CGIAR Research Program on Wheat

An Agri-Food System CGIAR Research Program

RESEARCH PROGRAM ON Wheat

CGIAR

Annual Report 2017

Contents

CGIAR CRP Annual Reporting Template

Name of the CRP WHEAT Agri-Food Systems
Name of the Lead Center CIMMYT
List of participating Centers and other key partners (as per Phase II Full Proposal) ICARDA, BBSRC (UK), ICAR (India), ACIAR (AU), INIA (Bolivia), INIAF (Uruguay), INRA (Morocco), IRESA (Tunisia), BARI (Bangladesh), G-20 Wheat Initiative, International Wheat Yield Partnership (iwyp.org). The complete list/map of partners is accessible here.

List of donors (W1&2): See Table J, pp.39-42.

Acronyms and abbreviations

CGIAR System Institutions and Processes

A4NH	CGIAR Research Program on Agriculture for Nutrition and Health
AfricaRice	Africa Rice Center
AFS	Agri-food system
ARI	Advanced research institute
BISA	Borlaug Institute for South Asia
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CIAT	International Center for Tropical Agriculture
CGIAR	CGIAR is a global research partnership for a food-secure future
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
CRP	CGIAR research program
CSISA	Cereal Systems Initiative for South Asia
DGGW	Delivering Genetic Gains in Wheat Program
EFSAC	Enhancement of Food Security in the Arab Countries project
EiB	CGIAR Excellence in Breeding Platform
FISH	CGIAR research program on fish
FLAR	Fondo Latinoamericano para Arroz de Riego (Latin American Fund for Irrigated Rice)
FP	Flagship project
FTA	CGIAR Research Program on Forests, Trees, and Agroforestry
GENNOVATE	Global comparative gender norms research initiative
GRiSP	Global Rice Science Partnership
GWP	Global wheat program
IA	Impact assessment or intellectual asset
ICARDA	International Centre for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDO	CGIAR intermediate development outcome
IEA	Independent Evaluation Arrangement of CGIAR
IITA	International Institute of Tropical Agriculture
IRIC	International Rice Informatics Consortium
IRRI	International Rice Research Institute
ISC	Independent Steering Committee
ISPC-SPIA	Independent Science and Partnership Council-Standing Panel on Impact Assessment
IWIN	International Wheat Improvement Network
IWYP	International Wheat Yield Partnership
KPI	Key performance indicator
LMS	Learning Management System
MAIZE	CGIAR research program on maize agri-food systems
MARLO	Managing Agricultural Research for Learning and Outcomes platform
MasAgro	Sustainable Modernization of Traditional Agriculture Program, Mexico
MC	Management committee
MELIA	Monitoring, Evaluation, Impact Assessment and Learning

MELIAG	Monitoring, evaluation, learning, impact assessment, and gender workshop
ME&L	Monitoring, evaluation and learning (also MEL)
NERICA	New rice for Africa (rice varieties)
ORNL	Oak Ridge National Laboratory, USA
PIM	CGIAR Research Program on Policies, Institutions, and Markets
PRAY	Phenomics of rice adaptation and yield potential
POWB	Plan of work and budget
RCM	Rice crop manager
RCT	Randomized control trial
RIICE	Remote sensing-based information and insurance for crops (project)
RTB	CGIAR Research Program on Roots, Tubers, and Bananas
RICE	CGIAR Research Program on Rice Agri-food Systems
SARD-SC	Support to Agricultural Research for Development of Strategic Crops in Africa
SeeD	Seeds of Discovery, CIMMYT
SIAC	Strengthening Impact Assessment in the CGIAR (project)
SLO	CGIAR system level outcome
SMB	System Management Board
SRP	Sustainable rice platform
STRASA	Stress-tolerant rice for Africa and south Asia (project)
WHEAT	CGIAR research program on wheat agri-food systems
YASP	Young Agricultural Scientists Program

Research and Development Partners

AAFC	Agriculture and Agrifood Canada
AARI	Ayub Agricultural Research Institute, Pakistan
ACIAR	Australian Centre for International Agricultural Research
AREEO	Agricultural Research, Education and Extension Organization, Iran
APAARI	Asia-Pacific Association of Agricultural Research Institutions
ARARI	Amhara Regional Agricultural Research Institute, Ethiopia
ARC	Agricultural Research Center, Egypt
BARI	Bangladesh Agriculture Research Institute
BBSRC	Biotechnology and Biological Sciences Research Council, UK
CAAS	Chinese Academy of Agricultural Science
CAPECO	La Cámara Paraguaya de Exportadores y Comercializadores de Cereales y Oleaginosas
CINVESTAV	Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Mexico
Cirad	Centre de coopération internationale en recherche agronomique pour le développement (The French agricultural research and international cooperation organization)
CORIGAP	Closing the Yield Gap in Asia (SDC-funded project)
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
DFID	Department for International Development, UK
EIAR	Ethiopia Institute of Agricultural Research
ESA	European Space Agency

EWG	Environmental Working Group, USA
FAO	Food and Agriculture Organization of the United Nations
FFAR	Foundation for Food and Agriculture Research
FOFIFA	Centre National de Recherche appliquée au Développement Rural, Madagascar
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Corporation for International Cooperation)
GOBii	Genomic Open-source Breeding informatics initiative, Cornell University
GRIN-Global	Germplasm Resource Information Network
ICAR	Indian Council of Agricultural Research
ICC	International Association for Cereal Science and Technology
IDS	Institute of Development Studies, University of Sussex, Brighton, UK
IFAD	International Fund for Agricultural Development
IIWBR	Indian Institute of Wheat and Barley Research of ICAR
INAT	Institut National Agronomique de Tunisie
INIA	Instituto Nacional de Investigación Agrícola, Uruguay
INRA	Institut National de Recherche Agronomique, Morocco
InSTePP	Innovative Strategies for Training, Education and Prevention Programs (US non-profit company)
IPNI	International Plant Nutrition Institute
IRD	Institut de Recherche pour le Développement (French National Research Institute for Sustainable Development)
IRESA	Institution of Agricultural Research and Higher Education, Tunisia
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
JHI	James Hutton Institute, UK
JIRCAS	Japan International Research Center for Agricultural Sciences
KALRO	Kenya Agricultural and Livestock Research Organization
KASIB	Kazakhstan-Siberian Network on Wheat Improvement
KIT	Royal Tropical Institute, the Netherlands
KVK	Krishi Vigyan Kendra (extension centers, India)
MoA	Ministry of Agriculture (many countries)
NARC	Nepal Agricultural Research Council
NARS	National agricultural research system(s)
NARES	National agricultural research and extension systems
NIAB	National Institute of Agricultural Botany, UK
PARC	Pakistan Agricultural Research Council
PAU	Punjab Agricultural University
PPPLab	Public-private partnerships lab, the Netherlands
PRISM	The Philippine rice information system
PROAGRO	Program for Productive Agriculture, Mexico
TAGEM	General Directorate for Agricultural Research, Turkey
TGAC	Earlham Institute (formerly The Genome Analysis Centre)
TNC	The Nature Conservancy
USAID	United States Agency for International Development
WRC	Wheat Research Center, Bangladesh

