains and wider development issues.***

In GLDC overall, FP2 was intended as the main instrument where research on agri-food supply/value chains and wider development issues would be undertaken. A role for work on these issues was also envisaged for FP1 as this FP was designed to ensure that *GLDC conducts inclusive, demand-driven research that responds to household and smallholder farmer needs, market demand, and local and national priorities*. The results of the activities under FP1 and FP2 were to inform the activities under FP3, FP4, and FP5, giving them a wider value chain/contemporary development agenda focus. In 2019 FP6

was added to GLDC. FP6 is to a large extent concerned with agri-food supply/value chains and wider development issues. It is therefore interesting to compare and contrast these activities with those planned/actually undertaken by the original GLDC CRP (see Annex 6b).

What actually happened during 2018 and 2019? Despite the best endeavors of GLDC, FP2 was not approved or funded when the program was approved. This rather tears the heart out of the right-hand side (Impact Pathway 2) of the GLDC IP and severely constrains the application of the associated ToC. The consequences of this are discussed below. In an attempt to mitigate the consequences of lack of funding for FP2, the cross-cutting theme Markets and Partnerships in Agri-Business (MPAB) was established in 2019. MPAB explored emerging market opportunities through a portfolio of scoping studies, with stakeholder engagement as a means to develop new funding proposals. Progress on the scoping studies to date includes a) implications of Kenya's sorghum and millet composite flour policy, b) future studies on GLDC crops as functional foods, c) neighborhood/food movement effects as a potential mechanism to change food habits, and d) a pilot study on sorghum fodder enterprises. The funding requested for the original FP2 research in 2019 was $12.3 million. The actual spend on MPBA in 2019 was $250k. Thus, this cross-cutting program barely compensated for the absence of FP2.

In the context of this deep dive, very relevant work has been undertaken in FP1. However, the focus and potential usefulness lie more in integrating socioeconomic science, contemporary development practice, and scaling partners than on agri-food-systems, although this is likely to contribute in the future. Key topics of relevant research include a) "aspirations" and "drivers" behind "farmers' strategies" for improved livelihoods, b) a review of an existing GLDC scaling framework, c) a review of 18 previously published impact studies of GLDC crops, and d) the development of a CRP-wide impact-evidencing working strategy (see Annex 6b).

The original thinking in GLDC was that crop improvement activities in FP4 and 5 would be driven by better understanding of the "market", "value chain," and "customer requirements" by FP2. With the non-funding of FP2, this was not possible to the extent originally envisaged. Hence their focus has been limited. This is not to diminish the important role that the product profiles emanating from FP1 play in the work of FP4 and 5. However, these profiles, based on *ex ante* studies, starting with economic issues and then expanded to capture key poverty and nutritional attributes of GLDC crops, while useful, cannot substitute for a concentrated and dynamic focus on the agri-food system as a whole.

In contrast FP6 has a distinctive value chain/bean corridor approach working across SSA. The successful national and regional value chain approach has much to commend it. In addition, its ToC includes an innovation platform approach and has a clear philosophy of subordinating the role of CIAT (the implementing center) to that of local partners/NARSs. There is much potential for cross-fertilization of ideas here between FP6 and the rest of the GLDC.

What key lessons were learned? For reasons explained above, a different approach was agreed for the current deep dive in that the focus was on how a cluster of issues considered important in the original GLDC proposal and in the 2016 SRF were followed through in subsequent program activities. GLDC is only in its third year and still evolving with an added FP6. While accepting that it is still early days for the program, it seems that the new paradigm for the Phase II CRPs, as encapsulated in the original GLDC proposal and in the 2016 SRF, is not yet prominent in FP3, FP4, and FP5. The 2016 SRF said it ***was going to be difficult***, take more time, and need reskilling if the CGIAR was going to move from its traditional strengths such as commodity breeding toward a systems approach. This, indeed, seems to be the case.

2.2.3 CRP Management and Governance

Management of GLDC is vested in a part-time program director (PD) (20 percent time allocation), part-time FP leaders (40 percent), and a full-time program manager (PM) in the Program Management Unit (PMU). The PD is also the ICRISAT DDG-R. The PD chairs the Research Management Committee (RMC), composed of 16 members including four FP leaders; gender and youth focal, capacity development and monitoring, evaluation, and learning focal points; six center focal points (ICRAF, IITA, ICARDA, ILRI, CIAT, and Bioversity), and three partners (CSIRO, IRD, and CIRAD). Some members serve two roles. FP leaders carry out leadership, management, and research roles in GLDC. They are supported by three to four cluster of activity (CoA) leaders.

