

Science Review of CABI

2020/21

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List of acronyms

AAFC	Agriculture and Agri-Food Canada
ABS	Access and benefit sharing
ACIAR	Australian Centre for International Agricultural Research
Aol	Action on Invasives
BMGF	Bill and Melinda Gates Foundation
BPG	BioProtection Global
CBD	Convention on Biological Diversity
CCFC	Canadian Collection of Fungal Cultures
CDF	CABI Development Fund
CGIAR	Consultative Group on International Agricultural Research
СОР	Convention of the Parties
COVID-19	Coronavirus Disease 2019
CSPM	Climate-smart pest management
DORA	Declaration on Research Assessment
DSI	Digital sequence information
EMT	Executive Management Team
EU	European Union
FAIR	Findable, accessible, interoperable, reusable
FAO	Food and Agriculture Organization of the United Nations
FCDO	Foreign, Commonwealth and Development Office (formerly DFID)
IBMA	International Biocontrol Manufacturers' Association
IPM	Integrated pest management
IPPC	International Plant Protection Convention
M&E	Monitoring and evaluation
MALDI-TOF MS	Matrix-assisted laser desorption/ionization time-of-flight mass
spectrometry	
MTS	Medium-Term Strategy
NGS	Next generation sequencing
NP	Nagoya Protocol
ODA	Official development assistance
OECD	Organization for Economic Co-operation and Development
PCR	Polymerase chain reaction
POMS	Plantwise Online Management System
R&D	Research and development
UN SDGs	United Nations Sustainable Development Goals
USAID	United States Agency for International Development

1. Executive Summary and Recommendations

CABI commissioned a panel of experts (hereafter referred to as 'the team'), composed of six members with diverse experiences and backgrounds, to closely examine the organization's progress since the 2015 review of its science programme. The team noted that the internal landscape of science within CABI has changed considerably with the publication of the organization's first Science Strategy in 2017, and the strong emphasis on science in CABI's latest Medium-Term Strategy (MTS, 2020-2022). It is expected that this review will provide CABI guidance for its next Science Strategy. In addition to this retrospective part of the review, the team was also tasked to provide a strategic outlook on several critical areas including climate change and social science research at CABI; the role of gender in the organization's research; the relationship with the private sector; and linkages (or the lack thereof) between CABI's science and publication activities. Specifically, the team was asked to test two key assumptions (see terms of reference in Annex 1):

- CABI needs to maintain a strong science programme in order to remain a credible organization in international development and publishing.
- CABI sees a clear need to focus in relatively few areas to maintain a world-leading position in one
 or two of those and to be world competitive elsewhere

Because of the COVID-19 pandemic, the entire review was carried out virtually. The team reviewed relevant strategy documents and databases, and also conducted virtual meetings with a wide variety of CABI staff as well as with many different partners and stakeholders of the organization.

The environment in which CABI operates and functions is presently going through dramatic changes. Nobody can predict the long-term effects of the COVID-19 pandemic, but it is the general consensus that many things will change profoundly. The huge costs of the pandemic for global economies will have repercussions on the ability and willingness of many countries in the Organization for Economic Co-operation and Development (OECD) to allocate resources for official development assistance (ODA), which most likely will have an impact on the funding situation of organizations like CABI. Yet on the other hand many governments have been made to realise the dramatic costs that an outbreak can have on the world economy, opening up prospects for new research and development activities for scientific organizations like CABI with a proven track record of working on invasive organisms throughout the world. Concurrently, several institutions in CABI's ecosystem are going through major consolidation processes, the 'One CGIAR' being a prime example. CABI will need to be well positioned for this changing environment, with a strategy to revitalize old, and foster new, partnerships. With its unique blend of skills and experience in research, development and knowledge management, and its extensive array of partnerships through its member country network, CABI should be in a prime position to make meaningful contributions. In that spirit, the team proposes the following preliminary recommendations:

<u>Recommendation 1:</u> A more strategic approach to partnerships is crucial for CABI's future. As CABI continues its current research and moves into new research areas, partnerships should be re-evaluated for relevance, and new partnerships actively pursued to fill gaps, develop skills and position for new opportunities. This applies to partnerships among the different CABI Centres as well as outside the organization. Partnerships are of special importance for areas in which CABI is currently not recognized, such as climate-smart agriculture, bioinformatics, gender and socio-economic analysis. The ongoing One CGIAR process may lead to an accelerated consolidation of agricultural research and development organizations. CABI will need to make sure 'not to miss the boat', by building closer ties with other stakeholders and forging strategic alliances. This could be achieved through a stronger focus on joint development of larger, multi-organization research and development (R&D) consortia. A prerequisite for this would be to focus on some of CABI's unique strengths, for instance in biological control of invasive pests, weeds and diseases; in innovative extension models; and in information dissemination, including pest distribution and development communication.

<u>Recommendation 2:</u> Since the previous review CABI has made significant progress on transitioning to a 'One CABI' model. However, communication among the Centres could be further improved, leading to

more collaboration, for instance through across-CABI utilization of specific services such as those offered by the Bioscience team. CABI management should strongly encourage and incentivize, for instance with awards, the development of larger project proposals that cut across several CABI Centres, with more involvement of junior scientists and additional stakeholders (cf. recommendation 3).

<u>Recommendation 3:</u> With the soon-to-be-ending Action on Invasives (AoI) programme and its imminent integration into the new PlantwisePlus programme, CABI should ensure that its track record and stellar reputation in classical biological control is maintained. There is tremendous potential for synergies in integrating AoI into PlantwisePlus, but for these to materialize, close oversight from CABI's leadership will be needed. Moreover, leveraging two key strengths of CABI in PlantwisePlus, i.e., novel extension and dissemination tools and techniques, and profound knowledge and experiences in classical biological control, should enable CABI to meaningfully contribute to large-scale initiatives, for instance in the context of the One CGIAR.

Recommendation 4: Since the previous review CABI has made progress in the inclusion of social science, and, to a lesser degree, gender in its research. While the actions undertaken were necessary, they were not sufficient. Rather than perceived as fundamental to projects, gender is often perceived as an 'add-on'. More funding and expertise should be engaged to mainstream gender, carry out gender analyses and integrate gender into project theories of change. To strengthen its scientific research in solving problems in agriculture and the environment, CABI should adopt a multi-disciplinary approach, with social scientists (including socio-economic, gender and monitoring and evaluation (M&E) experts) participating in the design and implementation of programmes and projects. This will require increased staffing, allocation of funding in project design and budgets, changes in programme and project development processes, and stronger internal collaboration. Current staff training in gender and raising gender awareness among scientists should be an on-going programme. Internally, gender balance varies widely across different parts of CABI; but even in those Centres where women are well represented among the younger staff, there is a predominance of male senior scientists. There are positive signs that gender is being considered as an important element in succession planning, with younger women scientists being placed in global leadership roles, for example, in PlantwisePlus. The consideration of gender should continue to be an important factor in succession planning. In areas where women are currently seriously under-represented, such as the Central and West Asia Centre in Pakistan, or Bioscience in the UK, gender should be a major consideration in every recruitment.

<u>Recommendation 5</u>: The integration of climate change in CABI's work is nascent. Although there is a strong institutional interest in climate finance, CABI lags far behind other agricultural research organizations in its climate change research and development work. A staff position for climate change was a positive first step, but integrating climate change into its programmes requires a stronger commitment by CABI senior staff, and climate-smart processes put in place that will result in good science as well as the potential to tap into climate finance. Climate actions to be undertaken to increase resilience (adaptation) and/or decrease emissions (mitigation). To strengthen CABI's ability to compete effectively in the climate change space, staff training in climate change, climate risks, adaptation and mitigation should be undertaken and CABI-wide indicators agreed and implemented.

<u>Recommendation 6:</u> CABI should develop a strategy and investment plan for data (including big data and data science) to overcome current bottlenecks in funding and to ensure visibility, sustainability and greater use (by CABI itself and its clients) of the data it holds, and of the platforms and data infrastructure built over the years. This is especially true for bioinformatics, where a comprehensive strategy is urgently needed, particularly for metagenomics and/or ecological studies, as opposed to genome sequencing and functional genomics. This is crucial if CABI wants to continue to be a global player in pest distribution data and diagnostics. In terms of data platforms outside genomics, CABI is ahead of many players in the field. CABI should make greater investment and/or build long-term partnerships supporting capacity and infrastructure to manage and utilize big data, with more emphasis on data science in its regional centres and country offices. The strategy should also envisage capitalizing on these opportunities and making use of the various content assets as sources of revenue through the development of new services, applications and decision support tools.

<u>Recommendation 7:</u> CABI has made good progress in supporting development of data sharing policies in several countries. There are significant challenges (and misconceptions) in data sharing, owing to the perceived sensitivity of data on pests and concerns about impacts on international trade. This appears to be a major obstacle in implementing biosecurity measures and publication of environmental genomics data requiring upload in GenBank with sample origin information. Using its expertise and global influence, CABI should support changes in policy and practice with regard to data use and data sharing, such as the concept of FAIR (findable, accessible, interoperable, reusable) data. This kind of policy work is in line within CABI's broader open agriculture approach, and needs to be pursued vigorously. CABI should also promote greater recognition of, and rewards for, the work on data, which is currently not at par with that afforded to scientific publications in peer-reviewed journals. In that regard, CABI needs to develop new metrics comparable with those used for scientific publications to promote better data management and sharing, as well as career-relevant metrics for scientists that both CABI and its funders can apply uniformly.

<u>Recommendation 8:</u> Commercialization of CABI's resources and services where applicable, e.g., from the genetic resource collections, should be enhanced through stronger engagement with the private sector, both individual companies and umbrella organizations such as the International Biocontrol Manufacturers' Association (IBMA) and BioProtection Global (BPG). This engagement should emphasize CABI's core strengths and expertise in biological control of weeds, and in classical and augmentative biological control of insects with fungal entomopathogens. This should lead in turn to joint product development and applications with commercial partners, where CABI could capitalize on its worldwide presence to target large markets. However, this would require overcoming perceived reluctance among some staff to work with private partners, which is still seen as conflicting with publications and intellectual property rights (IPR). Specifically developed incentive schemes from CABI management could bring about change here.

Recommendation 9: CABI's activities in identification by DNA sequencing, genome sequencing and MALDI-TOF analysis; microbiome analysis and functionality through next generation sequencing (NGS); the culture collection (pre-Nagoya Protocol specimens and others following access and benefit-sharing (ABS) negotiations); and bioinformatics, should be thoroughly reviewed. Ultimately, these research support services should provide a competitive advantage to all CABI Centres, become an incentive for membership, and increase revenue for CABI. CABI needs to decide which activities to continue in-house centrally, which ones to decentralize to regional centres, which ones to do in partnership or through contracts with academic or private partners, and which ones to let go. In making these decisions, all costs such as maintenance of equipment, keeping staff proficiency, and making the necessary upgrades for economies of scale, as well as all revenues through commercialization or collaborative research agreements must be taken into consideration. Poteltial revenues from sales of cultures should be realistic, based of experience from other culture collections. These decisions should also take into consideration that the 'omics' data analysis component ('wet lab') will remain increasingly important whether or not CABI relies on partners for the 'wet lab' services. These activities can strengthen CABI as a (preferred) partner in projects with the private sector.

Recommendation 10: With regard to the Nagoya Protocol, CABI should continue lobbying for easy access to genetic resources, and for biocontrol to be exempt from the provisions of the Convention on Biological Diversity (CBD), by forming a larger task force with other biocontrol stakeholders, including industry organizations as well as donor countries and the FAO, to form a stronger collective voice on these issues. CABI should also consider a consultancy or advisory role to researchers and the biocontrol industry, to assist them in matters relating to compliance.

<u>Recommendation 11:</u> Stronger emphasis on the impact factor of peer-reviewed scientific publications was one of the key recommendations of the previous review, which has been successfully addressed. The publication indicators have improved, as well as the annual reporting format of the publication metrics which has got more comprehensive every year since the last review. This progress needs to be maintained on both fronts. New metrics on collaboration and co-authorship are needed to assess improvements in partnerships and collaboration among CABI Centres (recommendation 2). Other metrics on impact should be added (e.g., an impact factor of CABI publications over time). The review team recommends that CABI signs the Declaration on Research Assessment (DORA) to join like-minded organizations in the search for better metrics. In order to maintain the momentum in quantity and quality of publications, the award system should be reviewed to make sure it remains effective (e.g. keeping a balance between rewarding senior "star" scientists and some young and upcoming stars, adding regional awards, or supporting data science). The use of the CABI Development Fund (CDF) for the preparation of research papers has obviously been a success, and CABI should consider increasing this kind of support, which should be especially beneficial to young scientists.

<u>Recommendation 12:</u> With the forthcoming retirement of the Chief Scientist, CABI will need to carefully define the role and responsibilities of a potential new recruit. If CABI truly wants to recruit a top-level advocate for its science programme then it will also need to equip the position with the necessary resources to advocate CABI's science internally and externally, as well to strengthen existing, and build new, scientific partnerships: see also section 8.4.

2. Acknowledgements

We wish to express our gratitude to CABI's senior management for inviting us to review the good work being done by CABI's highly skilled, motivated and committed scientific staff. We were impressed by the openness and enthusiasm that we encountered in all the teams we met from across the organization, and would like to thank them all for giving so freely of their time to explain their work and share their views. We would also like to thank the respondents in the external partner survey for contributing their valuable insights and perspectives. Lastly, special thanks are due to Ulli Kuhlmann and Matthew Cock for their guidance throughout the review process, and to Gitta Grosskopf-Lachat for all her logistical support and help with negotiating Zoom and MS Teams.

3. Introduction

In the autumn of 2020, CABI's Governing Board and Executive Management Team (EMT) commissioned a further external review of its science programme (the last having been in 2015), to assess the progress made during the last five years and provide a strategic outlook for science at CABI. The full terms of reference of the review are given in Annex 1.

A panel of six reviewers with diverse disciplinary and regional backgrounds was formed, with Christian Borgemeister as the coordinator of the team, and Janet Stewart providing editorial support. In Annex 2, brief CVs of all team members are provided. Because of the ongoing COVID-19 pandemic (see section 4), all meetings, starting with the inaugural get-together of the team on October 30, 2020 which also included members of CABI's senior management, were held virtually. During this meeting the terms of reference and the general organization of the review were discussed. Because of the travel restrictions and thus the inability of the team to visit any of the CABI Centres, it was agreed to increase the number of virtual meetings/ interviews with various staff groups and individuals from the organization, as well as with important partners and stakeholders of CABI, and in total almost 40 remote meetings were held.

CABI provided the review team with excellent technical and organizational help and assistance. Key here was Gitta Grosskopf-Lachat of CABI's Centre in Delémont, Switzerland who provided outstanding logistical and organizational assistance to the team. The team made extensive use of the virtual meeting and web-based services provided through CABI, especially the MS Teams site that proved to be a very useful and crucial resource for data collection, data sharing and exchanging draft texts during the write-up process.

The team focussed initially on a very comprehensive desk review, going through the substantial amount of data and information provided by CABI's management. This initial analysis helped the team to design and implement the subsequent virtual interactions with CABI staff, partners and stakeholders. Some of the information, combined with additionally gathered data (e.g. from Scopus, Google Scholar, PubMed), were then used for more detailed analysis, particularly in the field of scientific publications (see section 7.1 for details). There was obviously no feasible alternative to the virtual meetings, and generally speaking they went well. However, the limitations of such a format became evident, especially once the number of participants exceeded 7-10. The virtual meetings with the stakeholders suffered from the same shortcomings, but all in all provided some very helpful information for the team.

Because of the completely virtual nature of the review, this report has no doubt some significant limitations. No Zoom meeting can substitute for a frank and open discussion over a cup of coffee or

during lunch. No desk analysis will ever rival the information and insight gained through a field or laboratory visit. Conscious of these shortcomings, we held more virtual interactions with the different parties. The team was particularly tasked with finding out how the recommendations of the 2015 review had been implemented, how the organization was exploring relatively new fields of research like social and climate change sciences, and how these changes would position CABI in a rapidly changing environment.