WEcR	Wageningen Economic Research
WEnR	Wageningen Environmental Research
WUR	Wageningen University

Miscellaneous

2WT	Two-wheel tiller
ARI	Advanced research institute
AWD	Alternate wetting and drying, a water-saving technology for rice
BNI	Biological nitrification inhibition
BTF	Breeding task force
CA	Conservation agriculture
CoA	cluster of activity
CSV	Climate smart village
CWANA	Central, West Asia and North Africa
DNA	Deoxyribonucleic acid
DON	Deoxynivalenol
FHB	Fusarium head blight
GEM	Grain quality-enhancer, energy efficient and durable material parboiling technology
GHG	Greenhouse gas
GIS	Geographic information systems
GS	Genomic selection
GWAS	Genome-wide association study
G x E	Genotype by environment interaction
G x E x M	Genotype by environment by management interaction
HTPG	High-throughput genotyping
HTP	High-throughput phenotyping
IA	Intellectual assets
ICT	Information and communication technology
IP	Intellectual property
IVR	Interactive voice response
KASP	Kompetitive Allele Specific PCR
LAC	Latin America and the Caribbean
MAGIC	Multi-parent advanced generation inter-cross
NAM	Nested association mapping
NGO	Non-government organization
NRM	Natural resource management
NDVI	Normalized difference vegetation index
QTL	Quantitative trait locus or loci
R4D	Research for development
SI	Sustainable intensification
SMS	Short messaging systems
SNP	Single nucleotide polymorphism
SSA	Sub-Saharan Africa
STB	Septoria tritici blotch
YR	Yellow rust
ZT	Zero tillage

Statistical analysis applications

Spatial META-R	Spatial Multi-Environment Trial Analysis
BGLRR	Bayesian Generalized Linear Regression for prediction in genome selection
BIO-R	Molecular biodiversity
STAD-R	Descriptive statistics of experimental designs
RIndSel	Calculates phenotypic and molecular selection indices
ADEL-R	Generates and analyzes standard experimental designs
PED-R	Calculates parentage coefficient and pedigree analysis
ACBD-R	Generates and analyzes augmented designs

1. Key Results

Executive Summary

With its partners, WHEAT reached Intermediate development outcomes linked to SLO 1.1 (improved crops/methods adoption) and SLO 2.2 (increase yields), or identified the potential (*ex ante* studies), in all major WHEAT target regions. Long-term bilateral projects delivered improved income outcomes relating to SLO 2.1 (exit poverty) and several *ex ante* studies show the poverty reduction potential of interventions under WHEAT FP3 and FP4 – *see section 1.1 and Table 1-A, Table A-2 and Annex 1.*

For 2017, WHEAT can demonstrate clear actual or potential outcomes benefiting the poorest in remote areas in Afghanistan, based on 15 years of collaboration with NARS, in Ethiopia (emergency seed supply), as well as in India's Bihar state and in Pakistan - based on large, multi-year programs (Cereal Systems Initiative for South Asia Phases I – III & Agriculture Innovation Project, respectively) – *see sections 1.3.3 and 1.2 under FP4.*

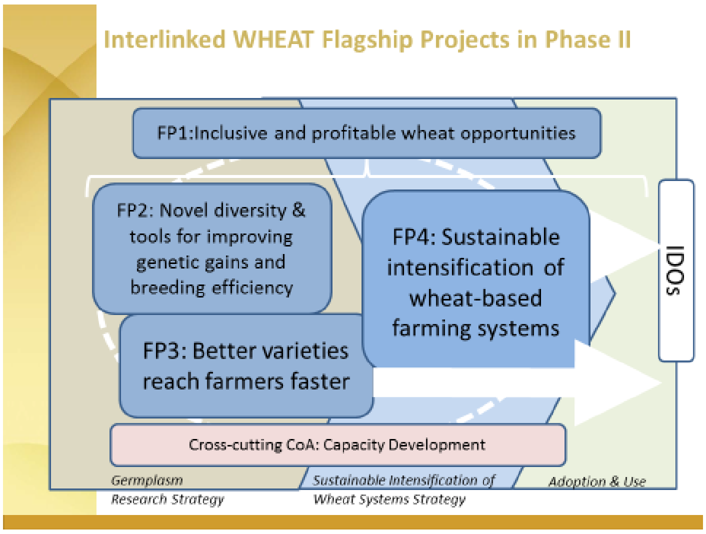
Gender R4D under WHEAT has generated further learning about gender dynamics in wheat-based systems and can report progress on building gender research capacity and mainstreaming a gender lens into some projects under WHEAT – *see sections 1.1 and 1.3.1.*

WHEAT is featuring a number of ongoing and new partnerships, both upstream, such as ***Connecting with advanced science on gene discovery with t*****he Foundation for Food and Agriculture Research (FFAR),** and downstream (with ICAR-India extension centers Krishi Vigyan Kendras (KVKs) and The Nature conservancy collaborating with CSISA – *see section 1.1, 1.4 (FP4) and Table G*. Collaborations with other CRPs and the new Platforms are described in - *Sections 1.1 (partnerships for impact), 2.4 and Table H.*

W1&2 funding equaled 26% of total budget and 22% of total WHEAT expenditure – *see Table J*.