The RMC is responsible for establishing, executing, and monitoring GLDC research, strategy, work plans, and budgets for W1/W2 funds. Meetings are arranged according to need; there is no formalized schedule. Fourteen meetings were held during 2018–2019 and minutes of meetings 6–14 were made available. Meetings 6–8 are comprehensive, showing attention to major issues facing GLDC, including good evidence of PD-driven commitment to developing an integrated program. Identification and development of the most appropriate partners for GLDC and leveraging funds from the private sector were priority discussion topics. Meeting 9 was a joint IAC-RMC meeting and demonstrated both interest and interaction of IAC members in GLDC's research and execution, with clear action points for RMC follow-up. Meetings 10–14 focused largely on administration issues rather than in-depth discussions on research. **There was a lack of information on how action points from all meetings were followed up in subsequent meetings. It also seems unclear how some key action points from the joint IAC-RMC meeting, including the need for more creative and proactive engagement between FPs and the need to better articulate the added value of GLDC's multi-crop nature, were addressed.**

Interviews with FP leaders provided additional feedback on the effectiveness of management processes and direction. Generally, management provides more guidance for FPs 4 and 5 leaders based in India but less so for FPs 1 and 3 leaders in SSA. Outside of the RMC meetings, FP leaders interact frequently with CoA leaders either through regular meetings or *ad hoc*. Interaction between FPs 4 and 5 has the advantage that both leaders are based in ICRISAT, India. **The geographical distance between FPs 3 and 4 leaders has limited interaction between breeding and agronomy and crop systems research, a situation that needs to be improved.**

GLDC functions with two funding streams. More than 80 percent of the funding is from mapped W3/bilateral projects for which core centers—ICRISAT, IITA, ICRAF, ICARDA, CIAT, and Bioversity—are responsible to funders. An apparent lack of linkages between major donors who fund according to their priorities further complicates the funding situation although two major donors—BMGF and USAID—are planning closer links. GLDC management has direct responsibility for only W1/W2 funds—less than 20 percent of the program budget. Under this complex scenario, it is a huge challenge to build a coherent, integrated project portfolio. A better description of GLDC would be a loosely packaged project portfolio organized into a logical structure of FPs.

GLDC is well administered, with timely reporting and control of finances. Program management supports day-to-day operations as demonstrated by program management documents. Overall, the RMC minutes demonstrated that program effectiveness is enhanced by its monitoring of work plans and its administration but less so by program integration. **FP linkages and portfolio coherence and integration would benefit from enhanced engagement between them and facilitated by an enhanced time allocation to the PD. Other CRPs such as RTB have shown that it is possible for the PD to have a greater role in facilitating and guiding the direction of W3/bilateral funds under a coherent program vision. If the PD had a greater role, it would also enhance**

ownership of GLDC as opposed to center ownership of individual projects. Currently this is impossible for a PD with only 20 percent time allocation. This issue is discussed in more detail under governance.

GLDC is governed by an Independent Advisory Committee (IAC) with 12 members, which include seven non-CGIAR members and five ex officio CGIAR members. One of the ex officio members is the lead center DG. The main functions of the IAC are to advise the ICRISAT Governing Board on relevant GLDC issues; to assess the overall performance of GLDC; to advise on partnerships; and to review the principles that guide resource allocation (W1/W2 funds). The IAC met four times during 2018–2019 with two mandated meetings each year. The minutes of these meetings demonstrate engagement with and interest in GLDC's research and accomplishments, but two key programmatic issues that have implications for GLDC effectiveness have not yet been effectively resolved.

First, GLDC was approved in late 2017 without approval of its functional heart, FP2. The lack of funding to FP2 was discussed in the IAC during 2018. Much effort was made by the PD and the chair of the IAC to secure funding. Action points were acted upon: a) to write to the SMB chair for reconsideration of FP2, and b) to advise the ICRISAT Governing Board to consider FP2 as a cross-cutting initiative. FP2 remained "in limbo," and the MPAB theme, with $250K from W1/W2, was established in 2019 with FP2 intent. Although management and governance considered that MPAB and strengthened activities in FP1 would be enough to meet the needs of other FPs, the current agri-food systems thinking across GLDC does not support this. **Although the joint IAC/RMC meeting (November 2019) agreed to make the ToC more explicit to the current situation, neither the ToC nor the Impact Pathways have yet been modified to reflect the gap left by unfunded FP2. Furthermore, the implications for other FPs in implementing approved objectives predicated on the existence of a functional FP2 have not been sufficiently addressed. It appears that GLDC has been in operation for more than two years with a ToC and impact pathways that do not accurately reflect its current activities.**

Second, serious reservations were raised by the ISPC on the time allocation to the GLDC director ("the role of the CRP director cannot be adequately met with just 20% of the time of the ICRISAT DDG-R. . . . cost-saving should not be used as a criterion alone") when GLDC was approved. AR 2019 recognized this as a risk to GLDC and recommended "an increase in the Director's engagement with focal points and partners." The IAC continued to review this issue during 2018–2019. A briefing paper was prepared recommending that consideration be given to increasing the time allocation to 40–50 percent to address the specific tasks of enhancing program integration and efforts to integrate W3/bilateral funding. This was not acted upon until November 2019, when it was referred to the ICRISAT Governing Board for decision in 2020. The decision has not yet been made. **Again, it is considered that 20 percent time allocation for the PD is not sufficient to direct the most complex CRP in the CGIAR portfolio (9 crops, 10 core partners, and 17 target countries) and especially for the important tasks of maintaining rich and productive interactions between FPs, integrating the two funding streams, and fostering partnerships to leverage funds with drive and passion.**