The main findings of the team are summarized in the Executive Summary and a series of 12 specific recommendations. Other areas of particular importance are outlined in the respective sections of the report.

4. The global context

There is probably no overstatement possible in terms of how the world has changed in the last year, let alone since 2015, the time of the last science review of CABI. The COVID-19 pandemic has led to more radical changes than any other event since World War II, and it is far too early to imagine the true nature and dimension for mankind of the long-term consequences of the pandemic. Thus, societies are dealing with an additional level of uncertainty, making predictions and forecasts in an era already dominated by climate change and global biodiversity loss even more complicated.

However, there is no doubt that these still uncertain consequences of the pandemic will have a huge bearing on the future of CABI and its research and development. Several of these consequences seem more likely than others:

- At the time of writing of this report in February/ March 2021 the global vaccination programme had just commenced, with most of the countries in the Global South facing huge shortfalls in vaccine stocks. Most analysts predict that global coverage will not be assured before the end of 2023. This will continue to have a significant effect on global health expenditures and obvious consequences for investment in agricultural R&D with implications for CABI's work.
- 2. OECD economies have so far proved to be more resilient than originally anticipated. Yet, this was primarily the result of unprecedented fiscal stimulus packages in the range of trillions of dollars. No comparative public investments were possible in the Global South. Thus, economies in developing countries have so far suffered disproportionally, leading to sharp rises in poverty figures. Moreover, the generous bail-out programmes in OECD countries will most likely be phased out in 2021, probably followed by a return to more austere budget policies, which, based on previous experiences, will lead to cuts in ODA and R&D expenditures, which obviously will have serious consequences for organizations like CABI.
- 3. The presumed biological origin of the COVID-19 pandemic has elevated awareness of the risks and dangers that habitat destruction, movement of pathogens, biodiversity losses and invasive species and zoonoses pose to mankind to another level. More and more policy makers are starting to realise that agricultural expansion into prime biodiversity hotspots can have huge human health implications, and adaptive research in this domain will become ever more important. Moreover, the public is now much more aware of the importance of accurate diagnostics, including some knowledge of the differences between antibody and antigen tests or even genotyping by DNA sequencing. In these regard CABI's work may gain more relevance and will become easier to explain.
- 4. COVID-19 has dominated the agenda of the last 12 months. However, the crucial climate summit (COP 26) to be held in Glasgow, UK in 2021 will bring climate change full-swing back onto the global agenda, certainly helped by the re-entry of the USA into the Paris Climate Agreement.
- 5. The public discourse on agriculture's global contribution to climate change has accelerated, with more and more governments in OECD countries as well as in the Global South looking for more climate-adapted and resilient alternatives, often under the flagship of 'regenerative agriculture' and also in the context of discussions around the United Nations Sustainable Development Goals (UN SDGs).

6. The ongoing comprehensive reform and restructuring process of the Consultative Group on International Agricultural Research (CGIAR) will most likely lead to far-reaching changes in the landscape of research for development in the Global South. A strong catalyst of the One CGIAR process is an alliance of key bilateral, multilateral and private charity funders, some of them also traditional supporters of CABI. The One CGIAR strives to become a more centralized and cohesive organization that is more responsive to the needs and priorities of national governments in the Global South. CABI will need to position itself well in this environment by relying on its core strengths and fostering new partnerships.

5. CABI's vision, mission and modus operandi

In its most recent MTS (2020-2022), CABI defines its vision that "CABI will be the number one 'go-to place' for insightful and practical science-based knowledge about agriculture and the environment', and its mission as to "improve people's lives worldwide by providing information and applying scientific expertise to solve problems in agriculture and the environment'. In both vision and mission, the organization highlights its strengths ion the two core areas of science and communication/ information dissemination.

Since the 2015 review of its science programme, CABI has certainly strengthened its science agenda which is well reflected in its considerably improved scientific output (see section 7). Striking the right balance between science communication and dissemination, and its own research activities, will remain a challenge for the organization. Similarly, CABI will need to focus even more on its core scientific areas such as biological control and plant protection in general, where its comparative advantage vis-à-vis likeminded organizations is very evident. For other areas, the need to foster strategic partnerships and alliances will become even more important.

6. Institutional implementation of the 2015 review

Since the last review of its science programme CABI has implemented a number of reforms and changes. some of them specifically addressing recommendations from the review. Chief among them were the development of a distinct CABI Science Strategy in 2017, as an annex to the overall MTS 2017-2019 of the organization, as well as, starting in 2015, the publication of Annual Science Reports, CABI's Science Strategy defines five priority research areas that reflect the disciplinary strengths of the organization, focussing very much on CABI's core expertise in pest management and in extension and information dissemination techniques, and four cross-cutting research areas that are more reflective of CABI's future research aspirations like big data management and advanced technologies. It also highlights the objectives of CABI to increase its scientific output, both in terms of guality and guantity. All these changes address, in one way or another, specific recommendations of the 2015 review. Looking at the implementation of these changes, this review team was very impressed by the substantially improved scientific output of CABI, and by the much stronger collaborative efforts of scientists among different CABI Centres. The number and quality of peer-reviewed publications, the latter primarily reflected by the metrics of journal impact factor and citations, has risen sharply since 2015 (for more details see section 7.1). Key factors for this success were certainly the various measures that CABI management has implemented to motivate and reward publication efforts of its scientists.

Over the last five years social science at CABI has made tremendous progress, because of its greater emphasis in the recruitment efforts of the organization. Yet efforts to improve integration of social science and social scientists into CABI's large programmes, in order to create inter- and trans-disciplinary synergies, need to continue (for more details see sections 7.4 and 8.1). Similar observations were made for other emerging research and development areas like climate science (see sections 7.5 and 8.1), mainstreaming gender research (see sections 7.6 and 8.1), use of big data (see section 7.7), private-public partnerships (see section 8.2), and biotechnology (see section 8.6).

Thus, in summary, over the last five years CABI has no doubt substantially strengthened its science programme by increasing its output (both in terms of quality and quantity) and capitalizing on its proven disciplinary strengths, but also by exploring new areas like social science. Stronger cooperation between

scientists from different CABI Centres and disciplines, as well as institutional support and a successful incentive scheme by CABI management, were among the main factors in this success.

7. Scientific performance during the reporting period

7.1 Scientific publications

The previous scientific review recommended to improve the quantity and quality of scientific publications, and find better ways to monitor progress. The CABI Science Strategy Action Plan heavily emphasized science output and impact, and had several milestones and targets directly addressing the quantity and quality of publications (e.g., maintain CABI's annual publication record; incentive programme in place to publish important or high-quality papers going beyond project objectives: see section 10). The CABI annual reporting over the past five years has shown a positive trend from the indicators, as well as improvements in the quality and thoroughness of the reporting itself. The committee conducted an independent review of the publications using Scopus. Although the list of CABI publications in Scopus may not be complete, it provided a good basis for trend analysis in addition to the annual reports from CABI (Annex 5).

In comparison to the 2006-2010 period, CABI scientific publications were already showing a positive trend regarding impact factor (IF): the IF median went from 1.8 in 2006-2010 to 2.2 in 2011-2015 (Annex 5 A.1). However, the improvements from 2011-2015 to 2016-2020 were much more significant, with more papers overall but also with about 100 more papers with IF > 2 reported in Scopus. This trend was particularly noticeable in CABI Africa, where there were about five times more papers, half of them in journals with IF > 2 (Annex 5 A.2). Activities of CABI in the Americas and in Asia are more recent and this trend is not yet apparent there. CABI should look into applying the approach taken in Africa to those two regions to improve the quality and quantity of outputs (see section 10).

Measuring impact of the research has to remain a priority for CABI: addressing this was part of recommendations from the previous review and should remain important for the next five years (see section 9). There has been a strong emphasis at CABI on journal impact factor but acknowledgement by the scientific community is also important. During the 2016-2020 reporting period, almost 60 scientific papers reported in Scopus had more than 50 citations, half of those from publications with an IF lower than 2¹ (Annex 5 A.3). This is not surprising given that CABI's work in agriculture often lends itself to highly specialized journals or books. The reciprocal is also true: a higher impact factor publication is not necessarily followed by a good citation rate (Annex 5 A.3). Metrics on impact should be added to the reporting and CABI should continue to search for the optimum key performance indicator (KPI) to maintain a balance between journal IF and overall impact of the science.

7.2 Stakeholder assessment of cabi's science programme

The following is a brief summary of stakeholders' perception of CABI. More detailed information can be found in Annex 4.

Stakeholders thought that CABI science was good. Many stakeholders thought that CABI could fill the current gap on soils, livestock and grasslands. What was valued by some stakeholders was the communication of evidence-based findings that were accessible and understandable to policy-makers, practitioners, extension agents, and farmers. On gender and socio-economic aspects, some stakeholders thought that CABI could improve on what they have done so far, although most also observed that these

¹ Titles from the most cited ones: "First report and distribution of the Papaya Mealybug, *Paracoccus marginatus*, in Kenya, "Small-scale fly larvae production for animal feed", "Rating consumption of traditional vegetables in Tanzania using the awareness, interest, desire and action (AIDA) model", "Steinernematidae: Species descriptions", "First report of Rhizoctonia disease of lily caused by *Rhizoctonia solani* AG-11 in Japan", "Taxonomic issues related to biological control prospects for the ragweed borer, *Epiblema strenuana* (Lepidoptera: Tortricidae)".

two areas have improved in the last five years. However, there was a strong feeling that evaluation of the socio-economic impacts of CABI science need to be improved.

If CABI no longer existed, most stakeholders said they would greatly miss the organization because of its contribution to their own activities and the collaborations they already have. Several mentioned that the close partnership with CABI, especially its responsiveness to queries, would be difficult to replace. Some would miss the classical biological control science that CABI provides, especially on invasive species. Others would miss the all-round national and international view of invasive species; knowledge and management of new and innovative tools; knowledge and products for plant protection; the instant solutions to invasive species such as fall armyworm that partners were able to access when most needed; and the well-coordinated biocontrol science that is accessible to farmers and which they benefit from.

According to the various responses, CABI plays a very important role both nationally and internationally. This includes capacity building at the national level and improving science infrastructure within the national agricultural research systems (NARS). CABI provides an interface between agriculture and natural ecosystems, and supports sustainable agriculture with particular expertise in biological control.

According to almost all the stakeholders, there is nothing that CABI should phase out. Respondents felt that CABI should take a leading role in taxonomy and biocontrol, though this does not necessarily imply doing all the work in-house. In taxonomy, for example, CABI's role could be as a strong international advocate and in establishing partnerships. Areas that should be continued include capacity building, providing biocontrol solutions to invasive species, and promoting IPM. Another area suggested for CABI to build on was its expertise in digital communication, to become a leader in digital outreach to extension workers and farmers, especially in fragile and unstable areas.

7.3 Scientific collaboration within CABI and with external partners

The Scopus database put together by the review team provided extensive data on the affiliation of each author in a publication as well as additional metrics on collaboration. In general, collaborative publications of CABI scientists from more than one of the five main regions (UK, Europe, Africa, Asia and Americas) has increased fivefold during the review period compared to 2010-2015, which is certainly an impressive achievement (for more details please refer to Annex 5 B). For instance, a publication entitled "Farmer responses to technical advice offered at plant clinics in Malawi, Costa Rica and Nepal" had CABI Africa, Europe, Asia and Americas all involved and has been cited 172 times already, as measured by Scopus. However, the vast majority of CABI's publications are still 'single region' contributions when it comes to the organization's main regions. Yet the network analyses nicely illustrate how much stronger the collaboration among the CABI Centres is these days, compared to just a few years ago. Notably, there are stronger links between the European Centres and those in Africa, but much weaker ones with CABI's Centres in Asia and the Americas. In particular, fostering closer ties between CABI's operations in Asia and Africa could hold great potential, for instance building upon previous successes in biological control operations such as with cereal stemborers.

Using publication output data, the network analyses also revealed much stronger regional collaboration of the different CABI Centres. For instance, CABI's Centre in Kenya over the last five years established many more and stronger links with collaborators from other African countries compared to before. The same is also true for the two European Centres of CABI that have greatly intensified and diversified their regional collaboration during the review period (for more details see Annex 5 B.2). Again here, the data for CABI's Centres in Asia and the Americas are less impressive and there is certainly room for improvement here. The Australian Centre for International Agricultural Research (ACIAR) and the United States Agency for International Development (USAID) are often mentioned in Scopus as funding sources for publications with multiple CABI Centres involved. It is not clear if they were really the major funder, or just happened to be added to the Scopus database. The team did not analyse further those publications involving multiple Centres but their impact, and any success story about funding to be potentially emulated, should be reviewed.

In terms of CABI's collaboration with external partners, the picture is very much dominated by scientists from European universities like the University of Fribourg in Switzerland (24 co-publications in the past

five years), Wageningen University in the Netherlands (21), the University of Bern in Switzerland (19), University of Reading in UK (11), and the Swedish University of Agricultural Sciences (SLU) in Sweden (10), to name a few (Annex 5 B.1). Within Europe, particularly strong partnerships exist with universities in the UK, France, Germany, Switzerland and the Netherlands, and globally with collaborators in the US, Canada and China. This reflects the still disproportionally high publication output of CABI's Centres in Switzerland and the UK that traditionally have very strong ties to UK, French, German, Swiss and Dutch universities but also to US and Canadian research institutes. Among the Global South, Kenyan, South African and to a lesser extend Ghanaian scientists are most strongly represented as authors and coauthors of publications with CABI scientists. Generally speaking, CABI should encourage stronger collaboration with scientists from Asia, Africa and the Americas. Moreover, scientists from other international research organizations, for instance those in the CGIAR, are relatively poorly represented. This probably reflects limited cooperation with such organizations, something that CABI should strategically analyse. It is also notable that very few papers are currently co-authored with scientists from the private sector.

7.4 Social science at CABI

Social science, especially as related to informing CABI's programme M&E, has made significant advances since the 2015 Science Review. One of the high priorities identified in the 2015 review was investment in strengthening economics and social science at CABI, with a view to determining the factors needed to scale up the implementation of promising biological control systems; gaining a better understanding of the adoption of management practices by farmers and their impacts; and further developing CABI's core competencies in plant health. Following on from the science review, the MTS 2017-2019 identified, as a key action, strengthening social and economic science and gender awareness to contribute to its science base. A critical milestone for the MTS, to have six social or economic scientists employed in at least three Centres and 10-15 CABI scientists trained, was met (with the training focussing on gender). Social science capacity has been strengthened through this recruitment of social scientists.

An analysis conducted in 2020, Social Science in CABI, highlights the importance of social scientists supporting biological scientists, to give rigour to lesson learning in the field. It also provides an overview of how social scientists and social research are contributing to the delivery of the four strategic goals2 in CABI's MTS 2020-2022. Many of the contributions are in evaluative research to support project implementation and consider the effects of projects, for instance determining the effectiveness of a specific programme or interventions; considering value for money (economy efficiency, effectiveness, equity); and exploring intended (and unintended) outcomes and impacts. Non-evaluative research that examined stakeholder perceptions (e.g., why farmers make certain decisions, how markets operate) has also been conducted, including feasibility assessments; situation and market analyses; assessments of the adaptive capacity of smallholder farmers; prioritization of interventions; and exploratory studies to understand the occurrence of phenomena affecting behaviour.

CABI now has a much wider set of social science skills than in 2015 and there is more recognition across the organization of the importance of social science in its research and development activities. There is a virtual social science team across CABI Centres and themes that includes socio-economists, data scientists, development communication specialists, anthropologists, M&E specialists, and gender and climate experts. There has also been an increase in the proportion of publications authored by social and biological scientists including articles on impact assessments, economic impacts of invasive species, understanding farmer responses to technical advice, repercussions of policy reform, social network analysis, impact of ICTs on raising awareness, and demand-led extension.