1.1 CRP Progress Towards Intermediate Outcomes and SLOs

Better varieties and practices reaching farmers' fields: Major outcomes (IDOs) globally, emergency actions and better understanding of gender dynamics in wheat-based systems



63 CGIAR-derived wheat varieties released globally in 19 countries. Farmer adoption data from 2017 showed that 79 CGIAR-derived winter varieties released between 2008 and 2017 are grown on 2.5 million ha in West and Central Asia, indicative of continued impact and high return on investment documented in the 1994-2014 global impact study. More than 70 wheat and other cereal varieties were tested and released during 2000-17 by the Kazakhstan-Siberian Network on Wheat Improvement (KASIB); in Kazakhstan alone, farmers grow wheat varieties stemming from that work on almost of 6 million ha. Nine of those are CGIAR-derived varieties grown on 130,000 ha. A key challenge for wheat farmers in Kazakhstan, West Siberia and the Ural regions is to improve productivity as climate change and disease pressures mount. In Ethiopia, emergency seed of improved varieties multiplied in response to catastrophic seed losses from the El Niño drought reached 271,000 rural households (1.6 million individuals) and was grown on 100,000 ha in the Amhara, Oromia, Tigray, and SNNP regions. Similarly, WHEAT partners provided Sub-Saharan African research programs with 20 tons of multiplication seed of improved varieties, via SARD-SC/Wheat innovation platforms. *See Table A, SLO 1.1 & 1.2.*

Success fighting wheat blast in record time. USDA-ARS, Bangladesh and Bolivian collaborators identified Borlaug 100 and BARI Gom 33 as resistant to wheat blast. The same lines showed high yields in Bangladesh and India. Seed multiplication in Bangladesh started in 2017 and the Government released the high-yielding wheat variety BariGom33, which provides the additional benefit of high zinc content. No individual institution could have responded faster to the emerging and potentially devastating threat of wheat blast than those in the WHEAT CRP. BARI Gom 33 is being tested in India for possible release. Key challenges ahead are the rapid increase and dissemination of seed, from multiplication efforts in Bangladesh, India, and Mexico, as well as development of more resistant varieties, based on multiple genes. With support from ACIAR, a wheat blast phenotyping platform was established in Bangladesh, to identify resistant lines from South Asian national and CIMMYT programs. See also section 1.2 under FP1 (ex-ante study) and FP3 (precision phenotyping platforms) – *see Table A-1, SLO 1.2.*

GENNOVATE WHEAT has generated further findings (see *Improved wheat helps reduce women's workload in rural Afghanistan*) beyond those reported in the WHEAT Annual Report 2016. Both women and men in Afghanistan spoke about how improved wheat varieties have eased womens' work cleaning wheat by providing uniform, better quality and seed-borne disease-free (in particular common bunt) seed and, as a result of higher yields, encouraged adoption of mechanical threshing, which further reduces work and ensures cleaner grain for household foods. The GENNOVATE WHEAT Report was published in August 2017.

For further details on variety releases, click here.

Sustainable intensification and climate: Major outcomes and impacts

In another outcome of the GENNOVATE-WHEAT project, scientists found that six of the 43 villages studied were "tipping point communities", featuring normative shifts towards more equitable gender relations that also foster more inclusive agricultural innovation. Both men and women in those communities reported significantly higher empowerment and poverty reduction, with greater acceptance of women's freedom of action, economic independence and civic participation playing key roles.

A viable solution to rice residue burning in rice-wheat cropping systems. Based on robust evidence, the best solution to dispose of large volumes of crop residues across millions of hectares is to recycle them in the field itself with conservation agriculture-based machines. The Happy Seeder technology coupled with Super SMS mounted combine harvesters[1] have been identified by the Government of India as one of the most cost-effective, innovative and scalable solutions to manage farm residue on-site. This benefits both farmers and the environment, improving soil fertility and farm yield and reducing the use of water, fertilizer, herbicides and air pollution; the 14 cities with the highest air-pollution globally are all in India and stubble burning is a major contributor. Based on a policy brief developed by WHEAT partners describing the above, the Government of India made a policy decision and launched a special scheme for in-situ management of crop residues, based on an action plan proposal called 'The Evergreen Revolution: Six ways to empower India's no-burn agricultural future'. This was developed by The Nature Conservancy (TNC), CCAFS, WHEAT and other partners – *see Table A-1, SLO 1.1.*

[1] Combines are mounted with straw choppers that is spread evenly on the surface.

Impact in the eastern Gangetic Plains of zero- and reduced-tillage conservation agriculture for sustainable intensification: See Table A, SLO 1.1. Researchers, using a representative household survey and remote sensing radar images from the Sentinel-1 & 2 satellites to identify different plowing practices, estimate that 0.87 million ha or 2.8% of total cultivated land is under zero-tillage across the Gangetic Plains of India, compared to 73% adoption in Punjab and 8% in Haryana, an assessment partially funded by ISPC-SPIA. CSISA Phase III success in facilitating zero-till service provider growth shows the potential for greater farmer adoption (*see Table A-1, SLO 1.1*), whilst government-supported scaling-out of zero-till continues in Kazakhstan (see section 1.2, FP4) – *see Table A-1, SLO 1.1.*

Partnerships for impact

Scaling out / mainstreaming partnerships in South Asia. Several years of joint work of the CIMMYT-led Cereal Systems Initiative for South Asia (CSISA) with ICAR-India extension centers known as Krishi Vigyan Kendras (KVKs) resulted in an announcement by Bihar Agriculture University that KVKs in the state would promote early sowing for 1.5 million hectares of wheat. Studies by CSISA and partners have shown that early sowing of wheat, using zero tillage and zero-tilled rice nurseries for timely planting, helps mitigate the effects of both variable monsoons on rice and high temperatures during wheat's grain-filling stage. This represents a potential $255 million in additional profits for the region from sowing wheat 5 days earlier than occurs following conventional practices. This research component was also supported by BMZ. *See Table A-1, SLO 1.2.*

Innovation in long-term breeding research partnerships. Launched by Norman Borlaug and celebrating 50 years in 2017, the International Wheat Improvement Network (IWIN) has collected 18.2 million raw phenotypic data points and provided returns on investment as high as 100 to 1, contributing to the development and spread of wheat varieties sown on more than 100 million hectares worldwide. In an article in *Science* magazine, experts from CIMMYT and diverse agricultural research organizations and companies proposed the creation of an integrated, global network to improve the yield and climate resilience of key staple food crops. Modelled on IWIN, the network would harmonize research and data sharing across crops and regions and speed adoption of vital technology. A related opinion piece making the case that "Governments must raise not cut funding for food security" was published in the Financial Times. *See Table A-1, SLO X1.2.*

Connecting with advanced science on gene discovery. The Foundation for Food and Agriculture Research (FFAR), a US nonprofit organization established through the US 2014 Farm Bill, joined with Bayer, Biogemma, KWS, FAPESP, Precision PlantSciences, Rijk Zwaan, and CIMMYT to launch the "Crops of the Future Collaborative," a new consortium that will accelerate crop breeding to meet global food demand 20-50 years in the future. Focusing on new ways to study and improve crop traits, including gene editing, crop genome sequencing and phenomics, the Collaborative is launching with a $10 million commitment from FFAR, expected to leverage significant additional investment from partners. As part of the International Wheat Yield Partnership (IWYP), in 2017 WHEAT has also expanded other public-private science partnerships (see p. 18 in IWYP report).