2.2.4 Progress along ToC (CRP and Flagships)

The ToC and original IP were discussed in section 2.2.1. With FP2 unfunded, much of the thinking in the original ToC and "Scaling and sustaining pathway" IP has been largely invalidated. It is possible that if technologies developed in the GLDC had had this pathway available for impact, then they could, in time, have had greater impact on development targets within a wider agri-food systems context, as they have for seed systems. No attempt has been made formally to revise the original ToC/IP in the light of the funding decision. The fact that the ToC/IP was not revised is not ideal, but since the ToC has two IPs,

there is a pragmatic solution. The other "Integrating solutions" IP is functioning, and it is possible to make an assessment of progress along this pathway. The research activities of GLDC in 2018 and 2019 have been significant for a total budget of $121.3 million. How have these ***research activities*** been translated into ***research outputs*** ("control"), and how have these ***research outputs*** contributed to ***Intermediate Development Outcomes*** ("influenced by") and then impacted ***System-Level (Development) Outcome****s* ("interest")? Although the CRP has *direct control* only over ensuring the research outputs are achieved, *the extent of the actual impact* of such research outputs ***on development targets*** will depend ***how are well thought through*** and appropriate the design of the research was ***in addressing the particular development target***. Given that GLDC consulted with over 7,000 different stakeholders, including all relevant SROs at the time of design, research ***should*** have been appropriately targeted and designed, but did it take account of the aspirational "***doing things differently"*** agenda? (See section 2.2.1 and Table 3).

Progress in 2018 and 2019 toward meeting GLDC CRP targets: **Intermediate (research) Outcome level:** This target requires *that woman and men, farmers, value chain participants, and policymakers increase GLDC productivity and food nutrition in* ***target agri-food systems***. It is credible to assert that the research outputs listed have impacted the productivity of farming households in the target GLDC areas. It is less certain that with the exception of seed systems (see Annex 6a), such benefits have to date reached value chain participants beyond the farm gate, certainly at any scale. This does not rule out such impacts in the future. Consumption of GLDC crops is likely to have increased in targeted GLDC areas, but more structured studies are needed to verify this. Prediction of positive nutritional consequences from greater availability of biofortified crops is notoriously difficult, and GLDC needs to work more closely with A4NH to address this.

End of CRP (research) Outcome level: This target *requires expanded and resilient production, value addition, trading, and consumption of GLDC in* ***target countries***. It requires that the impact that is asserted above at the household level as a result of GLDC activities has been scaled up to the country level by the end of the CRP. There have been no studies to date to determine whether this target is likely to be met, but there have been discussions within GLDC concerning the need for programwide impact studies.

Intermediate Development Outcomes (IDOs) level: GLDC's IDOs are a) increased resilience to climate change; b) Improved diets for poor people; c) more sustainably managed agroecosystems; d) increased incomes and employment**;** and e) increased productivity. At this level, with the absence of well-designed impact studies, the assessment moves away from being evidence-based into assertions and probability. Impact studies on seed systems have shown measurable contributions to the IDOs (Annex 6a). More impact studies and evidence are needed to assess the level to which productivity has increased and the extent to which it has contributed to other IDOs. FP3 has reported successful research activities leading to more sustainably managed agroecosystems, but further documentation of the spread is needed. FP4 and FP5 have reported achievements in releasing improved varieties that *have the potential* to increase the resilience of the poor farmers involved to climate change and other shocks. However, in part, it is *unfair to the researchers* even to pose the question in a program that has only been in operation for two years when it is recognized that development of such outcomes takes many years, if not decades. Issues concerning improved diets were discussed earlier. And as mentioned above, GLDC needs to work more closely with A4NH to better understand the complex social, economic, educational, and consumer preference issues that will lead to improved diets of poor people and reduced malnutrition.

CGIAR System-Level (developmental) Outcomes level: For the CGIAR System as a whole, the highest-level targets are a) reduced poverty; b) improved food and nutrient security for health; and c)

improved natural resources and ecosystem services. GLDC contributes to, but does not have control over, these. The further away from actual research outputs the target becomes, the more difficult it is to provide an opinion on impact without specific evidential studies. Thus, the thrust of the comments regarding the levels of uncertainty made above apply here. However, it is pertinent to reflect on the issues that *contemporary development thinking* suggests are necessary in designing agricultural research if maximum development impact on poor people is to be achieved over time. A full list of such matters can be debated, but there seems to be a consensus for inclusion of a number of issues in such a list, including, by way of example, the need for research to a) be participatory; b) consider the full range of stakeholder drivers and aspirations; c) consider the agri-food system as a whole; and d) fully involve scaling partners in the research. The relevance of raising these issues is to express interest in the extent to which they have been factored into the design of GLDC research flagships as a matter of course and hence whether or not the excellent research outputs of the program have the maximum potential to bring about development outcomes.