² Goal 1: Improve market access for smallholders to sustainable value chains

Goal 2: Improve capacity for the delivery of climate-resilient food and nutrition security

Goal 3: Help women and young people gain new opportunities from access to targeted, context-specific agricultural information and technology

Goal 4: Promote balanced utilization and conservation of biodiversity and ecosystems

7.5 Climate change science at CABI

Climate change has not been a significant research area for CABI. Aside from noting the greater awareness and acceptance of climate change, there is minimal mention in the 2015 Science Review of climate research or activities except for a passing reference to climate-related pest risks in the programme of the South East Asia Centre and the identification of climate change as a gap in the stakeholder interviews. The 2015 Review did note in the Global Context section that there was optimism that a climate agreement would be reached in Paris in December 2015. This optimism was well founded, the Paris Agreement was signed by over 190 countries, including all CABI member countries. The countries in which CABI currently designs and implements activities are parties to the Paris Agreement and have made commitments to climate mitigation by lowering greenhouse gas emissions, as well as to actions for climate adaptation, specifically for their respective agricultural systems, and to increase agricultural production.

Since 2015, the impact of climate change has emerged as a key global, national, and local interest for agricultural R&D consideration and action. Although CABI's MTS identifies climate-smart agriculture as a major trend and suggests that CABI delivers sustainable intensification and climate-smart agriculture approaches, it is still not readily visible in its programmes and publications. CABI is a relative latecomer and is not at the forefront of climate change related R&D, with a comparatively weak track record on climate change issues. Yet there are expectations by partner countries and donors that CABI will do more. A theme from the member country consultations was 'Building resilience in farming systems so as to mitigate or adapt to climate change and other shocks (climate-smart agriculture).'

Potential access to climate finance is another driver for CABI's interest in climate change. Finance for climate change action is growing and is becoming a major source of funding in the regions in which CABI works. Funding opportunities now anticipate or require that climate change be considered and informs the project, even if it is not its primary focus. While climate change will not be a stand-alone area of expertise in CABI, for climate finance opportunities, CABI must have credibility in climate science, underpinned by solid research and development actions.

In response to the increasing awareness of the potential impact of climate change and the demand to do more, CABI has increased its focus on the impact of climate change on the expansion of invasive pests, diseases, and weeds. Since 2015 CABI staff have contributed articles to publications and journals, and made presentations in conferences related to climate change, focussing on invasive species, climate and cocoa pests and diseases, livestock technologies, and climate-smart pest management (CSPM). The scientific work on CSPM progressed from an initial publication on CSPM as a practitioners' brief, available on the FAO website, to articles in scientific journal.

Recently, CABI has started to invest in climate change. An analysis of Climate Change and CABI was prepared in 2019 and in acting on its recommendation a new staff position for climate change was created. This was followed by a more in-depth climate analysis by the new climate change manager in 2020. However, the actions identified in the MTS and the Strategy on Agriculture and Climate Change (2018-2019) have largely not been acted upon. There is potential for CABI to do far more if, rather than retro-fitting or being an add-on, climate change risk analysis and actions for resilience were explicitly included in project design and implementation, and the contribution to climate adaptation and mitigation specifically identified and monitored. CABI's experience in R&D areas such as climate-smart pest management, invasive species, and early detection/rapid response (EDRR) are transferrable, and could inform and strengthen future climate research initiatives. So far, however, there is an ongoing gap between best practice for the inclusion of climate change in programmes and activities, and the continuation of a 'business as usual' approach in which the impact of climate change is not given the attention needed and expected. To some extent climate change faces similar constraints to gender in this regard: senior management and scientists are supportive in principle, but lack an appreciation of what inclusion of climate change interms of design, monitoring and budget.

7.6 Gender research at CABI

CABI began recognising the importance of gender both institutionally and in its programmes and projects only relatively recently. It was only in 2014 that its gender strategy was developed. In this, CABI

recognizes that "... gender equality is a management issue and the Chief Executive and EMT are responsible for the implementation of this strategy". This shows that internally, CABI management considers gender equality and women's empowerment important for internal development of the organization as well as for scientific work in the field.

While gender-related research was not highlighted in the 2015 Science Review, significant steps have been taken to strengthen CABI's gender awareness and research capacity. The 2016 Science Strategy included significant gender actions to be undertaken including: integration of gender considerations from project proposal writing, and throughout project design and implementation; gender analysis carried out at the start of projects; research questions focusing on topics such as the motivation and drivers for technology adoption by women and men; productivity constraints for women farmers as opposed to men farmers; and the effects of cultural and social norms on project implementation. The Science Strategy also noted the need to recruit new staff and link with partners with gender expertise.

The MTS 2020-2022 sets specific gender objectives including incorporating gender in all project development, planning, implementation, M&E and budget; and gendered measurement of outputs and outcomes, sharing lessons, and evidence on impact. These objectives were to be met through mainstreaming gender within CABI's organizational policies and practices; mainstreaming gender in CABI's programs and projects and developing and implementing gender 'transformative' projects, and supporting evidence generation and learning.

In response to the MTS's recommendations and the expectations of its donors and partners, there has been progress. Gender analyses have been conducted and/or used; gender activities are being built into some projects and proposals; for major programmes gender impact studies are being undertaken; and gender is being incorporated into baseline and endline surveys. Gender staff have been recruited and some comprehensive training has occurred (e.g., Gender and Social Inclusion (GESI)). Internally, gender balance varies widely across different parts of CABI; but even in those Centres where women are well represented among the younger staff, there is a predominance of male senior scientists. However, there are positive changes occurring. In the PlantwisePlus programme, for example, three of four new global leaders are younger women scientists; and this will also position them to compete for other senior positions going forward. Women scientists interviewed during this review reported that they had not personally experienced gender discrimination, and had been encouraged to take the lead in research opportunities.

Since 2015, there has been a sharp increase in publications in which gender has been integrated into the analysis or in which gender has been the primary focus. The findings of articles on a key topic such as access to plant clinics, credit, extension, rural advisory services, and ICT confirm the vital importance of the integration of gender and gender disaggregation in the research. The publications in which gender is the primary focus of the analysis reflect the significant contribution that gender analysis can play in identifying social norms, constraints, and opportunities and informing program design and implementation.

Unquestionably, since the last science review there have been significant changes within CABI which has enriched its research. However, while progress has been made, more needs to be done. The gender assessment of the Plantwise programme, for example, shows that despite its evident successes, gender mainstreaming has been limited: gender equity and equality, and empowerment of women, youth and marginalized communities, are not easy to identify and track in the project outcomes (especially because, in most cases, gender was not considered in the initial project design). CABI has yet to make gender fundamental to its programmes and to shift the perception that gender is an 'add-on' rather than essential for the success of much of its research and development activities.

7.7. Big data research at CABI

CABI has built an impressive range of data infrastructure and skills to handle critical data it has accumulated over the years. By definition data infrastructure encompasses people (data scientists, data stewards and improved skillsets in scientists), process (rules, guidelines, policy), and technology (platforms, infrastructure). CABI databases and compendia are extremely important as they are a significant source of revenue, and by far the most profitable part of the organization. In the words of the

Knowledge Business team, the databases "keep the lights on" in CABI. Using these databases, the publishing business generates a profit of over £4 million annually, which is obviously vital to CABI's revenue stream. These databases and compendia are frequently used by regulators, not only in managing quarantine pests and diseases but also to build additional tools, models and applications. Therefore, it is really important to continue to manage the databases prudently and profitably.

The 2015 science review team recommended (Recommendation 5) CABI to give "greater attention to defining the kind of data needed for significant research on pest and diseases and how collecting such data can best be integrated into Plantwise. Technological advances that would facilitate the collection and validation of research-relevant data should also be further explored". The review team further recommended (Recommendation 17) that "investment is needed in the maintenance and further development of the areas of CABI's core competences in plant health New areas for investment include strengthening capacity to manage 'Big Data' and to make greater use of geographic information systems (GIS)". In their management response, CABI management stated that they were developing an information and data management strategy to define what data they have/need and how to ensure it is well preserved and accessible. The CABI management response also stated that "Big data and GIS are already important aspects of plans for the CABI knowledge business and Plantwise". Accordingly, CABI incorporated these recommendations in its strategy. In its MTS 2017-2019, CABI acknowledged that data management and archiving would become critical, and investment would be needed to capture CABI's data outputs in an accessible and usable way, so that it could be reused and shared as open data. In that regard, CABI is to be congratulated on the very good progress made in internalizing and implementing the recommendations of the 2015 Science Review.

Several of CABI's themes and priority research areas require new and increased data management and numerical skills, including modelling, GIS, application of remote sensing data, bioinformatics and statistics. In that spirit, CABI also recognized the need for recruitment of staff with key expertise in modelling, GIS and data analysis. In the MTS 2017-2019 CABI management stated that by 2019, at least two new positions would be primarily concerned with these aspects. The two positions have been filled since then.

In terms of data platforms CABI is ahead of many players in the field. CABI is now managing big data including the (1) Earth Observation data; (2) Plantwise Knowledge Bank and Compendia; (3) CABI Distribution Database; (4) CABI Data Repository; and (5) Molecular database; and (6) BIOCAT database (see Annex 3). CABI Bioscience's molecular research team generates and works with large databases in their genetic research. Molecular technologies for genome sequencing and gene editing have continued to grow rapidly, are becoming less expensive and more precise. The metagenomics or environmental genomics data is now tightly linked to distribution data of organisms, adding new possibilities to modernize data acquisition for the CABI pest distribution maps. New systems have also been developed for managing and using big data. The 2015 science review team recommended that CABI should explore opportunities for increased outsourcing of its molecular characterization and wet lab work. The review team feels that careful consideration must be given to bioinformatics, given the long tradition of data management at CABI (see section 8.6).

From discussions with CABI staff, the review team learned that future plans include (1) seeking partnerships with big data organizations to deliver CABI projects; (2) keeping knowledge up to date on linked big data technologies such as earth observation, remote sensing, internet of things, artificial intelligence, and machine learning so that CABI can understand potential applications; and (3) increasing core funding to keep developing internal databases and tools to support CABI scientists. We consider that these are welcome developments. However, a coherent strategy for implementing these plans is yet to emerge.

In tandem with data management, CABI has made excellent progress in the application of data-driven innovation and digital technology to help fight agricultural pests and diseases. CABI staff (together with its partners) have applied modelling and statistical tools to develop species distribution models relating invasion levels to economic costs. A good example is the PRISE programme, which was launched in Zambia and Ghana in 2017 and in Kenya and Malawi in 2018. PRISE combines earth observation technology, pest outbreak models and real-time field observations to deliver tailored pest alerts and advice to farmers. It models the risk to crops from insect pests and plant diseases using environmental

data, then creates tailored messages which are made available through CABI's Plantwise network and other local extension services. A chatbot on Telegram, already used by plant doctors, sends weekly pest forecasts. A few days after each alert, users are asked to give feedback, which in future will be used to validate the model and add new data, including tapping into the increasingly important environmental genomics data. This feedback loop means greater confidence in the forecasts. The system now collects and combines disparate datasets, and manipulates data using computational and modelling expertise. The review team would like to commend CABI for this investment.

Another excellent data-driven application developed by CABI is the Horizon Scanning Tool, which supports decision-making and the identification, categorization and prioritization of invasive species threats. Here, information from the CABI Compendia datasheets is used to generate a list of species that are absent from the selected "area at risk" but present in "source areas", which may be chosen because they are neighbouring countries, are linked by trade, or share similar climates. There are two versions of the Horizon Scanning tool available; a premium version for subscribers to the Crop Protection Compendium and a free version for users of the open-access Invasive Species Compendium. One of the key issues the team identified is the absence of mechanisms to track the use of this excellent tool. Therefore, the team feels that there is a need for investment by CABI in awareness creation and training of its partners to ensure greater use of this underutilized but a powerful tool, possibly by teaming up with organisations like the International Plant Protection Convention (IPPC) or regional plant protection organisations. The team also recommends building strong linkages with research institutions, universities, and regulators, especially regional and national plant protection organizations.

During discussions with CABI staff, the team learned that most data collected by CABI are underutilized. The team feels that CABI should proactively engage graduate programmes in universities to make better use of the data, and also popularize CABI's work.

Overall, the team feels that it is important to add analytics widgets to the various databases (e.g. the distribution database) and applications (e.g., BIOCAT, the Horizon Scanning Tool, etc.) to enable CABI to monitor how these products are being viewed by users, and how often they are downloaded, cited and shared via social media (e.g., likes, comments, etc.).

In conclusion, many of the databases and repositories have been built in stages over a number of projects. As many of the projects that supported these outputs close down, there are fears that continued funding may become challenging. In that regard, the review team recommends that CABI develop a strategy and investment plan for data (including big data and data science) to overcome current bottlenecks in funding and ensure visibility, sustainability and greater use (by CABI itself and its clients) of the data that has accumulated and the platforms and data infrastructure built over the years. As big data is likely to become a competitive business, CABI could explore partnerships with other players. CABI should also make greater investment and/or build long-term partnerships supporting capacity and infrastructure to manage and utilize big data, with more emphasis on data science in its regional centres and country offices.

7.8 Implications of the Nagoya Protocol for CABI's research

The Nagoya Protocol (NP) of the CBD came into force in October 2014. It aims to facilitate access to genetic resources and ensure the equitable sharing of benefits arising from their utilization. The previous CABI Science Review in 2015 noted that CABI's ability to access and distribute living material, including plants, plant parts, insects and pathogens, was strongly influenced by the NP. To facilitate working with genetic resources, CABI was engaging with member countries to try to develop mutually acceptable and effective ABS mechanisms that were in line with the NP. Therefore, it was recommended that continued efforts should be made to develop mechanisms for the efficient and effective implementation of the NP, for the benefit of all countries. Further to this, the 2015 review team stated that supporting implementation of the NP was a particular area where CABI could play an important international role. On the other hand, the report stressed that "the review team is not overly confident that it will be possible to reach a satisfactory solution with all member countries in the short-medium term. Nevertheless, continued efforts should be made, especially in association with the Protocol/Treaty Secretariats and others, and ideally going beyond just developing effective mechanisms with member countries but contributing to a workable

implementation of the Nagoya Protocol appropriate for all countries. A significant breakthrough in this area would be of major benefit to countries around the world."

The full impact of the NP on access to genetic resources would have been difficult to foresee during the review in 2015, but in 2020 effects of the NP on ABS have become clearer. In general, the implementation of the Protocol is seen as a big hurdle and an enormous administrative burden for the exchange of genetic resources for research purposes, and for commercial activities ('utilization') arising from such research. This is underlined by many scientific publications. The European Union (EU) has developed a Regulation (No 511/2014) on compliance measures for users of the NP and ABS. Many funding organizations follow the regulation strictly in research proposals where compliance has to be shown. Only in 2021 has sector-specific guidance been published by the EU, which covers aspects of invasive alien species and biocontrol.

Since the 2015 Science Review, CABI has put a lot of effort into facilitation of access to genetic resources and compliance with the NP and ABS regulations. CABI realised early on (in 2010) that ABS could have an enormous impact on its activities, and started to address this issue in publications. It also lobbied for an exemption status for biocontrol in the ongoing negotiations. For internal projects, CABI started in 2015 to work on compliance with the NP by installing 'ABS champions' in its Centres; developing a best practice protocol to be used by all CABI Centres; keeping track of developments on ABS in national and international fora; and generating a good number of publications and presentations at conferences etc. to create awareness and keep the issue high on the agenda, both inside CABI and with relevant stakeholders.

CABI is both a provider and a user of genetic resources, and the NP impacts many aspects of its activities, including biocontrol; collecting natural enemies and antagonistic microorganisms; depositing microorganisms in the culture collection; and trans-boundary movement of organisms for diagnosis and identification purposes. Contacts have been established in many countries, including member countries, and due diligence mechanisms have been set up to comply with (often specific) national rules. Negotiations are continuing, as in some countries it is a very difficult and slow process to come to an agreement. Many countries have not yet set up an efficient internal system to deal with the CBD and the NP, and this causes delays, as well as increasing costs to CABI in terms of staff time. Where possible CABI tries to share benefits through non-monetary mechanisms, such as collaborations in mission-oriented projects and activities. Since many CABI scientists and Centres are involved in these negotiations, CABI should explore whether it would be more efficient to centralize and streamline its administrative activities on ABS within a small international team of CABI staff to minimize or avoid some of these delays and costs. CABI should also develop collaborations and partnerships with like-minded agricultural research institutions, especially those associated with national governments, to help them to consolidate their position at multilateral ABS meetings.