CGIAR-wide genotyping partnership (7 centers, 31 NARS) with private sector partner. A platform for low-density SNP genotyping is fully running: during 2017, genotyping of around 22,000 wheat lines was outsourced to the provider (Intertek) to enable marker-assisted selection, under WHEAT.

Intra-CGIAR collaboration: Within the CGIAR System, WHEAT has committed staff time and funding to shaping and implementing CGIAR Phase II (with W1&2 funding):

- CIMMYT staff co-led the MEL Community of Practice;
- The WHEAT Program Manager acted a CRP/Platform Leaders' Representative to the System Management Board (SMB), whilst the CIMMYT-DG remained an SMB Member.

1.2 Progress by CRP Flagships:

FP1: Inclusive and profitable wheat opportunities

Foresight on consumption/demand, diseases and heat under Climate Change

Changing wheat consumption dynamics in rice economies. WHEAT scientists show that by 2030 both rural and urban households in Bangladesh will consume more wheat, pulses and fish, but urban households will consume less rice than in 2015. The present study uses Bangladesh as a case study, but much research has demonstrated that household food consumption patterns across Asia and Africa are changing from rice to wheat or maize to wheat and rice (see, for example this study), under rising income, population and urbanization scenarios, with associated global policy implications.

Call for action to tackle wheat blast threat in South Asia. A spatial mapping and crop modeling study regarding the risk and potential spread in South Asia of wheat blast, a deadly disease from the Americas that unexpectedly infected wheat in southwestern Bangladesh in 2016, identified 7 million hectares of wheat cropping areas in Bangladesh, India, and Pakistan whose agro-climatic conditions resemble those of the Bangladesh outbreak zone. Currently in press, the study shows that, under a conservative scenario of 5-10% wheat blast production damage in a single season in those areas, wheat grain losses would amount to 0.89-1.77 million tons worth $180 – 350 million. This would strain the region's already fragile food security and forcing up wheat imports and prices. *See Table A-1, SLO 1.2.*

Hot spots where yield declines with rising temperatures. *Ex ante* modelling research that used data from irrigated spring wheat areas in India and Sudan and applied the model to irrigated spring wheat regions worldwide found that (i) wheat yield declined linearly with increasing temperature; (ii) wheat farmers in low-yielding environments characterized by high poverty (such as southern India, southern Pakistan, or Sudan) would be hardest hit and that those areas constituted future food security hot spots; and (iii) deficits to national wheat production from rising temperatures would be higher in high-yielding environments (e.g., northern India). The study (2016) involved researchers from CIMMYT, the University of Florida, and Stanford University.

Getting the best breeding gains from stressed environments: In a study (2018) involving winter wheat in Iran and Turkey, researchers sought to make breeding for rain-fed wheat and other highly-variable environments more effective. Modeling experimental data from combinations of environments and selected traits to improve genetic gains in grain yield, they found date of heading and plant height to be key traits and suggested the following strategy: (i) define optimal heading and height ranges for the different target regions; (ii) select new progenies based on optimal heading and height defined in the target regions; (iii) run yield trials comprising sets of those wheat lines, for each region; and (iv) identify the highest-yielding lines in each set.

Farmer-managed climate risk in the Himalayan region of Pakistan. Researchers found that most farmers in the Himalayan region were aware of climate and temperature changes, as well as variations in the rainfall patterns and wind, and that predominant climate risk adaptation strategies included adjusting sowing time, adopting tolerant varieties, off-farm employment, and exploiting crop-livestock interactions. Educated farmers having land rights, large land holdings, and more household assets were most likely to adopt adaptation strategies; adoption of those strategies also improved incomes and yields and reduced poverty.

FP2: Novel diversity & tools for improving genetic gains and breeding efficiency

Novel genetic diversity and traits-related discovery research

Wheat production must adapt to warmer climates. Research has forecast a 6% decline in global wheat production for each degree C of global warming (Asseng, 2015). A physiological breeding pipeline based on a conceptual model of heat-adaptive traits has made use of the 70,000 geno- and phenotyped genetic resources and a synthetics panel to test new progeny of physiological trait-based crosses in 50 sites worldwide. Through this global trial, scientists identified several lines that performed better than checks. Research activities in 2018 and following years will focus on understanding the genetic diversity of five heat-adaptive traits and wheat's response to heat shock.

Improved varieties, landraces and genetic diversity potential. The largest-ever genetic characterization (article in press) of wheat diversity from CIMMYT and ICARDA seed collections involved analysis of some 90,000 unique samples of breeding lines, existing cultivars, synthetics (crosses of tetraploid wheat with grasses), and wild relatives of wheat. The scientists found that, despite the recognized global reduction in on-farm wheat diversity that has resulted from pedigree breeding and farmers' widespread adoption of improved varieties, a fair number of elite lines from breeding programs maintain a wide range of diversity from original landraces. The scientists also identified many landraces whose genetic content is unknown and unused in breeding programs and which may represent a source of valuable new traits. See also this related study.

Innovation in breeding research and new methods and tools

A new study on genomic selection using pedigree, genomic, and field data for 59,000 Mexico and South Asia wheat lines showed that genomic prediction models provide greater accuracy if they take into consideration genotype × environment interactions (G × E), compared to single-environment genomic prediction models. Outcomes can help predict the performance of experimental wheat lines targeted for Mexico and South Asia (Bangladesh, India, and Pakistan).