2.3 Future Orientation

It is clear that the complexity of GLDC (merging 3 Phase I CRPs resulting in 9 crops, 10 core partners, and 17 target countries) and the difficulties in managing two funding streams have affected its ability to deliver its objectives as effectively and efficiently as would have been possible with a simpler structure and integrated funding. One could argue that all CRPs have faced similar difficulties but not to the extent that GLDC has. In the context of future orientation, these findings are more relevant to the CGIAR System as a whole rather than to GLDC alone. Within the CGIAR Phase II portfolio, two FPs are unique in each being entirely supported by one funder—FP2: HarvestPlus in A4NH and FP6: Common Bean in GLDC. Both are also noted for their achievements, some of which were highlighted in this report for FP6. **This model should be given serious consideration by the SMB and SMO in the forthcoming One CGIAR.**

Since its inception, GLDC has been constrained by the lack of funding for FP2 and limited adaptation to the implications of this funding shortfall for the rest of its FPs. Its level of integration has been compromised, the original ToC is not appropriate for its current operations, and the IP on "Scaling and sustaining" is largely not functioning as it was conceived. A rethink on its structure and FPs roles should have been implemented in early 2019. GLDC has been implemented as groups of projects producing high-quality research outputs packaged into a logical structure of FPs. It is designed as a pragmatic solution to the problem of two different funding streams—W1/W2 and W3/bilateral—and multiple funders. Notwithstanding, there are good examples of FPs working well together: e.g., FP1 with FPs 4 and 5 on product profiles, FP1 with other FPs on priority setting, and FPs 4 and 5 on breeding activities. There are also good examples of potential future contributions to the program's IDOs (improved diets for poor and vulnerable people, increased incomes and employment, and increased productivity and increased resilience of the poor to climate change and other shocks), which are referred to throughout this report. **However, for GLDC to clearly articulate its true potential future contribution, it needs to modify its ToC and Impact Pathways to seriously reflect its current operations without a functional FP2. It can then make realistic projections on the likelihood of ultimate delivery of outcomes and contributions to sub-IDOs and IDOs.**

The decision to terminate the Phase II CRPs one year early is already being addressed by GLDC. At the 2019 Annual Review meeting, decisions were made to give further support to research activities with potential for success by the end of 2021 and to de-emphasize less promising activities. However, the timeframe is short, and as one FP leader noted, there is time only for one more season for research

activities in West Africa. It is commendable that the IAC is already discussing how best to position GLDC for an active role in One CGIAR.

2.4 Cross-cutting Issues

Cross-cutting issues include capacity development, gender and youth, climate change, and partnership effectiveness.

2.4.1 Capacity Development

GLDC shows a clear commitment to capacity development throughout most research activities, which contributes to its outputs and outcomes. Of note are the many PhD projects, often with national universities, in FP5 to develop national research capacity. Although the planned budget of US$250K seems very small for what is required, much of the training and mentoring of students is funded by W3/bilateral projects. The physical outputs from training and learning activities in GLDC as reported in the 2018 and 2019 ARs are summarized in Annex 5j. Of note are a) facilitating over 5,000 beneficiaries in training courses with NARS and the private sector and b) mentoring 40 PhD students. This is considered traditional capacity building. The Capacity Development Unit collates the information and monitors the process. The GLDC capacity development strategy highlighted the need to modernize, and the Capacity Development Task Force (ICRISAT and ICARDA) was established to raise awareness of the diversity of capacity development interventions by supporting a less opportunistic and more strategic view. Efforts are being made to better understand the nature of capacity development activities, besides exploring the perceived demand for support in such activities, but it has been difficult to change traditional views. One enlightened example is the development in FP4 of CNGs, which are multistakeholder platforms for enhancing the pathway from varietal release to functional seed systems. These CNGs have taken account of the need for stakeholder capacity development to reach the desired outcomes. **One avenue for enhanced integration of modern capacity development in GLDC would be for the Task Force to be involved in project development to identify the key entry points.**

2.4.2 Gender and Youth

Gender is well integrated in GLDC through FP1 CoA3, major geographical regions have a gender specialist, and each FP has a bespoke strategy according to need. There are five strategic areas: (i) traits, preferences, and breeding product profiling (FP5 and FP4); (ii) inclusive seed delivery systems (FP4); (iii) gender gaps in cereals and legume production systems (labor, decision-making, knowledge access, yield, participation) and nutrition (FP3); (iv) gendered value chain development, learning, and impacts; and (v) social norms and behavioral change for men and women to support women's empowerment and impacts on delivery of GLDC research outputs (FP1). Lack of funding of FP2 restricted the ability of gender activities to integrate in GLDC beyond the development of technologies to look at demand, adoption, dissemination, markets, and livelihoods. Some of this work has been incorporated in W3/bilateral projects such as AVISA.

The physical outputs of the gender group in GLDC as reported in the 2018 and 2019 ARs are summarized in Annex 5j. Of note are a) the development of gender-responsive product- and customer-profiling tools for use in tailoring product profiles for breeders; b) the facilitation of the role of women in seed system development, contributing to impact acceleration in the use of improved varieties; c) capacity development of post-docs and interns in gender research; and d) establishment of communities of practice of breeders and social scientists across SSA to implement gender-responsive breeding projects.

The CGIAR Gender Platform facilitates gender activities across the CRPs, funds common studies, has set up a gender reporting structure, and hosts an annual conference of gender specialists across the CRPs. It is a source of tools, technologies, and advice for the GLDC gender group. Within it are communities of practice for each area of work—e.g., breeding and seed systems. It acts as an umbrella for all of the communities of practice. Gender activities are now well received by FP leaders, and there is good integration of gender in large bilateral projects such as Tropical Legumes (TL) III and AVISA. Such projects also enable development of gender teams within NARSs. **The integration and achievements are impressive, but the demand outstrips the supply. Further investment in gender is therefore needed.**

Progress has been made on the youth strategy, and a literature review will inform its further development. Inspired by young people in the dryland areas of Ethiopia, Tanzania, and Uganda, partnerships were established with national universities to look at youth definitions/transitions and youth aspirations/opportunity structures in the GLDC value chains to develop a strategy for intervention. In a webinar (https://gender.cgiar.org/webinar-youth-dryland/), early results on gendered aspects of youth definitions were shared.