Since 2015, CABI has gained a wealth of experience and knowledge on the NP, including compliance to its rules via best practices; due diligence mechanisms; and negotiations on agreements on prior informed consent (before accessing material) and mutually agreed terms (PICs and MATs) with many countries and world authorities in this field. CABI complies well with the EU regulations on the NP, and researchers have learnt to work with it. This depth of experience is probably unique among similar organizations worldwide, and CABI should investigate where this could provide opportunities for consulting, training of stakeholders and other partners, and potentially engaging with a new group of clients and partners. This could raise CABI's profile in biocontrol research, and therefore strengthen its position with regard to other research organizations. CABI staff expressed doubts about this because of legal consequences, liability and time requirements. Nevertheless, the review team believes that this would be a good chance to expand CABI's network of contacts and to increase its value as a partner in projects; and that the legal issues could be overcome. Training could be easier to organize, but it should not divert resources from research, so a specialist could be appointed to set it up.

A new and as yet unresolved issue in the context of the NP is digital sequence information (DSI). It is still to be decided how ABS rules should be implemented in relation to this subject. This is a very controversial area, which could potentially have a major impact on CABI's activities. CABI is taking part in negotiations in this field on trying to minimize its impact, or to lobby for biocontrol to be exempt from DSI. But CABI is only a small player in such discussions, and allying with other stakeholders, such as the

International Organization for Biological Control (IOBC-Global) and biocontrol industry associations such as IBMA and BPG, could be a way to gain a stronger voice. In the wider context of the CBD, biocontrol is just a small sector, although it will become essential to sustainable crop protection and food security in the near future. The review team recommends CABI to investigate setting up a task force to lobby for this issue at high level within the CBD and the Food and Agriculture Organization of the United Nations (FAO). The positive narrative around biocontrol and the benefits to biodiversity, more sustainable agriculture, the environment, and its contribution to the UN SDGs should be promoted, to avoid innovative developments being severely hampered by the NP.

The review team recommends that CABI stays strongly involved in NP discussions, as an organization which is internationally renowned for developing solutions for crop protection worldwide, both for its own purposes and as an advocate for biocontrol worldwide. CABI's network of member countries is also expected to be influential in this ongoing issue, as well as strengthening CABI's position in the short term. Many researchers worldwide have been trying to avoid NP issues so far, but new genetic resources are becoming ever more desirable, including for the private sector. CABI's unique experience and skills, which are aligned with its mission and goals and the principles of the CBD, puts it in a strong position to work for the benefit of biocontrol products developers, farmers and the growing world population.

8. The future of CABI's science programme

8.1 Integration of social science, gender and climate change

While there has been significant progress in CABI in the appreciation of the value of including social science and gender in research and development activities, for the next period we recommend that strong senior management support and additional investment be directed towards social sciences and gender in CABI's programmes. Social science and gender should be championed, in recognition of their potential contribution to CABI's success and international research standing.

For CABI's success in solving problems in agriculture, environment, and climate adaptation, a new mindset is needed with the adoption of multi-disciplinary teams, which include social scientists (socio-economists, gender and M&E experts) participating in program design, proposal preparation, implementation, and decision-making. More attention should be given to applying learnings to changes in implementation.

A similar change in mindset and steps towards integration is needed for climate change. Climate change will increasingly be a driver for CABI's work, as it exacerbates current vulnerability and results in reduced food security and increased water insecurity. Although not as visible as it should be, CABI is already engaged in building resilience. CABI should not only continue what it is doing, but expand its problem-solving outlook to explicitly address the influence of climate change on plant health, invasive species, soil management, value chains and trade. Given that climate change is already the cause of the movement and emergence of many pests around the world, CABI has an opportunity to market its expertise on CSPM and nature-friendly management of invasive species, contributing effective tools and approaches to this global crisis. This will require enhancing the staff's understanding of the influence of climate change on their work; embedding and highlighting climate change (and, as noted, gender) considerations in projects and programmes wherever possible; and capturing CABI's contribution to climate change adaptation and mitigation.

These proposed changes will require increased staffing, allocation of funding in project design and budgets, changes in programme and project development processes, and stronger internal collaboration. During this review, social science and gender staff noted that there was an expanding demand for their input – a good indicator of growing awareness within CABI of their positive contribution to programmes. However, there was also concern expressed of being overstretched without the capacity to meet this demand, given current staffing levels (e.g. more gender expertise is needed to support all the CABI centres, not only in CABI Africa where the only gender expert is located), and gaps in technical capacity (e.g. foresight analysis and ex-ante impact modelling). This concern is accompanied by an acknowledgement of CABI's reluctance to hire more staff unless their time is covered. For the integration of social science, gender and climate change to move forward, staff time and activities must be

incorporated into projects and interventions by including them in work plans and budgets to ensure that their costs are covered.

Mechanisms for promoting and encouraging collaboration between biological and social scientists are already in place, but could benefit from more attention to sharing and learning. These include establishing a [more formal] social science community of practice (there is not a formal grouping within CABI of social scientists), including social science champions within the CABI Centres, and CABI-wide seminars that would have joint presentations by biological and social scientists on the applied learnings from an assessment or study. Although gender trainings are underway, training and awareness raising on gender and climate risk should be on-going rather than one-off activities, and be strongly supported by EMT. The current proactive hiring of women scientists for positions in which they can assume leadership roles and be well placed for career advancement should be continued and enhanced.

Increasingly, science is evaluated in terms of its impact. The importance of social science, gender and climate aspects in the next phase of CABI efforts cannot be overstated, to maximize the impact of CABI science in improving livelihoods and sustainable management of the natural environment globally. Although CABI's research capacity in biological science is well established, capacity in social sciences, gender, and climate change will need to be strengthened to deliver the planned outcomes at the scale needed, and specifically, to meet the stated aim of CABI's MTS 2020-2022: "... to bring about sustainable economic development, improved livelihoods and better nutrition through greater market access for climate-resilient agriculture in healthy ecosystems".

8.2 Partnerships with the private sector

In the 2015 Science Review it was recommended to explore and strengthen partnerships with the private sector across all CABI Centres; and that CABI should focus on its core activities in biocontrol of alien invasive species.

CABI is renowned for its scientific achievements in the fields of classical biocontrol of invasive weeds and insects, and augmentative biocontrol of weeds and insects. The private sector, specifically the biocontrol industry, knows CABI primarily from classical biocontrol and to some extent from augmentative biocontrol, but that dates mainly back to the locust control product Green Muscle. Biocontrol companies do not operate in these two fields, because pest outbreaks are unpredictable: they prefer to deal with private clients such as (exporting) farmers who will buy products on an annual basis. Smallholders are not usually able to buy bioprotectants and should therefore not be the primary focus in projects with the private sector. CABI 's Centres in Switzerland and the UK do work with the private sector, as do to some extent the Centres in Kenya and Pakistan. However, at present CABI collaborates with only a small number of companies, in long-standing relationships which seem to be based largely on location. During the review process it has not been clear whether the number of public–private partnerships had increased compared to the previous period. To strengthen its relationship with the private sector, CABI needs to recognize its own strengths and weaknesses and seek opportunities to complement biocontrol companies' knowledge and expertise where these are lacking.

The biocontrol industry is developing rapidly worldwide: sales are increasing annually by approx. 17%. Companies range from micro to small/medium (SME) to agrochemical multinationals, and are rapidly building their capacities and partnerships. CABI is a potential partner of interest for some of them in areas where it can offer specific scientific support and expertise, mainly in the early phases of product development (collection of biocontrol agents, screening and field testing) rather than in production, formulation and registration. In order to set up more collaborative projects CABI needs to improve its communication about its specific skills, and to engage with industry associations such as the IBMA and its individual member companies, and other association members of BPG in India, South America and Africa. In the rapidly expanding biocontrol industry, relationships need to be developed within the next three to five years to take advantage of current developments. However, micro and small companies are generally not able to cooperate in such partnerships, and multinationals tend to keep developments inhouse, so medium-sized companies offer the best prospects for partnerships. To build relationships with the biocontrol industry, we recommend recruitment of a key account manager with a global remit for the biocontrol industry, with a science and industry background and a wide network to foster and coordinate these partnerships. It would be beneficial to both CABI and the private sector if this key account manager

is also knowledgeable on the NP and ABS topic (see section 7.8) and could assist companies in compliance with the NP.

CABI also wants to strengthen its relationship with private partners in the Value Chains and Trade theme, as mentioned in the MTS 2020-2022. However, this was not addressed during the review. Whether this is beneficial to CABI itself is doubtful; in specific sectors it could be valuable, such as in post-harvest problems and aflatoxin management, although CABI would need to rebuild some of its mycology expertise or build partnerships in the latter.

CABI is involved in a very large number of projects, which seems hard to manage. A focus on core competences (weed and insect control) would make this easier for the researchers, as well as making CABI's areas of expertise clearer to potential private partners. Additionally, specific knowledge and technologies in CABI will benefit partners in collaborative projects. Examples are identification or detection using DNA sequencing, and MALDI-TOF analyses if this technology becomes used significantly beyond clinical laboratories like DNA-based detection and identification (see section 8.6). Other research areas that could be of major interest for companies include microbiome and soil ecology studies. The culture collection, with its many pre-Nagoya Protocol strains, is another valuable asset in partnerships, as is CABI's deep knowledge and wide network of contacts regarding the Nagoya Protocol negotiations.

Collaborations with companies should focus on medium-sized organizations with a global approach, as this corresponds best with CABI's global activities and would also allow CABI's Centres to take part is such collaborations. Companies would greatly appreciate this potential extension of their markets. Information from the PlantwisePlus project could also assist companies in market development. With regard to funding, CABI should develop project proposals jointly with partners from the outset, whether for national or international funding sources. It should not expect companies to finance projects themselves, as their budgets are usually not appropriate. Working relationships which generate revenues from sales are more likely to be acceptable to industry, although expectations on incomes should be moderate. Publication of results of public-private research projects is often perceived as a bottleneck, however there are ways around that such as delaying publication until a patent is filed, and leaving out details of production and formulation.

In summary, the review team believes that the time is right for CABI to further develop partnerships with the private sector in biocontrol projects. However, CABI should also have realistic expectations in terms of revenues from such projects. As discussed above, medium-sized companies seem to offer the best prospect for partnerships, but such projects will only provide limited extra income as the biocontrol markets are relatively small niche markets due to their specificity. Nevertheless, those partnerships would result in more research, exchange of knowledge and in sustainable solutions for farmers. They would give CABI more exposure to and trust from the biocontrol industry, which would in turn stimulate support for the BioProtection Portal. This would be beneficial not only to CABI, but also to biocontrol companies and to farmers around the world. Strong private sector partnerships would also have a political benefit, by enhancing CABI's standing with many donors.

8.3 Future research partnerships and collaborations

During the last five years the 'One CABI' agenda has advanced considerably. As mentioned in the previous sections, inter-Centre collaboration has substantially increased, as illustrated for instance by more joint publications and projects (for details see section 7.1 and Annex 5). This is particularly true with regard to stronger links within the European and African Centres as well as between Europe and Africa. However, the Asian Centres and those in the Americas are still not well enough integrated. The team sees a real opportunity to advance the One CABI concept by strengthening such partnerships, especially in terms of more South-South cooperation.

Over the years CABI has established some excellent and highly productive collaborations with a number of well-respected universities and research organizations, particularly in Europe and North America. This has had a very positive effect on both project acquisition and academic publishing. However, this is only partially true for CABI's partnership with universities in the Global South. Here, this review team sees a lot of possibilities for enhancing collaboration and partnerships. For instance, universities in Africa are comparatively under-represented in many of CABI's programmes on the continent (Annex 5 B.1). Against

the backdrop of the improving performance of a number of universities in Africa, for instance the members of the African Research University Alliance (<u>https://arua.org.za/</u>), there should be ample opportunities for strengthened partnerships.

Traditionally CABI has always excelled in terms of partnerships with national partners, especially those from member countries. This review team was impressed by the level of cooperation with national partners and would strongly encourage CABI to pursue this strategy. This is clearly one of its unique selling points and sets CABI apart from many comparable international organizations.

Unfortunately, the same cannot be said of CABI's collaboration with the private sector. Thus, this review team sees a lot of potential in strengthening and expanding public-private partnerships (for more details see section 8.3).

Another focus area for enhanced collaboration in the years to come should be with international organizations like the One CGIAR and other international R&D organizations. This sector is going through a substantive consolidation process, driven partly by the desire of many large donor organizations to create economies of scale in terms of their investment policies, especially in Africa. With its unique strengths in plant protection, information dissemination, modern extension tools, and big data, to name a few, CABI should be in a prime position to become a sought-after partner in many of these developing consortia. However, instead of waiting 'to be asked to dance', CABI should actively pursue or better even initiate such opportunities.

8.4 Future role of CABI's Chief Scientist

In 2021 CABI's chief scientist Matthew Cock will retire from the organization. The CABI management and Board will soon need to decide whether to recruit a replacement, and if so, to define the terms of reference for this position and how it should be positioned within the organization. This review team is very impressed by the strengths of CABI's science programme, especially how much the guality and number of scientific publications and datasets have improved since the last review in 2015. Even the reporting format of scientific outputs has kept improving every year since 2015. No doubt this is, among others, also an accomplishment of Matthew Cock's work as CABI's chief scientist. Hence, we strongly believe in the necessity of such a position in CABI, and its value in steering the organization's science agenda in a changing world. As stressed several times in our report, the global landscape in which CABI operates has substantially changed since 2015. Thus, a future chief scientist or science director at CABI will face new and additional challenges, particularly in areas such as reinforcing existing and establishing new partnerships, but also in setting the R&D agenda and in science and development advocacy. The position therefore needs to be considerably better resourced than at present, to enable the Chief Scientist to provide dynamic leadership and real guidance to CABI's science programme, and to make substantial contributions on behalf of the organization to important present and future discourses in areas such as climate change, emerging infectious diseases, food security, global gender and socio-economic inequality, and sustainable resource use. In short, if CABI intends to participate in these high-level discussions, for instance in the context of the NP and ABS, it will need to equip its new chief scientist or science director with adequate means and operational support to do so. The new CEO and the Board also need to position the organization within the One CGIAR environment, which has the potential of changing the donors' landscape in a major way.

8.5 Emerging new R&D areas

The review team undertook analysis of titles and keywords of CABI publications over the past 30 years to better understand the trends in CABI's research areas, and to provide some suggestions on where to possibly go from here. The following are areas of research that CABI could consider in the future: they are not firm recommendations by this review team.

Publications from CABI as a whole have transitioned from a heavy focus on mycology and taxonomy to biological control and management of invasive species, with more emphasis on insects and weeds than before (Annex 5 C.1). This transition is particularly noticeable in publications from the UK Centre. The CABI Africa and Asia Centres have also emerged as more important contributors to scientific publications, and the R&D from those Centres is increasingly focussed on more applied studies, closer to the end

users. Interestingly, when assessing the trends in topics of higher quality publications, as measured by journal IF and/or number of citations, the words 'risk' and 'impact' become more prevalent in those higher quality publications than in the bulk of publications (Annex 5 C.2). Publications about risk and impact become also more prevalent during 2015-2020, compared to the previous five years. Although R&D on biological control and invasive alien species are clearly key strengths at CABI, the trend to have more R&D on evaluation of risk and impact should continue, given that such work is also important to address questions raised by donors and stakeholders. This area of research can provide both high quality publications and scientific evidence to support to CABI's efforts to convince donors of the merit of their work (see also section 8.1).