WHEAT and MAIZE biometricians and statisticians are providing freely available software to help breeders around the world make good breeding decisions based on sound statistical analyses. The software is in high demand: META-R has been downloaded over 3,700 times and GEA-R over 3,000 times. Use of the SampleTracker software is expanding due to the new partnership project with Intertek on low-density genotyping and through Genomic Open-source Breeding Informatics Initiative. Together with the Capacity Development unit, FP2 will attempt to track impact with users starting 2018. *See Table D-2.*

Innovations in pre-breeding and their impact on breeding research under FP2 & 3

Several new quantitative trait loci (QTL) associated with target traits were discovered by the FP3.8 team and breeders. These include QTL for yield stability, yield components (thousand kernel weight, grain number), diseases (rust, fusarium head blight), nematode resistance (crown rot) and nutrition (Zn content). Especially, a QTL for Fusarium head blight related low DON (a toxin) was confirmed and will be introgressed into elite lines. Two very stable QTLs for thousand kernel weight were observed across 5,000 bread wheat elite lines.

15,000 elite lines were genotyped with high-density markers for genomic selection or mapping purposes. The molecular breeding team (FP3.8) is operating in collaboration with high-density genotyping services, with partners TraitGenetics, Bristol University and Kansas State University.

FP3: Better varieties reach farmers faster

Getting improved varieties onto farmers' fields, on-farm diversity and precision phenotyping

The molecular breeding team (FP3.8) is operating a low-density marker platform in collaboration with 31 national partners and 7 from CGIAR (CIMMYT/ICARDA for wheat, see also Partnerships, above). The researchers genotyped nearly 40,000 wheat lines using from 1 to 10 gene-based markers. Marker-assisted breeding focuses on durable resistance to wheat diseases and insect pests, industrial quality and nutritious wheat, plant development, growth and yield, and in 2017 generated more than 200,000 data points. Up to 50 different genes were traced across wheat populations.

For the first time in 2017, all studies (either for breeding or research) were organized within the SampleTracker software, developed in-house. It designates each study with a unique project ID and each sample an individual ID. To speed the development of introgression lines for testing and use as parents in breeding, marker-assisted foreground and background analyses were applied simultaneously.

Heat tolerant and very early durum wheat varieties for the Senegal River Savannah. In research involving ISRA Senegal, CNRADA Mauritania, INRA and the University Mohammed V of Morocco, and SLU Alnarp, scientists developed a set of durum wheat varieties for the Senegal River Basin that can withstand temperatures of up to 40°C. At full scale, the varieties could generate 600,000 tons of additional food and help an estimated 1 million smallholder farm families to escape poverty. Researchers completed GWAS for heat tolerance and identified candidate genes for the trait. The work was awarded the Olam Prize for Innovation in Food Security and reported in over 100 media worldwide. *See Table A-1, SLO 1.2.*

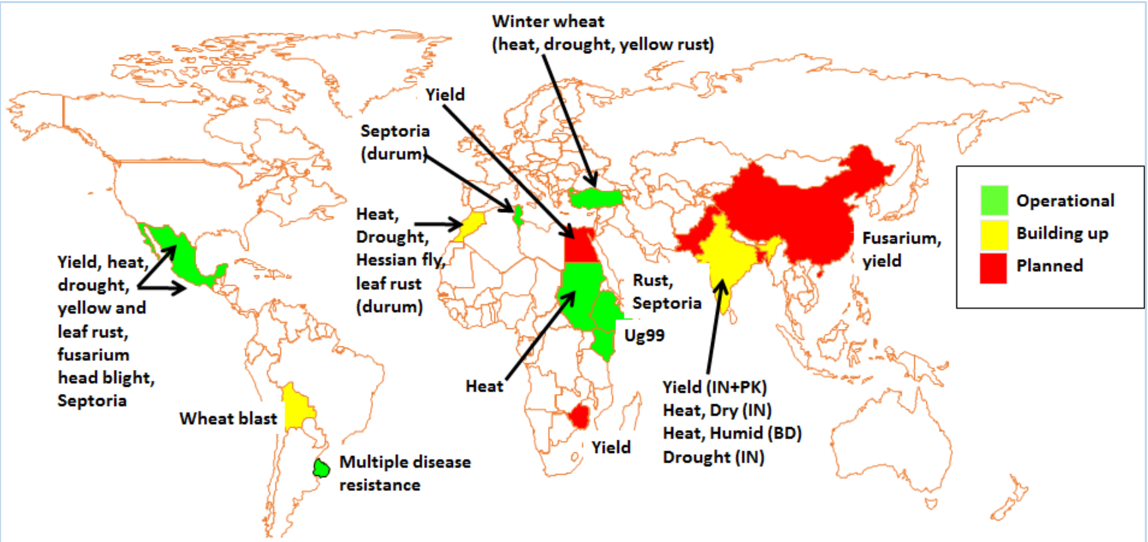
80 delegates from across the globe gathered at the 6th International Cereal Nematode Symposium in Agadir, Morocco, to discuss the spread of nematodes, strategies to lessen their impact on crops, and international research collaboration. Plant-parasitic nematodes destroy some 15% of global food production annually, a loss of more than $157 billion worldwide. Related research is of growing relevance, as climate change affects cropping conditions and nematode developmente. Organized by CIMMYTs soil borne pathogen program for wheat and the Moroccan Ministry of Agriculture (INRA), the meeting also covered host-plant resistance and integrated control methods. *See Table D-2.*

The 2016-2020 Delivering Genetic Gains in Wheat Program led by Cornell University (DGGW, $35M bilateral matched to WHEAT, funded by BMGF and DFID) has enlarged its R4D scope beyond rusts, with CIMMYT and ICARDA as the major implementing partners. 2017 achievements include expanding the Global Rust Monitoring System with 30,629 published geo-referenced survey records provided by teams from 20 countries, including (new in 2017) Italy, Ecuador and the Russian Federation. Project partners handled many more rust samples and race typing of isolates and genotyping, thanks in part to building capacity in Ethiopia for rust race analysis. Adaptive breeding in Ethiopia and Kenya via CIMMYT partnerships continued and the Njoro, Kenya, Wheat Rust Precision Phenotyping Platform tested advanced lines and breeding materials from USA, Canada, UK, Iran, Turkey, Uruguay, Nepal, Bangladesh, Afghanistan, India, Pakistan, Ethiopia, Hungary, South Africa and advanced research institutes. DGGW also implements a seed system innovation pilot in Nepal and manages the Women-in-Triticum Award program.

Four WHEAT (with W1&2) and NARS-co-funded precision phenotyping platforms are fully operational and two more (heat and drought, Morocco; yellow rust, Turkey) will be functional in mid-2018. The Sudan-based platform on heat remains operational and is funded entirely through national sources. Major research activities include:

- *For Septoria tritici blotch and durum wheat (Tunisia).* Evaluations at two field stations (Beja and Koudia). Data on more than 15,000 diverse accessions. The pathogen laboratory was renovated to reconfirm seedling resistance, characterize *Septoria* spp. populations, and prepare large amounts of inoculum for field evaluations.