2.4.3 Climate Change

A considerable amount of research is being implemented in GLDC that relates to adaptation to and mitigation of stresses under climate change, especially in FP3 and FP4 with tools and technologies developed by FP5. However, the research reported under this cross-cutting theme in the 2018 and 2019 ARs is from FP 3 only. No mention is made of research on breeding for drought and heat tolerance in eight of the GLDC crops in FPs 4 and 5 or foresight and priority assessment research in FP1. Surprisingly, none of this research shows links to CCAFS, although the CCAFS website indicates that all the activities implemented in other CRPs relevant to adaptation to and mitigation of climate change are mapped to it. **GLDC needs to clearly articulate its comprehensive climate research agenda and clearly indicate links with CCAFS.**

2.4.4 Partnership Effectiveness

Internal: Core GLDC centers mostly work individually on their mandate crops: ICRISAT on sorghum, millet, groundnut, and pigeonpea; IITA on cowpea and soybean; ICARDA on lentil; and CIAT on common bean. Only chickpea is common to two centers—ICRISAT and ICARDA. **Would GLDC be strengthened by one integrated chickpea breeding effort?** Disappointingly, breeders often refer to outputs as "ICRISAT varieties" or "IITA varieties" or "ICARDA varieties" and not as GLDC varieties. This suggests that crop-breeding programs operate in silos to some extent. W3/bilateral projects provide opportunities for cross-center collaboration, for example, on seed systems through TL I, II, III and AVISA, and collaboration with EiB is facilitating some integration. **Establishing a breeders' community of practice would further facilitate integration and effectiveness, especially when targeting cross-crop must-have traits such as drought and heat tolerance.** In addition, W1/W2 funds could be used more strategically to support cross-center links through projects with partners that improve collaboration and trust among scientists and capture synergies and complementarities across centers and crops. **Both the RMC and the IAC have important roles to play in fostering further creative and proactive integration among internal partners and enhanced recognition of GLDC for greater effectiveness, as has already been noted by the IAC.**

With CRPs and Platforms: Portfolio integration is a key objective of CGIAR Phase II where agri-food system CRPs enhance links with integrating CRPs, including PIM, A4NH, PIM, and CCAFS, and the

platforms. The partnership with PIM added value through updating the GLDC database of IMPACT (foresight modeling and ex ante analysis for priority setting). The partnership with the EiB is effectively modernizing GLDC breeding programs and building capacity for greater efficiency. In addition, partnerships with the Gender Platform and the Big Data Platform have provided further opportunities for added value for increasing GLDC's effectiveness. FP4 partners with ILRI and Livestock to improve fodder traits in sorghum, millet, and groundnut; FP3 partners with ILRI on the USAID-funded crop-livestock value chain project in West Africa; and ICRISAT partners with Livestock in another USAID-funded crop-livestock value chain project partnership in Kenya, but there is no mention of this project in GLDC ARs. No crop-livestock systems research appears to be active in SA currently. **Considering that crop-livestock systems are the most common farming system in the semi-arid tropics, links between GLDC and Livestock should be enhanced for added value and greater effectiveness.** GLDC is actively involved in a comprehensive research agenda of relevance to adaptation to and mitigation of climate change. This work includes breeding for drought and heat tolerance in eight GLDC crops for adaptation, developing options for managing abiotic stresses such as drought and heat for adaptation and mitigation, and natural resource-based cropping systems management for mitigation. Although these activities are linked to CCAFS as noted in the CCAFS website, this is not mentioned in the ARs. **GLDC needs to more clearly articulate its research on adaptation to and mitigation of climate change and indicate links with CCAFS.** GLDC has successfully partnered with HarvestPlus in A4NH in the development of iron- and zinc-biofortified crop varieties. HarvestPlus has developed a model for estimating impacts on nutrition. Assumptions are refined through studies looking at the links between biofortified variety adoption and eventual nutrition improvements. **GLDC needs to enhance its links with HarvestPlus to make sure the biofortification targets relate to the nutritional objectives in target countries to increase GLDC's effectiveness.**

With advanced research institutes (ARIs): Within GLDC, core partners CSIRO, IRD, and CIRAD contribute complementary skills, including agri-business, socioeconomics, systems expertise, crop improvement, and genomics/genetics, that strengthen the ability of GLDC to be effective. Additional partnerships with US and European universities for research and delivery add further skills, have built the capacities of GLDC researchers for research after projects have been completed, and created opportunities for capacity development of students in target countries.