Molecular Biology and Genomics: The importance of these areas was often mentioned during interviews, and they have become increasingly significant over the past few decades in all R&D institutions devoted to agriculture, including regulatory agencies (and was also raised as a concern by CABI staff with regard to recent developments related to DSI in the context of the NP - see section 7.8 for more details). CABI has limited capacity in molecular biology and genomics, as shown by the small number of publications in these areas, but this is understandable given the scale of investment that it requires. It is late in the game for CABI to become a leader in these areas, and investments in technology development projects without very strong partners should be avoided. Whether or not CABI decides to support in-house wet lab molecular testing and genomics (see section 8.6), there is no doubt that the quantity of genetic information to analyse, even for pest impact and risk studies, will continue to increase exponentially. CABI should therefore consider developing a bioinformatics strategy to handle the genetic data needed for its core activities, and to complement their existing strengths in data management and pest distribution mapping. There are many major microbiome and biological observatory projects around the world generating large amounts of environmental genomics data, and this creates a major opportunity for CABI to add new layers of data to their pest distribution maps. Moreover, when new invasive species emerge, it is very likely that there will be DNA sequence traces of those emerging threats from metagenomics studies. It is imperative for CABI to acquire expertise of their own to analyse the increasingly large amount of molecular data, define species boundaries in collaboration with taxonomists, and extract distribution data from such microbiome and metagenomics datasets. The Dutch National Plant Protection Organization is a world leader in the usage of DNA barcodes and related training for regulatory diagnostics (e.g., Quarantine Barcode of Life project). Given the strong linkages between CABI and Dutch organizations, there is good potential to develop international projects on diagnostics.

Invasion biology and emerging infectious diseases: The current COVID-19 pandemic has shown the strong link between environmental degradation and the emergence of new, most-often zoonotic infectious diseases. CABI with its decades of work on invasion biology and biology of invasive arthropods, pathogens and higher plants should be in a prime position to make meaningful contributions to this ever-growing field of research.

Climate change: CABI can bring to climate actions a history of over 100 years engagement in agriculture and food security, and a reputation for scientific rigour, evidence-based research and extension. CABI should play a leading role in CSPM to ensure that pest management is ready to either prevent or withstand pest invasions, and to manage existing populations that are increasing in number.

Holistic impact assessment research: To effectively pivot its programmes to be more effective in the uptake of good agricultural practices and anticipate potential barriers and opportunities, CABI should consider increasing its inclusion of social science and gender in its research. CABI is in the position to apply the learnings from its social science research to on-the-ground interventions generating meaningful results.

8.6 CABI Bioscience

The Bioscience group is unique within CABI, as it provides microbiology and molecular services, maintains the microbial culture collection, and is involved in applied microbiology research. The previous review recommended putting further investments in this area on hold until cost-benefit analyses and partnerships, as well as out-sourcing options, were evaluated. CABI is now undergoing such a review of CABI Bioscience, a separate exercise from the present science review, and the points below were written without having seen this internal review.

CABI Bioscience research and services are cross-cutting, providing molecular identification for insects, weeds, fungi or bacteria, maintaining microbial strains of pathogens and biocontrol agents, as well as being involved in microbiome research, including cryopreservation of samples.

Since the advent of PCR about 30 years ago and high throughput or next generation sequencing (NGS) about 15 years ago, taxonomy, characterization of microbes and environmental microbiology using DNA sequences have undergone transformative changes and moved at a very fast pace. Instruments can become obsolete guickly and economy of scale is critical for core service laboratories to maintain and replace equipment. Moreover, a critical mass of staff must remain on top of technology developments and must be skilled in handling very large amounts of data. Some level of automation in sample and data processing in both the 'wet' and 'dry' labs is required to support and use effectively those highly qualified human resources and this requires some computer programming skills. Without some automation it will be hard for CABI to provide and maintain cost-effective in-house molecular services. One option is to have the different CABI Centres prepare 'ready to load' samples to be sent to CABI Bioscience where the Sanger or NGS DNA sequencing equipment is located. Yet this will work only if the regional centres really need their own molecular laboratories to perform routine tests such as direct detection by PCR of organisms which are almost impossible to identify (e.g. pest and beneficial insects at the egg stage), or pathogenic and beneficial microbes. Therefore, as part of an internal assessment, CABI must decide if some level of molecular capacity is desirable and feasible in other centres. If the infrastructure in UK is not used by several CABI Centres or CABI research groups, external services with partners should be considered as the alternative to in-house services.

Maintaining an in-house infrastructure for molecular testing. CABI must consider carefully the full cost of maintaining DNA sequencing and MALDI-TOF MS infrastructure, including depreciation of equipment, service contracts, and maintaining a critical mass of proficient technical staff, all essential if several laboratories are dependent on timely identifications or detection. DNA sequencing has become a routine technique for both identification and detection of organisms in environmental samples, and some inhouse capacity may be desirable given the wide acceptance and use of this technology. The very significant benefit of such wide acceptance is the exponential growth of reference databases and environmental data for meaningful identifications and comparisons which are very much aligned with the traditional role of CABI in providing diagnostics and distribution data on pests. The MALDI-TOF MS technology, on the other hand, is not at this maturity for identification and biome characterization, especially outside the clinical world. It is hard to see how it will ever have the same level of accurate and broad digital comparison as DNA sequences. Given that CABI Bioscience appears to be using MALDI-TOF MS for applications that are not mainstream in agriculture or environmental science, a 'go/no-go' decision point should be set in the not-too-distant future to decide if commercialization is successful and if CABI should maintain any MALDI-TOF MS in-house capacity instead of out-contracting.

Bioinformatics: This is another area where infrastructure is expensive and must be upgraded on a regular basis, and where highly qualified staff with computer programming skills are essential. Bioinformatics data storage and analysis capacity will be critical, whether or not the data is being generated in-house. Therefore, CABI Bioscience must continue to establish partnerships, including possibly one with a cloud service provider, to make sure that its research and databases capitalize on the exponential growth of genome and environmental genomics data worldwide. It is not desirable for CABI to generate its own bioinformatics infrastructure given the cost of maintenance and the high depreciation. There should be some staff capacity on the research support side, but research capacity in bioinformatics *per se* may not be desirable at this time as CABI scientists would not have any in-house or long-term partner infrastructure to work with.

Culture Collection: CABI no longer has a critical mass of taxonomists to keep a large, well-curated collections like the Westerdijk Institute or the Agriculture and Agri-Food Canada (AAFC) Canadian Collection of Fungal Cultures (CCFC). Because of its long history, the CABI collection does have many unique strains of great value to the scientific community. CABI should try to obtain Sanger sequences on all strains, something that Westerdijk and CCFC recently secured and completed. It does not require a large bioinformatics infrastructure or large amount of DNA extracts like whole genome sequencing does. Rather it is fast, relatively cheap, and would help a lot in characterizing the collection, providing solid guidance on what to do next, even if a barcode like ITS (internal transcribed spacer) is not perfect in terms of taxonomic resolution. However, it would provide solid guidance on what to do next. Many pre-Nagoya

strains with biocontrol potential would be found for example, providing much better background data for possible public-private partnerships. The next group of strains of importance would be those ITS sequences found in environmental metabarcoding but not in reference databases, helping to resolve potential trade conflicts. Those strains would be easily identified as highly desirable for purchase by some researchers. However, it should be pointed out that sales of strains will only cover a rather small portion of all the expenses associated with the maintenance of a large culture collection.

8.7 Ethical implications of CABI's research and development activities

Ethical policies and ethical clearance procedures formerly tended to be mainly in the domain of health and public health research. However, it is increasingly common that also in other disciplines, including development research, ethical considerations are becoming a key issue to consider and include at the design stage of new activities, projects etc. Public and charitable funders, as well as scientific journals, increasingly require an ethical clearance. Consequently, more and more international R&D institutions are developing specific ethics policies and establishing clearance procedures. We therefore recommend CABI management to consider the development of a comprehensive ethics policy and establishment of the necessary procedures, including setting up an ethical clearance committee. This is particularly important for field-based research and development activities, especially any involving potentially vulnerable people or children. Key issues to consider are (i) confidentiality, by taking the necessary steps to preserve anonymity and keep data secure; (ii) consent, by recognizing that consent must be informed, voluntary, and made by a competent individual; (iii) children, as working with them requires consent from the child as well as from their parent/guardian, (iv) vulnerable and dependent persons, by establishing clear guidelines on how consent is to be taken from vulnerable (e.g. politically/economically marginalized) and dependent (e.g. females in certain societies) persons; (v) environment, organisms, animals and plants, by defining measures to protect animals, plants and ecosystems, including genetic resources, and to reduce the impact of the research upon the environment; (vi) integrity, by using appropriate techniques, and reporting findings accurately and truthfully; and finally (vii) feedback, by explaining how findings will be used, and how (as appropriate) findings will be shared with participants.

Since various institutions in the development field have already designed appropriate and effective ethics policies, we believe there is no need for CABI 'to reinvent the wheel'. Rather, CABI should scan the landscape of existing policies and 'assemble' the most appropriate one for itself. Good examples would be, for instance, the ethics policy of the School of International Development at the University of East Anglia, or the one from the Institute of Development Studies (IDS) at the University of Sussex, both UK.

9. CABI Knowledge Business

CABI's publishing business has done an outstanding job over the years in expanding its product base and related services. Many of these products and services now play a vital role in CABI's science strategy and in global agricultural research and development. In that regard, CABI is to be congratulated on the very good progress made since the last review in 2015. Important areas where progress has been made include CABI's contribution to open data and open access, and databases and data communication.

9.1. Open data and open access

In its Science Strategy (2017-2019), CABI undertook to ensure that the knowledge it generates and the information and data it collates are communicated and shared through open content, open processes and open infrastructure. This is a welcome development: as donors and research institutes continue to introduce policies and guidance for implementing open data³, researchers are now required to respond to multiple requests and requirements. CABI has shifted to new opportunities for open access, in order to enable data from the research conducted to become more easily available to more people around the

³ Smith F, Fawcett J and Musker R. 2017. Donor open data policy and practice: an analysis of five agriculture programmes. *F1000Research* **6**:1900. (https://doi.org/10.7490/f1000research.1115013.1)

world. Using its expertise, CABI has provided support to changes in policy and practice with regard to data use and data sharing in line with the concept of FAIR data. CABI also hosted the Global Open Data for Agriculture and Nutrition (GODAN - <u>https://www.godan.info/</u>) Secretariat focussing on advocacy to promote open data and data sharing, and building on its experience with advocacy and think tanks. This led to interest from the Bill and Melinda Gates Foundation (BMGF) to commission CABI to help them support data sharing more systematically in their agricultural development programmes. As a result of this, CABI has supported institutions in Kenya, Rwanda, Tanzania, Ethiopia and India to address the core constraints to data utilization. CABI has also made good progress in supporting development of data sharing policies in several countries.

Nevertheless, there are still significant challenges (and misconceptions) in data sharing, owing to the perceived sensitivity of data on pests and concerns about impacts on international trade. This appears to be a major obstacle in implementing biosecurity measures, and to publication of environmental genomics data requiring upload in GenBank with sample origin information. Using its expertise and global influence, CABI should support changes in policy and practice with regard to data use and data sharing, such as the FAIR concept of data. This kind of policy work is in line within CABI's broader open agriculture approach, and needs to be pursued vigorously. CABI should also promote greater recognition of, and rewards for, the work on data, which is currently not at par with that afforded to scientific publications in peer-reviewed journals. In that regard, CABI needs to develop new metrics comparable with those used for scientific publications to promote better data management and sharing, as well as career-relevant metrics for scientists that both CABI and its funders can apply uniformly.

9.2. Databases and data communication

CABI Knowledge Business publishes a number of databases and resources including CAB Abstracts, Global Health, Internet Resources, print journals and Thesaurus, and Compendia, among other things. However, there is a fear that these products are at risk as users, including students, now increasingly go straight to Google Scholar.

CAB Abstracts - This is one of the largest databases maintained by CABI. Its abstracts consist of life science A&I services, containing over 10 million abstracts and 500,000 full text articles. This is a high value product sold directly and via intermediaries (EBSCO / Clarivate / Ovid), and it is the most important revenue generator; in 2019 CAB Abstracts accounted for over 71% of the revenue from the CABI Knowledge Business. The review team was informed that its future focus is on maintaining profitability via efficiencies, and developing technology to allow added value tools and analytics.

Global Health - Global Health is another product focussing on public health content including topical news. In 2019, Global Health accounted for over 11% of the revenue from the Knowledge Business. Although there was a downturn in book sales, income from the sales of the Global Health database continued growing by 7% with an upward trend in 2020. Notably, from early 2020 to August 2020, CABI made over 17,000 relevant coronavirus records from Global Health and CAB Abstracts available for free to support the international effort to fight the outbreak of COVID-19. This move was a welcome contribution given the urgent information needs of public health professionals, researchers, academics and policy makers to respond to the unfolding outbreak.

Internet Resources – These comprise a series of contents including abstract records, compendia datasheets, and some book content. They are subject to review because some are more successful than others, although all are profitable given their 'spin-off' nature. In 2019, Internet Resources accounted for over 8% of the revenue from the Knowledge Business. The review team was informed that the Knowledge Business is pursuing better ways of creating subject-based products from internet resources in the future.

Print journals - This product consists of 30 titles. The review team was informed that this product accounted for 10% of the revenue from the Knowledge Business in 2019. Nevertheless, it is feared that these products may experience significant attrition as libraries dispense with print, so their future is uncertain. In view of this, the Knowledge Business team needs to develop a strategy if it wants to maintain this service.

Thesaurus – This is a world-leading standard vocabulary that mainly supports CABI's abstracts products. Although it is a product in its own right, its main value is in underpinning other CABI publishing products. The review team was assured by the Knowledge Business team that this product is poised for further improvement to increase sustainability and modernize data structure.

Compendia - The CABI compendia consist of reference datasets for research and practitioner use, providing information on crops, pests, species and geographical distribution data. There are six compendia varying in size and revenues. The Invasive Species Compendium is project-funded and an open access product, attracting over 2.3 million visits per annum. The other compendia are subscription products, with the Crop Protection Compendium being the largest. The review team was informed that these compendia are the bedrock of CABI's new tools and applications. Tools built on the compendia data include the Horizon Scanning Tool and Pest Risk Analysis tool. Historically, the focus has been on commissioned datasheets, but emphasis is now shifting to acquisition and loading of datasets. This is anticipated to increase the comprehensiveness and value of the products, and improve future potential for data licensing.

CABI Books - The Knowledge Business produces predominantly monographs and some textbooks. In 2020 alone, CABI published 72 books in print and e-book format. In total 19 books were produced as open access books. These are a critical resource, especially for students in the developing world, and given the state of many African libraries.

The agriRxiv reprint services - Preprints enable rapid sharing of research finding before they go through peer review process. CABI publishing provides a preprint service for agricultural research dubbed agriRxiv. This product was launched on 1 June 2020 in partnership with Open Access India, with >80 preprints. Initially, this was called Agricultural One launched by Open Access India in 2016/17 on free software from the Center for Open Science (COS) in the USA. When COS started charging in early 2020, CABI took over the hosting and migrated it to CABI. Currently, agriRxiv represents the only preprint service for agriculture offering a free, citable and shareable version of a draft manuscript prior to peerreview. There is no fee to post or to read content on agriRxiv. However, uptake has been quite low, and CABI is not making any money from it at present. The review team is not yet clear about the future of this service, but it was informed that CABI is presently seeking funding to support outreach.

In addition, the Knowledge Business also produces the Plantwise Knowledge Bank, the Plantwise Factsheet App, and the Plantwise Online Management System (POMS). The Knowledge Bank is a gateway to practical online and offline plant health information, including diagnostic resources, best practice pest management advice and plant clinic data analysis for targeted crop protection. The Factsheet App is a condensed, practical information source for plant doctors and extension workers with step-by-step instructions on how to recognize and manage a crop problem. POMS provides data management support allowing partners to input, store and manage information from Plantwise plant clinics. The CABI knowledge team is also planning to embedded digital learning in PlantwisePlus. The team has already created e-learning packages on crop pest diagnosis and management.