- *For Septoria, leaf rust, and Fusarium head blight in bread wheat (Uruguay)*. Evaluation of more than 2,300 wheat lines from 12 institutions or seed companies of six countries.
- *For wheat blast (Bolivia and Bangladesh).* Evaluation protocols were developed for two field locations in Bolivia (Quirusillas, summer; Okinawa, winter) and one location in Bangladesh (Jessore, winter). Data were recorded for more than 6,500 wheat accessions and 2 elite lines were found to be resistant.



Global wheat phenotyping networks, 2017.

[Enhancing on-farm diversity of wheat landraces grown by farmers.]() Work conducted under the Turkey/CIMMYT/ICARDA International Winter Wheat Improvement Program (IWWIP) over 2016-2019 to return improved landraces to farmers is fostering community practices for enhanced wheat diversity among 3,000 farmers in 8 provinces of Afghanistan, Iran, and Turkey. Participants evaluated the genetic diversity of winter wheat landraces grown in farmers' fields in Turkey, Tajikistan and Uzbekistan and formed a core collection to analyze in detail the most promising and genetically diverse accessions. In Afghanistan, high-density genotyping allowed identification of 94% the varieties grown in farmers' fields, 60% of which aligned with farmers' assessments. A larger portion than expected of improved varieties are grown in the three regions studied, the most widely-grown varieties were the two CIMMYT lines Chonte #1, a CIMMYT line released in 2010, followed by Muaqawim-09, released in 2009. The percentage of landraces in farmers' fields has decreased. *See Table A-1, SLO 1.1.*

A new, exhaustive review of recent scientific studies on cereal grains and health has shown that gluten- or wheat-free diets are not inherently healthier for the general populace and may actually put individuals at risk of dietary deficiencies. This special compilation of 12 reports published in *Cereal Foods World* during 2014-2017 draws on more than 1,500 peer-reviewed studies regarding the dietary and health effects of eating cereals and wheat-based foods. It provides robust and consensual evidence that eating whole grains is actually beneficial for brain health and associated with reduced risk of diverse types of cancer, coronary disease, diabetes, hypertension, obesity and overall mortality. Wheat is also a significant source of fiber, important for good digestion. The results and other wheat health and quality research will be discussed and publicized by more than 200 experts from over 40 countries at 2 major conferences to be held in Mexico City in March, 2018, the

4th Latin American Cereals Conference and the 13th International Gluten Workshop, organized jointly by CIMMYT and the International Association for Cereal Science and Technology (ICC).

FP4: Sustainable intensification of wheat-based farming systems

Climate-smart agriculture in South Asia: *Ex ante* analysis, policy influencing, user adoption and collaboration with CCAFS.

Climate Smart Agriculture. An *ex ante* analysis revealed that a high-yield, low-greenhouse gas emission pathway is possible for agriculture in India through wide-scale adoption of improved technologies and practices such as zero tillage, irrigation, and precise management of residues, farm manure, and nitrogen fertilizer. Socioeconomic factors (gender, level of education, training) significantly influence the adoption of technologies contributing to high-yield, low-emission pathways. Along the same lines, a study focusing on farmer behavior suggested that adoption of zero tillage could be expanded if agricultural extension enabled farmers from different social strata to spread messages within villages, especially among poorer farmers, and the social inclusiveness of ZT could be enhanced by supporting the emergence of more ZT service providers, based on business models that lower costs for smaller farms. *See Table A-1, SLO 3.2.*

The Cereal Systems Initiative for South Asia (CSISA Phase 3) on sustainable intensification in South Asia has delivered results that include the following:

- Potassium fertilization is crucial for stress resilience, quality and high yields but inadequate and inappropriate in most intensive wheat production systems, due to policy issues. Based on a stakeholder dialogue, participants developed a policy brief on efficient potassium management in Indian agriculture to support national governments and other stakeholders.
- To support accelerated adoption of conservation agriculture based sustainable intensification in smallholder systems of South Asia, enabling policies are critical. Based on a regional policy dialogue involving key policy planners and other stakeholders, a policy brief was developed and circulated that advocated prioritizing investments to scale out conservation agriculture for sustainable intensification in South Asia.
- Indiscriminate use of ground water has depleted surface and ground reserves, and serious water deficits will worsen under the higher temperatures expected for South Asia, threatening agricultural sustainability. Fresh water withdrawals in India during 2008-2012 totaled more than 760 billion m3, 90% for agriculture. Research from WHEAT partners shows that combining layered sub-surface drip irrigation with conservation agriculture will allow increased productivity while consuming half the water in rice-wheat rotations.
- The government of Bangladesh is pushing surface water irrigation (SWI) for sustainable intensification. Remotely sensed, geospatial, and farmers' yield data integrated to target SWI show the practice could benefit more than 100,000 hectares of rain-fed cropland, substantially increasing maize and wheat productivity. A new online tool can help the development of irrigation schemes.
- Also in Bangladesh, axial flow pumps, reapers, and seed fertilizer drills to support sustainable intensification are being used widely: 2,000 agricultural machines were obtained and used by 1,800 service providers, reaching 90,000 farmers.

Remote sensing for nitrogen fertilizer dosing. Wheat farmers' over-application of nitrogen fertilizer and the consequences are well documented (2018 publication) and researchers are exploring and promoting alternative such as remote sensing to improve the precision of fertilizer use. The Sentinel-2 satellite system of the European Space Agency (ESA) is producing large, free data sets. ESA has commissioned development of Sen2Agri, which automates data processing and generates information layers such as normalized difference vegetation index (NDVI) and leaf area indices, which can be used for crop land or crop type classifications or to recommend nitrogen fertilizer dosages and timing for standing wheat crops. In tests of Sen2Agri to identify crop land and crop types in Mexico and Bangladesh, WHEAT scientists found the system identifies wheat in the Yaqui Valley of Mexico with more than 95% accuracy. Next steps include use of Sen2Agri for GreenSat.

The spread of zero tillage in Kazakhstan continues. In 2017 no-till was practiced on at least 2.7 million ha in Kazakhstan. In Almaty province (South-East Kazakhstan), one of the main winter wheat growing regions, the area increased by more than 5% over 2016 levels, with an associated average yield gain nation-wide of 0.1 t/ha in irrigated areas and 0.2 t/ha in rain-fed areas. *See Table A-1, SLO 1.1.*

Crops lands under different management practices in Kazakhstan.