With NARSs and NGOs: Core centers in GLDC have a long history of successful partnerships with NARSs and NGOs. In addition, GLDC has benefited from IRD/CIRAD's successful network of partnerships with NARSs in West Africa. W3/bilateral-funded projects provide numerous opportunities for ongoing collaborations with existing partners and new partners. Donors now recognize the importance of such partnerships and include support for NARSs in project budgets. Although the evaluation of partnership effectiveness was limited by a lack of site visits, Skype and email exchanges with 36 GLDC members and partners indicated that most NARS and NGO partners were satisfied with the partnership, but **some issues were raised about partnership equity and level of involvement. Several noted that more funds were needed to support the partnerships.**

With the private sector: Private sector partnerships are well established with seed companies in India through the hybrid parent research consortia for sorghum and pearl millet. This model is being spilled over to ESA. Other partnerships include those with Corteva Agriscience for advanced breeding technologies; Mars for high oleic acid groundnut; and Advanta Seed, Bayer Bioscience, and the Syngenta Foundation. More opportunities should be sought with the private sector as this will help leverage funds for projects.

3 Conclusions

3.1 Quality of Science

3.1.1 Quality of Research Inputs

The skill sets among program members are appropriate for the activities implemented in each FP. However integrated agri-food systems thinking across GLDC is limited, at least partly owing to lack of agribusiness expertise resulting from the non-funding of FP2. In general, FP teams are appropriately diverse according to partner institutes, geographical locations, and gender for the research activities. **The skills and diversity of the many partnerships clearly add value and enhance the ability of GLDC to address its objectives throughout its program.**

3.1.2 Quality of Process

GLDC is implemented through a multitude of internal and external partners. New partners are sought depending on the needs of the project. The overall approach is to use the skills available within GLDC and seek partners who bring complementary skills. **However, GLDC has not explicitly analyzed its comparative advantage.** With the exception of seed systems research, lack of funding for FP2 has compromised the forming of partnerships for scaling out innovations in agri-food system development. Mixed feedback was received from discussions with FP leaders and internal partners on the level of involvement of external project partners during project development. More effort is needed to take full account of external partner equity and priorities during this process. **There was general consensus that the current internal management system is fair and transparent.**

3.1.3 Quality of Outputs

The quantum of publications in ISI and open access journals generated by GLDC is impressive. The quality is also high, with 24 papers attracting 20 or more citations and some attracting more than 50 citations during 2017–2018. Most are in high-IF journals on genomics and genetics, but there are also papers in high-IF remote-sensing, agronomy, and economics/social science journals. External recognition of GLDC publications is clear from the numbers of citations, altmetrics, and h-indices of the first authors reaching high scientific and academic quality standards. The h-indices of first authors generally indicate good international peer recognition of the scientist through citations. Legitimacy through coauthorship is demonstrated by the acknowledgment that a diversity partner made a notable contribution to the research that generated the publication. A large proportion of publications were rated as of good to high significance with notable contributions to IPGs. Publications from FP4 and FP5 and ICRISAT are the dominant publications in the higher-impact journals. **GLDC should be congratulated for this effort.**

The quantum and quality of physical products produced by GLDC is also impressive, and many showed broader applicability of IPGs generated. Seed systems activities have already achieved impact at scale. Key examples include the efforts by FP1 in generating 10 expert reports addressing prioritization and lessons learned from Phase I, which enabled GLDC. The development of 115 sustainable intensification indicators, a platform, and a framework in India, Niger, and Burkina Faso that can be used throughout SSA and SA is a notable achievement that other CRPs are adapting for their use. Significant progress was made in modernizing prebreeding and trait discovery approaches and methods in partnership with the EiB Platform.

3.2 Effectiveness

3.2.1 Achievement of Planned Outputs and Outcomes

The program's outputs, milestones, OICRs, and science quality show that research outcomes have been impressive and of good scientific quality. More than 50 percent of planned milestones have been met, and the OICRs tell a positive story, mainly concerning the adoption rates of GLDC improved varieties and the positive impact this is likely to have on development targets. The decision not to fund FP2 has meant that the program continued largely in a commodity breeding/farming system management mode. Without funds, it could not mainstream the fresh paradigm encapsulated in the GLDC proposal and the 2016 SRF. There are exceptions to this statement, including much of the work in FP1 on priority setting and the GLDC cross-cutting gender program.

3.2.2 Demonstrated Importance of Outcomes

The deep dive on seed systems OICRs documented at least some of the following measurable outcomes: increased adoption of improved varieties, increased area planted, increased productivity, increased income to farmers, good market access and growth, increased welfare and reduced poverty incidence, and significant economic benefits. Engagement with cross-cutting issues and intensive engagement with partners were demonstrated. All showed the importance of the enabling environment to achieving outcomes—functional institutions and markets, and a conducive policy environment. **In addition, the analysis of these studies identified a number of areas that require further research: farmer demand for quality seed, farmers' choices to adopt improved varieties, market preferences, scaling models, and key factors contributing to the establishment of sustainable seed systems.**

Much of the work in FP1 on priority setting and impact acceleration encompasses the spirit of the new paradigms on agri-food systems and value chains. However, other FPs indicated lesser engagement with these paradigms and wider development issues, preferring to fall back on the comfort zone of increased productivity. Undoubtedly, the absence of funding for FP2, which would have enthusiastically advocated a greater focus on agri-food systems, has not helped. The decision not to fund FP2 has therefore had a major impact on the nature of the GLDC's research and potentially the nature and extent of its development impacts. **It has resulted in GLDC's continuing to perform well broadly as a conventional CGIAR commodity-breeding/farming system program rather than as a program serving the agri-food system as a whole and integrating socioeconomic science, contemporary development practice, and scaling partners into its work.**