The Knowledge Business also maintains the BioProtection Portal, now available in nine countries. This is a free online tool that enables users to discover information about registered biocontrol and biopesticide products around the world. Available online, with an offline version coming soon, the portal helps growers and agricultural advisors to identify, source and correctly apply biocontrol and biopesticide products against pests in their crops. The portal was developed using mixed funding sources spanning several donors and corporate partners. The team is not clear about the future funding prospects for this product.

The Knowledge Business team has also been running workshops in many countries, including Tunisia, Saudi Arabia and China on how to get research published. There is an opportunity for CABI to re-educate scientists on how to do better science with research protocols, proper structure, sound methodology etc., and so get their research published.

9.3. CABI Agriculture and Bioscience Journal

In early 2020, CABI launched the Agriculture and Bioscience Journal, an open access journal in collaboration with BMC (Springer-Nature). This journal was conceived to have a standard similar to PLoS One, and to be funded through article processing charges. The journal offers a full waiver for low-income

countries and a 50% waiver for lower-middle income countries. At the time of writing this report, the journal has published so far 16 articles, aiming for 90 articles in 2021 and 135 articles in 2022. A critical challenge for the journal has been the difficulty to recruit regional editor-in-chiefs, section editors and associate editors especially from Africa, and to attract many scientists to publish in it. Two critical challenges still remain in attracting scientists to publish in this journal, i.e., the relatively high article processing fee and the lack of an impact factor. As such the journal was unable to attract contributions even from CABI staff (so far only 2 vs corporate target of 5). The criteria used by the UK Foreign, Commonwealth and Development Office (FCDO) for bonus payments to CABI depend partly on a certain number of papers in journals with IF > 2. This is perceived to deter CABI scientists from publishing in this journal. The team therefore recommends that CABI management engages with FCDO and explains to them that the IF requirement is creating problems. The team recommends encouragement and motivation of senior CABI scientists to support the journal, for instance through reviews and meta-analyses of topical issues in agriculture, as well as strong publicity and media coverage of newsworthy articles published in it. There are many highly cited publications that were not in high impact factor journals (see Annex 5 A.3). therefore, CABI authors of manuscripts destined to lower impact factor journals that are likely to be cited heavility should be encouraged to publish in this new CABI publication. If this is really important for CABI, CDF allocations for preparation of such manuscripts could be given a high priority (see recommendation 11).

9.4. Impact factors, and other performance indicators

The team recognizes that science quality in CABI is often judged by the number of articles published in international refereed journals, and more specifically those with an IF > 2. Recommendation 9 of the 2015 Science Review emphasized that "not all stakeholders regard publication in high IF journals as being the most important indicator. Many are satisfied to see CABI science quality measured by publications in lower IF but well respected national and international peer-reviewed journals, and give more importance to citation analyses as evidence for the relevance and utility of the science".

Since the 2015 review, CABI has performed well in terms of its publications record by devising incentive schemes for scientists to publish in journals with IF > 2 (see section 7.1 and Annex 5). However, CABI is yet to come up with a metric that measures evidence of the relevance or utility of the publications. CABI will also benefit from developing alternative and composite metrics, where several factors are combined into a single index. An example could be a "social impact factor" that is optimized and does not disadvantage scientists from lower/middle income countries. However, the Knowledge Business team felt that this would be a big undertaking and perhaps should apply for funding to develop such a metric, possibly in cooperation with the International Network for the Availability of Scientific Publications (INASP).

There is a growing pressure from the donor and development community to improve the ways in which researchers and the outputs of scholarly research are evaluated. To that end, DORA⁴ was developed in 2012 during the Annual Meeting of the American Society for Cell Biology in San Francisco. Since then, DORA has become a worldwide initiative covering all scholarly disciplines and all key stakeholders including funders, publishers, professional societies, institutions, and researchers. To date, over 17,000 individuals and 2,141 organizations in 144 countries have signed DORA⁵. The signatories including many of CABI's donors and funders including the BMGF, EU, UK Research and Innovation councils and many of the universities with whom CABI partners. Signatories support the adoption of new policies and practices for hiring, promotion, and funding decisions. Signatories also support reforms in research assessment including the responsible use of journal IFs as the main measure to assess of the quality of individual research articles, an individual scientist's contributions, or in hiring, promotion, or funding decisions. This development will have implications for CABI's performance indicators in relation to the

⁴ <u>https://sfdora.org/</u>

⁵ <u>https://sfdora.org/signers/</u>

FCDO funding and incentives to staff. Therefore, the team strongly recommends that CABI signs up to DORA and implements the necessary reforms.

10. Incentive structure for publications

To implement one of the Science Strategy recommendations, in 2017 CABI launched the Scientific Publication Recognition Scheme after consultations with a number of CABI scientists and Centre Directors. This scheme was meant to decide how best to acknowledge the high-quality research that is being carried out by CABI staff.

In 2017, three awards were proposed:

1) Award 1: The CABI staff member with the largest number of authored / co-authored papers in journals with 2016 IF>2 in the previous year;

(2) Award 2: The CABI staff member who has published a paper as first author in the highest impact factor journal in the previous year;

(3) Award 3: The CABI staff member with a paper (authored / co-authored) published since 1 January five years previously with the largest number of citations on Google Scholar, as established on 31 December the previous year;

(4) Award 4 (added in 2019): The CABI staff member with the largest number of authored / co-authored papers with a socio-economic focus in journals with IF>2 in the previous year;

(5) Award 5 (added in 2020): The early career CABI staff member with a first author paper in the journal with the highest impact factor.

Each winner received £2,000 to be spent as the awardee saw fit within overall CABI work plans, potentially including items such as staff time, equipment, consumables, reference materials, student assistance, or attending a scientific conference. So far, the beneficiaries of these scheme have mainly come from the CABI Swiss and UK Centres, mostly well-established researchers but fewer young scientists. The review team believes that (1) the award schemes need to be popularized among young scientists; (2) a regional award structure needs to be created to create a level playing field; and (3) equivalent remuneration does not exist for data scientists and this needs to be explored. By reviewing the awards programme in these ways, CABI would support and facilitate the behavioural changes required to implement the new developments, incentivize people involved in data, and justify new hires. Regional awards should also be considered to sustain the progress that has been made, especially in Africa, and to foster the same impressive output growth, in both quantity and quality, in Asia and the Americas as well. New metrics may also need to be devised to promote better data management and sharing, and career-relevant metrics for scientists that both CABI and its funders can apply uniformly.

The 2015 Science Review recommended that the costs associated with publishing research should be included in funding proposals to donors whenever possible; both staff time and the cost of publishing in open access journals should be included. In that regard the 2015 report specifically states that "We see the provision of assistance and incentives for staff to publish more and higher quality research papers as an important means of strengthening CABI's research reputation and culture). Thus, we believe that greater efforts should be made to cover the cost of publishing research ...". In that regard, CABI has modified its project development and project management systems to make sure that the resources to publish are considered and as far as possible included (staff time and open access fees). CABI has allocated CDF to provide staff time to prepare and publish papers 'left behind' by legacy projects. The review team was also informed that CABI has (1) set aside a CDF budget to support selected synthesis and vision leadership papers, (2) set a target of all CABI first-author papers made open-access, (3) tasked projects to include the resources for this when possible, and allocated core and CDF resources to cover this when projects cannot, and (4) this has led to a 95% success rate in getting these papers published open access. In summary, while the award scheme and the use of CDF to support publication have clearly been a success, CABI should consider further increasing the use of the CDF to keep the overall momentum on quantity and quality, as well as the further support of young scientists and regional centres where improvements are needed.

11. Conclusions

The review team was impressed by the progress CABI's science programme has made since the 2015 review. Most of the recommendations of the 2015 review have been successfully implemented, and several of the institutional changes like the development of a distinct CABI Science Strategy have been bearing fruit, as evidenced by the substantially improved scientific output of the organization.

There has been also considerable progress in terms of advancing the One CABI agenda with more and stronger inter-Centre collaboration than in the past. This was particularly true for stronger cooperation, in terms of joint project development but also in scientific publications, between the two European Centres and between them and CABI Africa. However, the linkages among the CABI Centres in the Global South are still relatively underdeveloped, and there should be ample opportunities for closer cooperation, for instance between CABI's operations in Asia and Africa.

The team was similarly impressed with the level of job satisfaction by all CABI staff we talked to. CABI has done really well in maintaining a loyal core of highly motivated and competent scientists, a significant achievement under its challenging funding environment. However, we believe there is need for a scheme of service/career progression, as well as a policy/ human resource manual to help especially young scientists project their career path. This manual should help to maintain and even improve this loyalty and motivation of the highly qualified and competent personnel.

Over the last five years CABI has tried to advance its footprint in the fields of social science, gender mainstreaming, and climate change. The team acknowledges and appreciates these efforts, but concludes that more needs to be done for the organization to become a meaningful player in these very important areas. This will necessitate further strategic investments by CABI in terms of recruitment, integration of these areas into programme planning and development, and appointment of women in decision-making positions; but also, additional measures to incentivize interdisciplinary collaboration within CABI.

A review of CABI Bioscience is currently underway. The committee put together some considerations regarding this review and outlined some of the options that should be considered (see section 8.6).

Despite some efforts CABI's links to the private sector are still rather weak. The review team recommends the organization to prioritize private-public partnerships in specific areas such as biological control. CABI has great expertise and knowledge on negotiations on compliance with the NP and ABS rules, and should explore possibilities to exploit this for consultancies to companies. This would also strengthen its relationship with the private sector.

Another area that holds great promise, as already highlighted in the 2015 review, is big data.-In terms of data infrastructure and platforms, CABI is ahead of many players in the field. Its databases and compendia are also being efficiently used to build other services, applications, models and decision support tools for use by regulators managing quarantine pests and diseases. However, progress has been relatively limited in some areas such as data science, although CABI has strengthened its in-house capacity in data analytics. This is especially true for bioinformatics where a comprehensive strategy is urgently needed, particularly for metagenomics and/or ecological studies. This is crucial if CABI wants to continue be a global player in pest distribution data and diagnostics, and to work in partnership with regulatory organizations.

We think that CABI should maintain and continue to strengthen its science programme. However, we also believe that the organization would benefit from a stronger focus on its core disciplinary strengths, which we see in areas such as biological control, integrated pest management (IPM), data and information management, capacity building and training, while also developing greater capacity in social science and climate research. Moreover, the landscape in which CABI is operating in is undergoing massive changes. At the time of writing this report, the long-term impact of the COVID-19 pandemic is still unclear. However, it is reasonable to assume that it will significantly affect CABI's operations due to shifts in donor funding, but it may also create new opportunities aligned with CABI's strengths in distribution, diagnostics and mitigation of invasive species. Thus, we believe that it will be prudent for CABI to develop an investment plan; develop new partnerships and re-evaluate existing ones; and reposition itself to be more competitive in the ever-changing funding landscape, especially with a view to joining larger R&D consortia.

ANNEX 1: Brief and Terms of Reference

CABI's mission

CABI is an inter-governmental, not-for-profit organization that was set up by a United Nations treaty. Our mission and direction are influenced by our 49 member countries.

CABI's mission is to improve people's lives worldwide by providing information and applying scientific expertise to solve problems in agriculture and the environment. CABI has scientific research, international development, knowledge management and publishing at its core.

To achieve this mission we have set ourselves four goals: to contribute to greater food and nutritional security, to help smallholder farmers increase their incomes and improve their livelihoods, to protect the environment and preserve its biodiversity, and to provide the knowledge farmers need to improve agricultural practices. By generating and increasing access to scientific knowledge, and delivering change through development projects we work to improve crop yields, combat agricultural pests and microbial diseases, protect biodiversity and safeguard the environment, which enables the world's poorest communities to feed themselves.

SR2020 team and overview

The 2020 Science Review team includes:

- Oversight from a CABI Board member
- A geographical, and gender balance
- A balance of science and development experience
- Key competencies:
 - Application of biological, social and economic science in development work
 - Knowledge of crop health (includes, plant, soil, seed health)
 - o Insight into the implications of factors such as climate change, gender, youth, big data
 - o Insight in the dissemination and application of science
- An editorial assistant to be provided by CABI.

Context of the Science Review:

- CABI's mission and existing themes: Invasives, Development Communication and Extension, Value Chains and Trade, Digital Development
- Plantwise and Action on Invasives programmes
- CABI Medium-Term Plan 2020-2022
- Geographical spread of Regional Centres and Offices
- Sustainable Development Goals
- A review of the last 5 years but focus mainly on future opportunities and helping CABI to achieve vision and goals
- The need to maintain appropriate scientific expertise.

Key assumptions to be tested:

 CABI needs to maintain a strong science programme in order to remain a credible organisation in international development and publishing. • CABI sees a clear need to focus in relatively few areas to maintain a world- leading position in one or two areas and to be world competitive elsewhere.

Science Review Programme

It is anticipated that the review will be addressed as two work packages.

Work Package 1- Retrospective

In light of the above context and assumptions, has CABI's science programme since the last review (2015) been fit for purpose? Have we delivered to stakeholder requirements and CABI strategic plans? Aspects to consider might include:

- Response to and implementation of recommendations from the 2015 science review
- Delivery on the CABI Science Strategy 2016-2019
- Scientific publications quality and impact
- Quality of science/resources/people in key areas
- Science relevance/responsiveness to member country priorities
- The role of strategic scientific institutional partnerships (e.g. Joint Labs)
- Communication of our science outputs (visibility, website, social media)
- · Development of CABI's social and economic science capability
- CABI's response to the Nagoya Protocol (ABS policy, guidelines and progress with implementation).

Work package 2- The Future

Given the two key assumptions listed above, and the need to develop the next CABI Science Strategy, consider and make recommendations on aspects including:

- What should CABI's focus areas be, building on current areas of actual (or perceived) strength? Specifically include consideration of social and economic science, impact assessment, climate change, and gender amongst other topics.
- Based on the identified key areas to build on for the future, how do we optimise our science programme towards achieving CABI's mission and goals?
- What new and emerging technologies, facilities and skillsets should we consider (in-house / out-house) in order to pursue the recommended focus areas?
- Accordingly, identify areas where stronger external links and collaboration including existing and potential joint labs with national agricultural research partners would lead to greater impact in prioritised areas, and suggest good strategic partners.
- The future role of young researchers in CABI's science strategy (research studentships; MAS-ICM students; future staff members) and how this could be resourced.
- Comment on the need for a CABI ethics review / oversight process, and what form(s) this might take.
- The optimum inter-relationship between CABI's science programme and CABI Publishing initiatives (particularly CABI Agriculture and Bioscience, agrXriv, SciDevNet).
- How should we disseminate, monitor and evaluate our science going forwards, including publications, open access, and social media? Comment on CABI's current policy, guidelines and future targets with regard to open access of publications and open data.

Tasks

• Select and review from the material that CABI makes available and identify any additional documentation or information that you would like to see, or like prepared.

- Discussions with CABI senior managers (including Executive Management Team and International Development senior management group as far as practical), selected scientists (self-selected and selected by review team) and key scientific partners (e.g. AAFC, CAAS, KALRO). Site visits are not anticipated but virtual meetings involving prioritised centres and delegated review team members will be organised.
- Review team discussions and drafting of report.

Outputs

- The Review team will provide a report together with a set of recommendations for investment in terms of staff, capital expenditure, partnerships and priority developments for each region / theme. The content and format of this to be discussed and agreed with CABI Liaison Group (EDGO, CS, DDR (CABI Africa) and oversight Board member) and the review team leader before commencement.
- Draft report to be finalised in light of feedback from EDGO, CS, DDR (CABI Africa) and oversight Board member
- Powerpoint presentation and discussion of key findings to EMT.

Time frame

- Confirmation of SR2020 leader. Beginning of Q3 2020.
- Selection and recruitment of SR2020 team; finalise ToRs, and materials that CABI will provide / prepare. By end Q3 2020.
- Initial virtual meeting of team; agree report structure; schedule for visits and team responsibilities. By end Q3 2020.
- Programme of virtual visits and meetings. Q4 2020.
- Draft report and discussion with CABI senior management. End Q4 2020 and early Q1, 2021.
- Final report, Board meeting. March 2021.