Practice	Area (million hectares)				Operations
	2008	2012	2014	2017	
Conventional	11.6	8.0	7.7	6.2	Multiple tillage trips with blades and sweeps, (mostly mono-cropping system)
Minimal tillage	6.2	9.2	9.3	10.1	Direct seeding with V-shaped openers or with narrow chisels regularly combined with shallow harrowing/ cultivation, (few diversification)
No-tillage	1.2	1.8	2.0	2.7	Direct seeding with narrow chisels or double discs openers (diversification)

SARD-SC/Wheat successes: The African Development Bank's assessment of the ICARDA-led SARD-SC project noted that achievements had exceeded targets for increase wheat yields by 135%. Major short-term development outcomes have been:

- Nigeria: Household income of innovation platform-participating wheat farmers increased by 46-105%, compared to non-participating farmers. Wheat farmers in Nigeria were linked to a guaranteed output market, with a formal agreement signed between the Nigerian Farmers Association and the Nigerian Millers Association in 2016. Wheat area in Nigeria increased from 50,000 (2012) to 100,000 hectares (2016), production increased by 257% (from 70,000 to 250,000 tons) and wheat productivity increased by 78%, from 1.4 (2012) to 2.5 t/ha. Policy outcomes have been significant.
- Sudan: Driven by the Gezira Innovation Platform, enabling financial conditions have improved: loan amounts available to wheat farmers increased from $771,400 (2012) to $3,241,810, with much improved repayment rates (100% in 2016). Wheat area increased by 23%, from 185,000 to 230,000 hectares. National production increased by 133%, from 324,000 to 787,400 tons (e.g. 1.7 t/ha to 3.39 t/ha). Sudanese wheat imports dropped from 78% (2013) to 64% (2016) of total production. Similar achievements have been documented for Ethiopia, which should be considered in the light of a range of previous and ongoing R4D interventions funded by other donors.

Progress and challenges in addressing farm power (smart mechanization). MAIZE and WHEAT participated in developing the Framework for Sustainable Agricultural Mechanization in Africa (SAMA), South-South knowledge-sharing on mechanization and developing a mechanization strategy for sustainable intensification. Wheat strip tillage with a 2Wheel Tractor (e.g. mechanical row planting of wheat and fertilizing in single pass; no prior land preparation) is moving from the piloting to validation in Ethiopia, thanks to multi-year donor engagement. In Nepal, with the support from the government, USAID and as part of CSISA scaling-out efforts, the Nepal Agricultural Research Council (NARC) established an Agricultural Machinery Testing and Research Center, and the Department of Agriculture Directorate of Agricultural Engineering of Nepal's Department of Agriculture launched the Central Agricultural Machinery Training Center; both represent the country's intensified commitment to scale-appropriate mechanization research and development. *See Table D-2.*

Agroforestry and wheat-based systems: A study of interactions largely ignored by the land-sparing and land-sharing advocates showed that forests are crucial to ensuring the dietary diversity of nearby rural households. Forests can also sustain agriculture through pollination, pest control, water regulation, and climate regulation. The study area outside Munesa Forest, Oromia, Ethiopia featured mixed crop (wheat, maize, potato, legumes) and livestock farming. Investigators concluded that nutrition-sensitive agriculture in remote crop-livestock systems can be achieved by combining rational management of landscapes (retention of forest and pastures), livestock and nutrients, and household fuel sources (e.g., alternatives to livestock dung).

Faidherbia albida, a leguminous tree, sheds its leaves in the rainy season unlike most other trees. For this reason, it is highly valued in agroforestry as it can grow among field crops without shading them. At field scale, a three-season experiment in the Ethiopian Central Rift Valley showed that *F. albida* trees increase soil mineral N and wheat's water use efficiency, as well as reducing heat stress and significantly increasing yield. With greater heat and moisture stress as a result of climate change, *F. albida*, with its impact on microclimate modification, maybe a starting point to design more resilient and climate-smart farming systems.

Progress on Scaling approaches: MAIZE and WHEAT participate in the GIZ-led Scaling Task Force of 8 CIM experts, placed in 7 CRPs. Achievements of this new, dedicated Cluster of Activities under FP4 include development of a scaling tool and building capacity on scaling in the MASAGRO/PROAGRO projects with Mexico. The tool is embedded in a training package, and four training events were conducted with Mexican partners, after being tested with 46 PROAGRO / MASAGRO trainers. The Sustainable Resilient Farming Systems Intensification (SRFSI) project's phase 3 revolves around capacities for scaling. In late 2017, CGIAR and national partner researchers started a big Training of Trainers campaign in Nepal, Bangladesh and India. Third, WHEAT and MAIZE co-founded a CGIAR Scaling Community of Practice with the Royal Tropical Institute (KIT; NL), PPPlab (NL) and IITA, and joined the Scaling Up Community of Practice, coordinated by IFAD and with experts from the World Bank, MSI, USAID, DFID and others. *See Table D-2.*

1.3 Cross-Cutting Dimensions (at CRP level):

1.3.1 Gender:

Transformative technologies and gender in Ethiopia: As part of a 2017 review of gender-transformative methodologies for Ethiopia's agriculture sector, WHEAT specialists have been presenting widely about the people-centered, evidence-based approaches and these are being taken up by agriculture-for-development professionals. Involving participatory research to help households and communities assess their situation and develop solutions to problems, the methodologies also engage men and boys and allow communities to set the pace of change, helping to avoid backlash against women.

The WHEAT-relevant part of the GENNOVATE project involving 137 villages in 26 countries has found that both men and women in Afghanistan believe that improved wheat varieties have eased women's work of cleaning wheat seed by providing more uniform, better quality and bunt-free (a seed borne disease) seed. They also said the higher yields of the improved varieties encouraged the adoption of mechanical threshing, which further reduces work and ensures cleaner grain for household foods. GENNOVATE findings that debunk gender myths were published and continue to be promoted by the Platform for Gender Research under PIM.

Women, work, and wage equity in wheat farming in Morocco: In research supported by WHEAT and Dryland Systems (Phase I), scientists found that women predominantly performed lower-paid, time-intensive tasks in wheat agriculture in Saiss, Morocco, and were systematically paid less than men even when they performed the same tasks, despite existing legislation that ensures equal pay. A revalorization of agriculture is needed, because farm labor is seen as an occupation of last resort. In two provinces in Afghanistan, participants in the "Forage options for smallholder livestock in water-scarce environments of Afghanistan" emphasized that attitudes towards women farmers, and beliefs about what constitutes "masculine" and "feminine" tasks are changing.