3.2.3 CRP Management and Governance

GLDC is well managed through regular RMC meetings and a productive Annual Review meeting. RMC meetings have covered major issues facing GLDC, initially giving significant attention to partnerships but now appearing to be more focused on the administration of the program. This has limited the ability of GLDC management to drive the program as a coherent and integrated portfolio and facilitate consensus building and implementation of decisions across the FPs and the core partners. Interactions between FP leaders varies: FPs 4 and 5 have the advantage that both leaders are based in ICRISAT, India, but the geographical distance between leaders of FPs 3 and 4 has not facilitated interaction between breeding and agronomy and crop systems research, which needs to be improved. **FP linkages and portfolio coherence would benefit from enhanced creative and proactive input from the PD if he had more time. This would also enable the PD to play a greater role in facilitating and guiding the direction of W3/bilateral funds under a coherent program vision.**

The minutes of the IAC meetings demonstrate engagement with and interest in GLDC's research and accomplishments, but two key programmatic issues have not yet been resolved. The significance of lack of funding of FP2 was discussed by the IAC, which recommended revising the ToC to make it better suited to the current situation. **However, insufficient attention has been given to modifying the original ToC or impact pathways to align GLDC with the realities of its current functioning structure. GLDC has been in operation for more than two years without an appropriate ToC or impact pathway.** Although serious reservations were raised by the ISPC on the time allocation to the GLDC director and the IAC made a recommendation to increase the programmatic activities of the PD, the decision is still pending with the ICRISAT Governing Board. **A time allocation of 20 percent for the PD is not sufficient to direct the most complex CRP in the CGIAR portfolio, especially for the important tasks of maintaining rich and productive interactions between FPs, integrating the two funding streams, and fostering partnerships to leverage funds with drive and passion.**

3.2.4 Progress along ToC (CRP and Flagships)

With FP2 unfunded, much of the thinking in the original ToC and master IP has been invalidated. No attempt has been made by the program to formally revise these in the light of this funding decision. The original IP had two pathways: the first pathway on "farmers adopting GLDC technologies" and the second concerning "agri-food systems." Progress along this latter pathway has been limited. Good progress has been made on the first pathway, which is more limited in scope, but it can be argued that such **GLDC technologies may have been more relevant to, and have had greater impact on, development targets had they taken wider agri-food systems issues into account.**

3.3 Future Orientation

The complexity of GLDC and the difficulties in managing two funding streams has affected its ability to deliver its objectives as effectively and efficiently as would have been possible with a simpler structure and integrated funding. The future of this CRP model in One CGIAR needs serious analysis. **A simpler model based on specific targeted packages of research supported by a specific funder, as exemplified by FP2: HarvestPlus in A4NH and FP6: Common Bean in GLDC, could be more effective in achieving System goals.**

Since its inception, GLDC has been constrained by the lack of funding for FP2. Its level of integration has been compromised, the original ToC is not appropriate for its current operations, and the impact pathway on scaling and sustaining is largely not functioning as it was conceived. Notwithstanding, there are good examples of FPs working well together and of potential future contributions to the program's IDOs (improved diets for poor and vulnerable people; increased incomes and employment; and increased productivity and increased resilience of the poor to climate change and other shocks), which are referred to throughout this report.

The work of GLDC is critical to the hopes and aspirations of millions of poor people in semi-arid and sub-humid lands, and the outputs achieved in past two years have impacted positively on those poor people. The reviewers consider that the concepts, activities, and aspirations envisaged for the GLDC in the original proposal were well thought through and appropriate. **However, for GLDC to clearly articulate its true potential future contribution, it needs to modify its ToC and impact pathways to reflect its current operations without a functional FP2. It can then make realistic projections on the likelihood of ultimate delivery of outcomes.**

3.4 Cross-cutting Issues

GLDC shows a clear commitment to capacity development throughout most research activities, which contributes to its outputs and outcomes. The many PhD projects with national universities are noteworthy. Efforts to modernize capacity development activities, however, have not been helped by traditional training-based views. **Greater Task Force involvement in project development would help to identify the key entry points for modernizing capacity development.**

Gender is well integrated in GLDC, and each FP has a bespoke strategy according to need. The achievements are impressive. Lack of funding of FP2 restricted the ability to integrate gender activities in GLDC beyond the development of technologies to look at demand, adoption, dissemination, markets, and livelihoods. The youth strategy has made progress with SSA universities, looking at youth definitions/transitions and youth aspirations/ opportunity structures in the GLDC value chains.

GLDC has a comprehensive research agenda contributing to adaptation to and mitigation of climate stresses under climate change, especially in FP3 and FP4 with tools and technologies developed by FP5. However, the research reported under this cross-cutting theme in ARs is from FP3 only. **GLDC needs to clearly articulate its overall climate change research agenda and emphasize links with CCAFS.**

GLDC is a complex CRP that lacks coherence owing to insufficient integration between some FPs and difficulty in managing two funding streams. Establishing a breeders' community of practice would further facilitate integration and effectiveness, especially when targeting cross-crop must-have traits such as drought and heat tolerance. **In addition, the W1/W2 funds could be used more strategically to support cross-center projects with partners that improve collaboration and trust among scientists and capture synergies and complementarities across centers and crops.** Both the RMC and the IAC have important roles to play in fostering further integration among internal partners and enhanced recognition of GLDC for greater effectiveness.