Materials / resources to be provided

- Access to relevant documents and CABI's internet resources, including:
 - o Science Review 2015
 - o CABI's 2020-2022 mid-term plan
 - CABI Science Strategy 2017-2019
 - o CABI Science Reports 2017, 2018, 2019
 - o Relevant guidelines/policies (science, gender, others)
 - o CABI Scientific Outputs Portal (internet)
 - Science sections of annual DFID review of CABI's programme of work
- Videoconference with any CABI scientist(s).
- Drafting and administrative support.

ANNEX 2: Science Review Team Curricula vitae

Christian Borgemeister

Professor Christian Borgemeister obtained his PhD in Horticulture from Leibniz Hannover University (LUH) in 1991. He lectured at LUH before embarking on a research career in Africa in 1992. Until the end of 1997 he worked at the International Institute of Tropical Agriculture (IITA), in Benin, West Africa, first as a Postdoctoral Fellow, then as an Associate and finally as a Senior Scientist coordinating a multi-country program on the integrated control of an invasive stored-product pest. He returned to Germany in 1998 working as an Assistant, then Associate and since 2003 as a Full Professor for Applied Entomology at LUH. From 2000–2001, he was a Visiting Professor for Applied Zoology at the Justus-Liebig-University Giessen, Germany. From 2005 to 2013 he served as Director General of icipe, the International Centre of Insect Physiology, a Nairobi, Kenya headquartered pan-African R&D centre. He is a Fellow of the African Academy of Sciences, the Royal Entomological Society and the Entomological Society of America (ESA), received in 2011 the International Plant Protection Award of Distinction of the International Plant Protection Convention (IPPC), and in 2015 the Distinguished Scientist Award of the International Branch of ESA. C. Borgemeister was for more than eight years Editor-in-Chief of the International Journal of Tropical Insect Science (published then by Cambridge University Press) and has affiliations with other distinguished scientific journals as reviewer. He has authored and co-authored more than 150 papers in peer-reviewed scientific journals, co-authored a book on biological control in Africa, and has written more than 10 chapters for different scientific books.

Wanjiku Chiuri

Professor Wanjiku Chiuri obtained her PhD in Planning and Resource Development from University of Waterloo, Canada (UoW) in 1996. Her University career started at Kenyatta University in 1990 as a tutorial fellow till 1997 when she joined Egerton University as a lecturer. She was promoted to senior lecturer in 1999 and in 2008 to Associate Professor in Environmental Studies. In 2003-2004, she served her sabbatical leave on a Fulbright scholarship at Beloit College, Wisconsin, USA, In 2008, she took leave of absence from Egerton University and joined the International Centre for Tropical Agriculture (CIAT) as a senior social scientist till 2014. While at CIAT, she served in several projects providing the much needed socio-economic and gender support to agricultural science. She engaged in gender research, gender mainstreaming and analysis as well as engaging scientists in gender debate and helping them wear the gender lenses in breeding and project implementation and the need for sex disaggregated data for decision making and for ensuring gender equity/equality and women empowerment. In 2015, she was appointed the Deputy Vice Chancellor in charge of Academic, Research and Student Affairs at Laikipia University, Kenya. She has served in this position till November 2020. She is currently serving as a member of the Independent Steering Committee of the Roots, Tubers and Bananas program of the CGIAR where she provides the gender expertise. Wanjiku is a registered Environmental Impact Assessment and Audit lead expert in Kenya. She is a member of the Gender Water alliance, Environmental Institute of Kenya, and United Women Sacco where she serves as a member of the supervisory committee. She received the alumni of the year 2020 award from UoW's Faculty of Environment. She has authored one book on gender and land tenure in Kenya, and coauthored 8 book chapters and 32 peer reviewed journal articles, several peer reviewed conference proceedings and a number of online publications.

André Lévesque

Dr. C. André Lévesque was Senior Scientific Director within the Science Branch at the Canadian Food Inspection Agency from 2017 until he retired in November 2020, and prior to that he was a research scientist with Agriculture and Agri-Food Canada (AAFC) for 25 years, leading research teams and supervising the Core Sequencing and Molecular laboratory as well as the Bioinformatics facilities of the largest centre of AAFC in Ottawa. He has significant experience and recognition in the area of plant health focussing primarily in mycology, plant pathology and genomics. He has published several book chapters and about 125 peer reviewed scientific publications. He received the Government of Canada Public Service Award of Excellence for Scientific Contribution twice and is a former president of the Canadian Phytopathological Society.

Willem J. Ravensberg

Dr. Willem J. Ravensberg holds a MSc in Biology from the University of Leiden in the Netherlands and in 2010 obtained his PhD from the University of Wageningen (WUR). Since then, he is teaching a course on IPM to students at WUR. W.J. Ravensberg began to work in 1981 at Koppert BV, then a small producer of natural enemies for greenhouse pests. He established Koppert's R&D department, and with the team, that steadily grew, selected and developed a range of natural enemies: predatory mites, midges and bugs, and parasitoids. He also developed and set up a quality control system for the final products. In the 1980's, entomopathogenic nematodes were added to the activities of the company as well as the first microbial insecticides. EU-research projects on biocontrol of plant diseases increased the company's interest in this direction and the strategy of Koppert broadened to include the control of insects and plant diseases. In 1999, Ravensberg headed the newly established R&D Department Microbials where the focus was and is on control of foliar and root diseases as well as on control of insects with nematodes. microbiological and natural products. He has been strongly involved in the registration of invertebrate biocontrol agents, and even more in the registration of microorganisms and natural substances as plant protection products, in the EU and in other countries. He has been an active member of Artemis, a Dutch (Belgian) association of biocontrol producers and distributors, and in the International Biocontrol Manufacturers Association (IBMA). From 2013 - 2018 Willem served as the President of IBMA where he and his team professionalized the association and developed a strong lobby for improved regulation of bioprotectants. Currently, W.J. Ravensberg is Sr. Corporate Governmental and Regulatory Manager at Koppert. He has published > 80 scientific publications and several book chapters on biocontrol and some publications on registration issues meant to help applicants and evaluators in the evaluation of microbial plant protection products.

Katherine (Kadi) Warner

Dr. Katherine [Kadi] Warner began her career as a young Peace Corps Volunteer in Sierra Leone. The low agricultural yields, degraded environment, high infant mortality and entrenched poverty of the community in which she lived led her to devote her career to gaining an understanding of the 'why' such conditions occur and what is needed for change. As an East West Center grantee, she obtained her PhD in Ecological Anthropology from the University of Hawaii. She has significant expertise in agriculture, climate change, gender, forest and natural resource management working with governments, international agencies and organizations, and NGOs for more than 25 years in countries in Asia, Sub-Saharan Africa and the Pacific. She has held senior positions at the World Resources Institute, FAO, IUCN, Winrock International, New Zealand Aid, and RECOFTC and currently has an adjunct position at the University of the Sunshine Coast in Queensland, Australia. During the last ten years she has been focusing on understanding climate risks and strengthening climate resilience of communities and nations. She has authored over twenty-five risk assessments of countries in Africa, Middle East and Asia, guidelines for climate risk assessment in agricultural and sustainable water interventions, and an article on climate justice.

Sileshi Gudeta Weldesemayat

Professor Sileshi Gudeta Weldesemayat holds a BSc degree in Biology (1987), MSc in Agriculture (1994) and a PhD in Entomology (2001). Currently, he is a Fellow of the African Academy of Sciences, Adjunct Professor of Biology and Biodiversity Management at Addis Ababa University in Ethiopia, and Honorary Fellow/Professor at the University of KwaZulu Natal in South Africa. He is also the Deputy Coordinator of Design and Evaluation of Experiments in the International Union of Forest Research Organizations (IUFRO) (2017-todate) and member of the Editorial Board of Forest Ecology and Management. From 1987 to 1997 he was a lecturer at Alemaya University of Agriculture in Ethiopia where he also served as the Assistant Dean of Student Affairs and Head of the Department of Biology. In 2000-2001, he briefly worked as a Research Associate at the International Centre of Insect Physiology and Ecology (*icipe*) in Kenya. Then he joined the World Agroforestry Centre (ICRAF) as a post-doctoral fellow in 2002 and

worked in Zambia. In 2006, he moved to Malawi where he was Senior Scientist in agroecology at ICRAF (2006–2011) and then the Regional Representative of ICRAF's southern Africa program (2011-2014), where he developed and managed the regional program *Building a Large Evergreen Agriculture Network for Southern Africa* composed of projects implemented in Malawi, Zambia, Zimbabwe, Mozambique, Botswana and South Africa. He also managed the *Malawi Agroforestry Food Security Program* consisting of a number of projects aimed at improving livelihoods of smallholder farmers. He has published > 200 peer-reviewed papers of which 162 are refereed journal articles. He has also co-authored three books and > 30 book chapters. He has served as a reviewer for > 50 scientific journals and received a certificate of Outstanding Reviewer from 5 ecology journals. As a consultant, he has also reviewed a number of projects and programmes.

ANNEX 3: Databases, data platforms and compendia

The Earth Observation data include land surface temperature (source: Meteosat), soil moisture (source: ERA-5), vegetation index (source: MODIS), and Land Cover (source: European Space Agency CCI), which are used in the Pest Risk Information Service (PRISE) project.

The Plantwise Knowledge Bank is an open access gateway to plant health information and services, consisting of services ranging from diagnostic and management advice to maps of pest locations and customized alerts on pest news. The database consists of pest and disease records collected though the Plantwise programme, and the POMS involving data collection, storage, analysis and reporting tools. The Plantwise knowledge bank has been built at the cost of several million \$US, mainly from donor project funding. As CABI moves to develop new apps and decision support tools under the PlantwisePlus programme, it is likely that the data held within these key content assets will be invaluable in the development of new services.

The open access Invasive Species Compendium is one key asset and the costs of keeping it relevant, up to date and open access are around £100-200k per annum. These costs are covered by core funding from the Knowledge Business. It is now so embedded in products that Knowledge Business is likely to see the value in maintaining it and bear much of the costs in doing so. The review team feels this will guarantee sustainability.

The Distribution Database consists of a central store for CABI's geospatial data to provide data-driven products. Currently, it consists of over 800,000 distribution records. This database, which is now CABI's key geospatial database of pest distributions, was developed using a mix of project funding and core funding. This database now underpins and reduces the costs for updating knowledge product and allows insights on distribution from one initiative to be automatically shared with others. As in the Compendia, the Knowledge Business is likely to bear the costs of maintenance.

The CABI CKAN Data Repository is built on open source, free software which provides a website for uploading and accessing agricultural and environmental datasets. In conjunction with the Open Data Kit, researchers can collect data directly into the repository, where it can also be cleaned, visualized and downloaded for further analysis. The CKAN data repository has been built in stages over a number of projects, and most of the cost involved is in the adding of new data assets to it and some subscriptions for plug ins. At the moment it's not clear where the maintenance costs would come from beyond 2021. There is no specific project to pick up the tab. The team therefore feels there is an urgent need for investment in this area to ensure sustainability.

BIOCAT is a unique database of introductions of insect biological control agents for the control of insect pests. Most of the required data has been collected and collated to bring the database up to date to the end of 2017. CDF funding has been used to make checks and corrections to BIOCAT, as well as publications arising from analyses of the BIOCAT data. However, it is not clear where future maintenance costs will come from.

ANNEX 4: Stakeholder/partner survey results

Sixteen individuals from partner and donor organizations around the world, familiar with CABI's science, were interviewed by members of the review team. The individual replies to each of five key questions have been re-ordered, and in a couple of cases slightly edited, to help preserve respondents' anonymity.

Participating organizations

- World Vegetable Centre (AVRDC), Shanhua, Taiwan
- International Centre of Insect Physiology (icipe), Nairobi, Kenya
- International Institute of Tropical Agriculture (IITA), Nairobi, Kenya
- University of Fribourg, Switzerland
- Agriculture and Agri-Food Canada (AAFC), Ontario, Canada
- Stellenbosch University, South Africa
- Foreign, Commonwealth and Development Office (FCDO), London, UK
- Ministry of Foreign Affairs, The Hague, Netherlands
- Andermatt Biocontrol, Grossdietwil, Switzerland
- Koppert Biological Systems, Rodenrijs, Netherlands
- Real IPM Ltd., Nairobi, Kenya
- Kenya Plant Health Inspectorate (KEPHIS), Nairobi, Kenya
- Kenya Agricultural & Livestock Research Organization (KALRO), Nairobi, Kenya
- Council for Scientific and Industrial Research (CSIR), Savanna Agricultural Research Institute, Tamale, Ghana
- Ministry of Agriculture, Director for Department of Agriculture, Lusaka, Zambia
- Plant Doctors, Kiambu County, Kenya

Responses

1. How would you rate the quality of CABI's scientific work in the areas with which you are familiar? On what information is your opinion based?

Views the value of CABI as an institution to navigate boundary between science and 'real world' and do something with it. Strong point of CABI is the balance of science and the development

CABI does scientific work that is evidence based and is usable for the plant doctor and the farmer. It not only identifies the problem but also works on the solution.

CABI has the relevant knowledge and skills, scientific knowledge and approach to applied science, they understand the practical situation and try to find solutions for farmers.

The impression is very good, CABI has the relevant knowledge and skills, scientific knowledge and approach to applied science, they seem to understand the practical situation and try to find solutions for farmers.

We have been entirely happy with the quality and promote delivery of quality advice and product.

On a scale 1-5 rank CABI 3.5 to 4. I know CABI primarily from their development and applied science work, here in particular on IPM and a little on modelling, and not so much in the context of more upstream science. In addition, their communication tools and knowledge management work are excellent.

CABI develops excellent handbooks and various equally good information and dissemination tools.

On a scale from 1-5 ranked 4. The reason is particular Plantwise. In addition, CABI has many assets in digital services and its virtual repositories.

CABI has a proven track-record for producing high-quality of research, this is evidenced by their publication of scientific results in well-respected peer-reviewed journals.

CABI rated excellent both on applied and basic work. Provides a great complement to basic ecology (of their applied work). Opinion is based on publications, positions on international consortia, on joint student supervision etc. and applies to CABI staff in Switzerland and UK.

CABI's science quality rated as "reasonably high". Good ethics at CABI; they show genuine concerns about resolving real problems.

On a 1 - 10 scale, rate CABI's scientific work as 10. Much of my work with them has been in crop protection.

CABI is indeed a wonderful collaborator in many aspects of Phytosanitary such as: Development and regular update of the Crop Protection Compendium (CPC) which is very useful for our carrying out the Pest Risk Analysis (PRA) process. There are other tools within the CPC such as the horizon scanning and PRA tool which are very instrumental in the PRA work.

Rate CABI in the upper 95-100 percentile. Their scientific work is excellent and up to date. The output of this research also contributes to research for development.

Quality of CABI's scientific work is good. Have been exposed to plant wise Knowledge bank where a number of scientific pieces of work have been deposited. The tools help stakeholders in Agriculture to have their capacity built.

2. Do you see any major gaps in CABI's current scientific work programme? In particular, is an appropriate level of attention given to (a) socio-economic aspects, and (b) gender issues?

Social science and gender have improved, built it into M&E and have a good team. In terms of climate change, CABI's niche ('a tricky niche) is on the climate impact of climate change on pest and disease.

CABI's 'lose less to earn more' addresses the issue. What is not sure, is if it does help farmers; CABI needs to give advice that goes beyond a specific problem.

CABI is "getting information" rather than "providing information", meaning lack of knowledge and understanding on practical topics, from working at farm level.

None.

A stronger emphasis on detailed economic impact assessment studies, for instance related to Plantwise, could be a great opportunity for CABI.

I have limited knowledge of CABI's current (science) program.