There are good examples of effective partnerships with other CRPs and platforms—e.g., PIM, CCAFS, EiB, and the Gender Platform. **Partnerships could be strengthened, following the examples of Livestock/ILRI and HarvestPlus/A4NH.** Effective partnerships have been established with core partners CSIRO and IRD/CIRAD. Partnerships with US and European universities have added complementary skills and developed capacity. Long-standing successful partnerships between GLDC core centers and NARSs and NGOs have been integrated into GLDC. W3/bilateral-funded projects provide numerous opportunities for ongoing collaboration with existing partners and new partners. Private sector partnerships are well established with seed companies and with Mars, Corteva Agriscience, Bayer Bioscience, and the Syngenta Foundation, and more effort would help leverage funds for projects. Feedback from most partners was positive.

3.5 Overall Conclusion

The quality of GLDC science is high overall, and novel approaches are being used to generate many IPGs, as noted in this report. Notable development impacts have already been achieved in seed systems projects. GLDC scientists and partners should be congratulated for their commitment and productivity. However, GLDC is not a sufficiently integrated CRP. And, perhaps, this is asking the impossible owing to the inherent complexities of combining 9 crops, 10 core partners, and 17 target countries. In addition, lack of funding to FP2 took the heart out of the scaling and sustaining IP, which is barely functional. That said, there are also good examples of integration. GLDC management and governance should strive during the remainder of the program to foster and facilitate integration where relevant in preparation for One CGIAR.

If FP2 had been funded, even more could have been achieved, and those achievements could have stimulated even greater development impact, if they had been based on the wider agri-food system and social science agenda, as originally planned. GLDC has less than two years to run, and it is assumed that all or parts of the program will continue generating further high-quality and development research outputs. The planned restructuring of the CGIAR research agenda as One CGIAR will provide opportunities for already generated and planned research outputs to have greater impact on the following SLOs: a) poverty reduced; b) improved food and nutrient security for health; and c) improved natural resources and ecosystem services. Phase II was conceived to respond to the vision embodied in the SRF of adopting an agri-food systems approach, with the objective of transforming food systems for greater impact on the SLOs. **The concepts and thinking contained in the original GLDC proposal (mirroring those in the SRF) are still appropriate and should be reconsidered in the forthcoming One CGIAR.**

4 Recommendations

4.1 Quality of Science

Recommendation 1: In spite of the disappointment of GLDC's being terminated one year early, it is recommended that GLDC members continue to generate high-quality outputs with the drive and passion clearly evident from the first two years of operation.

4.2 Effectiveness

Recommendation 2: It is recommended that future research in seed systems take account of farmer demand for quality seed, farmers' choices to adopt improved varieties, market preferences, and key factors contributing to the establishment of sustainable seed systems.

Recommendation 3: Although GLDC has made good progress in developing strong linkages with integrating CRPs and platforms for increased program effectiveness, it is recommended that links with A4NH be strengthened to ensure that the biofortification targets relate to the nutritional objectives in target countries and with Livestock to fully address the research and development needs in crop-livestock systems, the most common farming system in the semi-arid tropics.

Recommendation 4: It is recommended that GLDC should as far as possible develop an enhanced systems approach that extends across the whole agri-food system for maximum development impact.

Recommendation 5: It is recommended that the time allocation of the PD be increased to 40–50 percent to allow the PD to drive the program as a more coherent and integrated portfolio and to play a greater role in facilitating and guiding the direction of W3/bilateral funds under an agri-food systems program vision through enhanced dialogue with partner centers and funders. RTB offers a proven model.

4.3 Future Orientation

Recommendation 6: It is recommended that GLDC clearly articulate its true potential future contribution by modifying its ToC and impact pathways to reflect its current operations and to make realistic projections on the likelihood of ultimate delivery of outcomes.

4.4 CGIAR System-level Recommendation

Recommendation 7: It is recommended that the SMB and SMO incorporate the concepts and thinking contained in the CGIAR SRF, which are still relevant for transforming food systems for greater impact on the SLOs, into the forthcoming One CGIAR.

Recommendation 8: It is recommended that the simple model of each FP being entirely supported by one funder, as exemplified by FP2: HarvestPlus in A4NH and FP6: Common Bean in GLDC, be given serious consideration by the SMB and SMO in the forthcoming One CGIAR.

5 Lessons Learned

As CGIAR annual reports are summaries of summaries, it is not possible to include enough pertinent information for CRP reviewers. This could lead to inaccurate interpretations and as a result erroneous conclusions. The annual report template should be revised to ensure that all relevant information is captured, especially with regard to cross-CRP linkages and portfolio integration. Initial discussion of the TORs with CRP management would help to identify useful documents.

CGIAR Advisory Services (CAS) Secretariat

Via dei Tre Denari, 472/a, Maccarese (Fiumicino), Italy

tel: (39) 06 61181 - email: cas@cgiar.org

https://cas.cgiar.org/