CABI's work is very well in the fields of development and scaling up of technologies. Less is the area of discoveries. Yet the problem with such an approach is that if you are not really involved in the discovery process of technologies and innovations then you might run into problems during the scaling. Suggested that CABI becomes more engaged in the discovery process, for instance in the form of co-discovery. Meaning, it wouldn't be expected that CABI develops 100% on its own but contributes some 20% to the process.

Appropriate level of attention given to socio-economic aspects as well as gender issues.

On gender issue, saw a higher proportion of female students as well as newly hired female staff members. On socio-economic aspects, biocontrol is not doing well in general. CABI could play a leadership role in developing protocols for post-introduction monitoring programs. Need better ex ante and ex post introduction evaluation to evaluate impact and evaluate cost of "doing nothing".

biocontrol often falls short when looking at the effect on large areas and on determining economic Benefits? Rated highly recent work of Urf Schaffner on health benefit of ragweed biocontrol, highly relevant to socio-economic aspects. Was also positive about work of Arne Witt and his questionnaires to local farmers. About gender issue, worked with several graduate students at CABI from East Africa and the male: female ratio was about 1:1.

Reports that I read are very informative and contain a lot of detail and appropriate contextual analysis of the situation that they seek to resolve. The socio-economic context of burning scientific issues have always received attention. On gender issues, CABI have always insisted that selection of farmers for on-farm work must be gender sensitive.

Management of diseases. Partner organisations should be better represented in CABI publications.

In the area of gender main-streaming we have seen men gaining more from CABI scientific programmes (e.g., from plant clinics) than women. The scientific work program needs to consider training more female plant doctors and nurses to encourage the participation of women in the programmes.

3. What would you miss if CABI no longer existed?

Miss working with a great partner. CABI (esp. their individuals) are a great people to work with, that have a good understanding of our organisation. He can call and ask "I need one sentence that says X" and the CABI staff member that she/he called knows what her/ his organisation is looking for.

If no more CABI than we have a big problem! They are in immediate contact with farmers, able to deliver into practice. Dedicated to help extension services.

A worldwide oriented and dedicated institute that investigates agricultural solutions in the field of Classical biocontrol and augmentative biocontrol, with its wide scope and worldwide coverage.

A worldwide oriented and dedicated institute that investigates agricultural solutions in the field of Classical biocontrol and augmentative biocontrol, with its wide scope and worldwide coverage.

Knowledge management and new and innovative extension tools.

Their information services, especially the CABI books that are truly excellent and very valuable. I also appreciate their various dissemination tools emanating from their plant clinics but also their IPM guidelines. Yet CABI needs to improve its presence in the digital world.

Knowledge products, especially in the field of plant protection.

Without CABI, the ability to carry out classical biological control research for invasive insect pests in Canada would essentially be paralysed.

Would miss a great collaborator. CABI does not have the big "omics" machinery like universities but provide the more rounded and worldwide/international view that narrowly focussed academic programs do not have, which is attractive to students.

CABI is a big player in the field of biological control. If they go, another institution will need to take its place but it would take time to build this capacity (analogy about a country or an area of the world getting rid of its national air carrier).

The opportunity to conduct well-coordinated scientific studies that adequately addresses developmental challenges and problems farmers consider key in their day-to-day life.

Access to the crop protection compendium. Assistance to undertake diagnostics of unknown pests. Engagement with the very resourceful CABI scientists.

Oh yes, we would most definitely miss CABI. This is the one international research organization that not only strengthens the research programmes but also guarantees sustainability, of research products, and is the only one that directly impacts the smallholder farming systems.

In Zambia CABI has played a very important role in strengthening the linkages among research, extension and farmers through the provision of funds for training and information for use by stakeholders. Provided fora for these agricultural actors to function and contribute to the common goal of improving the status of the farmer. More important CABI has helped in research (e.g., on invasives) meaning that it has helped provide dynamic solutions in an environment where our farming community has new problems emerging every day. While in existence it has provided continuity of these activities. CABI's work has also

enhanced the Early Warning Systems in invasives such as the Fall Armyworm making the country respond better to such threats.

4. What do you see as CABI's main role in national and international agricultural research systems?

Key bit is in plant health (more specific than CGIAR) and work with national partners.

Advise national institutions: bio-substances that are more suitable for pests; promoting less chemicals and substances.

Helping farmers, small holders, in poor areas, to agricultural solutions, and education, training, they facilitate biocontrol and uptake of IPM. Commercial companies cannot do that today.

Helping farmers, small holders, in poor areas, to agricultural solutions, and education, training, they facilitate biocontrol and uptake of IPM. Commercial companies cannot do that today. They are not competing with companies, rather collaborating, which altogether is very valuable.

R&D on biotic stress of plants and crops and findings solutions. This has taken on a major significance with invasive species in particular in recent years.

(1) Economic impact assessment studies focussing on pests, weeds and diseases (incl. invasives like FAW). Most of the existing information on economic impact assessment rather anecdotal. Hence real comprehensive analyses would be a huge opportunity and no organisation more qualified and in a better situation to carry them out than CABI. (2) Developing novel extension approaches/ tools. (3) Novel information dissemination tools, techniques and approaches. (4) Knowledge management.

Their ability to link science to users, similar to what CTA used to do. However, I would think that CABI needs to up their game in terms of digital.

Capacity building like training of trainers (ToTs). However, presently CABI's presence in this field rather fragmented, i.e., in one country strong, in others more or less absent. Hence, these activities should be better coordinated, especially in the field of training new extension specialists where CABI has a particular expertise.

CABI should try to play a larger role in capacity building. For instance, to date the number of people trained by CABI in India won't make a difference considering the population of the country. Presently CABI's work is primarily producer centred. However, the organisation should consider also a stronger consumer focus as a push from this side might lead to greater adoption of CABI technologies and innovations. Few real discoveries emanate from CABI's work. Either the organisation should consider phasing out discovery work, or should adopt more of a co-discovery approach, though the latter would require better and stronger partnerships with other research organisations. CABI should focus more on its successful work on invasives. CABI and the other AIRCA members need to carefully watch the One CGIAR development. Will be critical that AIRCA members will convincingly demonstrate their comparative advantage in certain areas. This necessitates the development of joint work programs through jointly funded activities.

Capacity building in developing countries to support the development of integrated pest management strategies and plant health initiatives. Conduct scientific research to support biological and ecological studies in agriculture, with both national and international partners, with the aim to address global issues related to invasive species, integrated pest management, and biological control.

Huge potential in conservation (e.g., grassland and rangeland) and integration of management tools (e.g., Integrated Weed Management).

CABI is about agriculture with strength on crop pests and their control, and has a major role to play at the interface, like rangeland, and where people are using natural ecosystems for agriculture.

CABI has always provided scientific leadership and technical backstopping that transcends local situations to ensure sustainable agricultural research systems are established in their host countries.

At national level, CABI is offering leadership in emerging pest issues in capacity building, awareness creation, surveillance, diagnostics and other collaborative ventures with several national partners. At international level, CABI has been actively involved in regional initiatives undertaken by regional

economic communities such as East African Community (EAC), COMESA, AU-IAPSC and IPPC. The involvement is very useful in offering solutions to the trans-boundary pest incursions which have been witnessed from time to time.

CABI is a very strong partner in crop health but needs to increase research in weed management in priority cropping systems and not just invasive weeds like parthenium. Should continue to undertake research in invasive pests, e.g., FAW and in particular storage pests. CABI should increase its efforts on the management of diseases of economic importance and improve on the research infrastructure and capacity of NARs scientists. CABI need to increase research on management of storage pests using biological methods or more safe pesticides. CABI's role in crop health management extension system is key and should continue its role in this area. CABI's publications are good references for agricultural research.

CABI's products help agricultural researchers and policymakers at national and international level develop strategies that support agriculture and the environment, and ultimately improve livelihoods. CABI information systems help national/international agricultural systems enable national extension systems/advisory services to provide better advice to farmers on agricultural practice, helping them lose less of their crops to pests and diseases, improve crop quality and yield, and sell their produce for better prices.

5. What shifts, if any, would you like to see in CABI's scientific focus going forward? Are there particular research areas which you think could be phased out? And any which you think should be given more attention? Do you know of cases where there is evidence of impact from CABI's work?

Appreciates CABI impact-oriented work, with examples like fall armyworm or Green Muscle but also Pest management decision guides.

More attention to unstable and fragile states. Money invested in CABI is well placed. CABI should continue to develop digital to deliver information and knowledge; not only the science, but how you bring it to end-user.

None. It is good as it is. Maybe plant disease control is lacking, but they need to focus anyway, there portfolio is too big now.

As priority areas invasive species as crop pests. In terms of impact, microbial services and identification. Biopesticide knowledge on modes of action, formulation and delivery.

(1) Invasive species, but CABI should try to avoid doing everything and focus on better partnership, also with other research organisations (for instance for more upstream work). (2) For CABI's predictions models interventions should be targeted to the most suitable environments (which would require for CABI to conduct more refined modelling). (3) CABI should address the missing link between soli and plant health. (4) Try to become more known in Africa. CABI only known for Plantwise. Should communicate better what the organisation is doing in the region.

They should build upon their Plantwise experiences and make (more & better) use of this data.

No shift in science focus is needed. CABI's Science Strategy is made up of 5 priority research areas, all of which are currently relevant, and are likely to remain relevant over the next few years.

CABI should play a leadership role in filling the GAP in taxonomy, possibly through partnerships instead of filling the gaps themselves. Conservation and biodiversity areas are opportunities for CABI. Continue the "Common Wealth" expansion as an international biocontrol endeavour. Address Climate change with a focus on herbicide and pesticide reduction. Landscape and habitat management: Early detection and rapid response remain crucial and CABI is well placed.

CABI could play a broader role in avoiding competition between agriculture and natural ecosystems, reducing environmental consequences of agriculture.

Worth considering expanding the scope of on-farm work with farmers. CABI's work has tremendously impacted farmers lives by providing first hand solutions in the form of fact sheets and technologies that have increased yields on farmer's field. The work of CABI has also impacted significantly on the environment by pushing for the adoption of environmentally benign solutions in small scale subsistence farming systems.

CABI needs to focus more on those aspects that other international organizations have not tackled. For instance, in Kenya, we have *icipe* which is very strong on entomological research, so once CABI goes deep into entomology, there is a possibility of creation of competition, instead of complementing the already existing initiatives. CABI needs to consider more focus on phytosanitary research. Pest management strategies that include post-harvest treatment will enhance market access initiatives by governments and also strengthen plant import controls, and yet not much attention has been given to this area.

More focus on biological controls that can be managed at the farmer-level. CABI needs to increase research on the management of diseases. CABI needs to increase its role in horticultural crops seed systems. CABI should not phase out research areas; the current research programmes should continue. Impact of CABI research work - CABI has woken up insufficient or dead agriculture extension in many countries by capacity building of plant doctors under the Plantwise programme. This is a fantastic success. The PRISE project is the precursor to developing an early warning system for pests of economic importance on maize, beans and tomato. CABI has rehabilitated partner research laboratories; renovated control temperature rooms; procured several laboratory equipment; renovated several screen-houses; procured a state-of-the-art generator; and also funded several research activities in biological control. CABI has capacity built several scientists in the area of biological control and entomology research. The Plantwise activity of training plant doctors and establishing plant clinics are embedded in our Strategic Plan. This demonstrates the importance of crop health management and also the importance of this data in directing research activities in crop health. Many factsheets have been developed jointly with CABI that are available online for use by all.

Increase facilitation in greater linkage to value chains among farmers. This would create a better system where farmers would earn more. No need for phasing out any particular research areas. Stronger emphasis on linkage to value chains, evidence-based decisions and policies, and effective, innovative public and private sector partnerships. CABI's work has been impactful in areas of knowledge creation, improving research-extension-farmer linkages, and capacity-building especially through the Plantwise programme.

ANNEX 5: Analysis of CABI publications in Scopus using rscopus (1991-2020)

Methodology

- On October 27, 2020, scientific publications from CABI for the 1991-2020 period were mined using Scopus and rscopus (1694 publications retrieved) and analyzed with R. The query string was the following:
 AF-ID ("CABI United Kingdom" 60024459) OR AF-ID ("CABI Brazil" 60111547) OR AF-ID ("CABI India" 60111544) OR AF-ID ("CABI Kenya" 60070565) OR AF-ID ("CABI Malaysia" 60111545) OR AF-ID ("CABI Pakistan" 60111543) OR AF-ID ("CABI
 - Switzerland" 60000140) OR AF-ID ("International Mycological Institute" 60013564) AND (PUBYEAR > 1990) AND (PUBYEAR < 2021)
- R analyses were performed for the different 5-year time periods in this range.
- A relational database was created with Scopus affiliation data from all co-authors and Scopus publication data from each publication.

CABI Center	CABI Region	CABI Center	CABI Region	CABI Center	CABI Region
CABI Ghana	CABI Africa	CABI Bolivia	CABI Americas	CABI China	CABI Asia
CABI Kenya	CABI Africa	CABI Brazil	CABI Americas	CABI India	CABI Asia
CABI Uganda	CABI Africa	CABI Trinidad	CABI Americas	CABI Malaysia	CABI Asia
CABI Zambia	CABI Africa	CABI Europe	CABI Europe	CABI Pakistan	CABI Asia
		CABI Serbia	CABI Europe	CABI UK	CABI UK

• In some analyses, CABI centres were further grouped by regions using the following table:

- Annex 5 A.1 Box plots of impact factors distribution of CABI publications extracted from Scopus (all centres). Impact factors for 2019 were extracted from here (https://impactfactorforjournal.com/journal-impact-factor-list-2019/). Some journals were not listed and for those publications frequently used by CABI (e.g. Acta Horticulturae) they were found manually.
- Annex 5 A.2 Same as above with publications grouped by region of CABI centres.
- Annex 5 A.3 Correlation between Impact Factor of CABI publications and number of citations reported in Scopus when data was collected. The publications are coded by their publication year range.
- Annex 5 B.1 Scientific Network Collaboration Maps all CABI publications extracted from Scopus (1991 2020). Affiliation data from Scopus was used for these analyses. Dot size is proportional to # of publications by an institution, line thickness is proportional to # of co-publications between partner institutions. In order to visualize all collaborators, the co-publication cut-off was set to the minimum one publication by each collaborator. The maximum varies depending on the graph and the minimum number of publication (cutoff) was set above 1 to simplify some of the plots (see at bottom of graphs).

- Annex 5 B.2 Scientific Network Collaboration Maps with collaborators grouped by continent. Same as above except that collaborating institutions were grouped by continent.
- Annex 5 B.3 Internal collaborations within CABI: Histogram with number of regions of CABI centres represented on a publication. Regions were Americas, Africa, Asia, Europe, and UK.
- Annex 5 B.4 Scientific Network Collaboration Maps internal to CABI centres grouped by regions.
- Annex 5 C.1 Word Clouds of CABI publications from Scopus since 1991 (titles and keywords): Word Cloud representation of science focus over time based on title and key word frequency in scientific publications. Largest words within a cloud suggest a key area of interest during that time period; evolution in size of a given word over time demonstrates trends and changing science focus.
- Annex 5 C.2 Word Clouds of CABI publications subsets extracted based on impact factor and/or citations

Scopus Data Limitations

- Not all publication reported by CABI are in the Scopus database.
- Scientists sometimes self-identify with another affiliation (e.g. a university adjunct professorship) and, therefore, their papers may not be captured properly by the search.
- Impact factors were not found for all journals, therefore those IF analyses did not have all Scopus entries.



Impact factor of CABI publications extracted from Scopus (all centres)

Publication Year



Impact factor of CABI publications extracted from Scopus (by centre regions)







Collaboration among CABI regions over the years (number of CABI regions involved in a publication)





Network Map for only internal CABI collaborations (2006 to 2010) – based on 14 co–publications extracted from Scopus







Network Map for only internal CABI collaborations (2016 to 2020) – based on 62 co–publications extracted from Scopus



Word Clouds of CABI publications from Scopus since 1991 (titles and keywords)



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Word Clouds of all CABI publications from Scopus since 1991 (titles and keywords) - subsets were extracted based on impact factor and/or citations





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2006 to 2010 (number of publications = 317)

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