WHEAT funded and promoted the CIMMYT Gender capacity development program roll-out in partnership with KIT (NL). Trainings were delivered in six country offices and two parallel trainings at CIMMYT HQ. In total more than 170 staff participated and gave very positive feedback.

1.3.2 Youth:

As young people are increasingly a focus of agriculture and food security funder programming and interventions, **research with the** Institute of Development Studies (IDS), University of Sussex, Brighton, UK, examined the potential opportunities that agricultural value chains, technology, and entrepreneurship offer for youth employment from a rural transformations perspective. Scientists analyzed young people's economic room to maneuver in rural contexts and the differential capacities of young people to exploit opportunities. Using cereal agri-food systems as an example, the authors point to new research on how young rural people in Africa engage and propose an analytical framework built around key contextual factors that constrain or enable young people's economic activity. The authors warn against constructing youth as a new and supposedly homogeneous target group whose concerns can be addressed independently of the rest of society.

1.3.3 Other Aspects of Equity / "Leaving No-one Behind[2]"

CIMMYT and ICARDA's collaboration with Afghanistan for 15 years. Complementary intermediate development outcomes have been achieved, but big hurdles remain (see APAARI report below), whilst "overall food insecurity in the country is on the rise" (FAO, 2017). ICARDA and national researchers have worked together on sustainable forage seed markets to improve livestock productivity, as well as developing pulse production in cereal-based systems. In the last five years, the Agricultural Research Institute of Afghanistan (ARIA) has used CIMMYT breeding lines to develop and make available to farmers seed of 15 high-yielding, disease resistant wheat varieties. Long-term donor commitment has been instrumental. However, FAO reports showed that farmer access to 10,000 tons of certified seed in 2017 meant that only 3% of Afghanistan's total wheat area would be planted with the best new varieties[3]. This is indicative of the challenges described in the 2017 APAARI country reports, which for Afghanistan lists low human capacity, insufficient research infrastructure or access to markets, among others. *See Table A-1, SLO 1.1.*

[2] https://unstats.un.org/sdgs/report/2016/leaving-no-one-behind

[3] By far the most important source for seed of new varieties in Afghanistan – and most developing countries - is seed from neighbors. Assuming a 3 t/ha yield and 50% of the certified seed is used for non-certified seed production for the coming season, 100 000ha are sown in year 2 (Hans Braun).

Regarding WHEAT R4D in other least developed countries and sub-national regions, please see information about outcomes or impacts in Pakistan (p.2&4) and India's Bihar (p.2).

1.3.4 Capacity Development:

In 2017, the ICARDA-led Enhancement of Food Security in the Arab Countries (EFSAC) project continued to spread improved wheat production technologies. More than 2,100 large-scale demonstrations conducted under farmers' conditions showed that farmers in the Arab region can increase wheat productivity under various production systems when they apply recommended technical packages. Field data from 2016-2017 showed that yields more readily increase in the fields of farmers involved in the project than in those of neighboring farmers. The average increase across all 9 countries was 26% and the average maximum increase 72%.

Fully mapped to WHEAT Phase II, EFSAC also strengthens the capacity of farmers and extension and technical staff, organizing during 2017 more than 560 events attended by more than 17,500 participants, 68% of whom were farmers. In addition six young researchers were trained during 2017 through the Young Agricultural Scientists Program (YASP) at ICARDA research platforms and locations to improve the productivity of wheat-based systems. The YASP program has provided advanced training for 54 young wheat scientists from the Arab region, 19 of whom were woman. Phase II of EFSAC will continue in 2017-18.

Advanced conservation agriculture training in Asia. Gateway for sustainable intensification. The 8th edition of the two-week "Advanced Course on Conservation Agriculture (CA)" was held at Ludhiana and Karnal, India, covering topics from the calibration and operation of scale-appropriate CA machinery to modeling systems, climate change mitigation, and precision water and nutrient management for smallholders. Having trained nearly 150 researchers from nine Asian countries since its launch in 2010, this most recent course was organized jointly by CIMMYT, the Borlaug Institute of South Asia (BISA), and CCAFS, MAIZE, and WHEAT, with support from Indian research organizations including the Indian Council of Agricultural Research (ICAR) and Punjab Agricultural University (PAU).

Demand-driven training supports international wheat blast control effort. With backing from leading international donors and scientists, nine South Asia wheat researchers recently visited the Americas for training on measures to control wheat blast. The two-week workshop took scientists from Bangladesh, India, Nepal, and Mexico to U.S. greenhouses and labs, as well as to fields in Bolivia where wheat lines are tested for resistance under actual blast infections. "Scientists in South Asia have little or no experience with blast disease, which mainly attacks the wheat spike and is completely different from the leaf diseases we normally encounter," said Prem Lal Kashyap, a scientist at the Indian Institute of Wheat and Barley Research (IIWBR) of ICAR, who took part in the training. Alumni will use the experience to refine screening methods in South Asia, maintain communication with blast experts from the Americas, and raise awareness among farmers and policymakers in their home countries. The training followed on from a February course organized at the Wheat Research Center (WRC) of the Bangladesh Agriculture Research Institute (BARI), in collaboration with CIMMYT, Cornell University, and Kansas State University. *See Table A-1, SLO 1.2.*

Promoting gender equity in agricultural research. CIMMYT held a series of training courses promoting the integration of gender awareness and analysis in research for development. Conducted in partnership with the Royal Tropical Institute (KIT), the courses reached 174 staff (123 male, 51 female) in 7 CIMMYT offices/countries.

MAIZE and WHEAT co-funded a project to establish, pilot and implement a *Learning Management System (LMS)*. External experts in 2016 designed it after the fact-finding mission. The LMS with its functionalities was developed based on 13 pilot courses that represent the different training formats and environment at CIMMYT locations (offices & field). The System will be launched at the end of January 2018. Processes and workflows were defined and staff trained in the use of LMS, so that all training activities will be managed systematically through this system. Common methods and approaches will be defined to improve the interoperability between CIMMYT and ICARDA LMS system. The developers have connected with IITA and ICARDA from the outset and during 2018, the LMS will be presented to other CGIAR centers. ***See Table D-2.***

1.3.5 Open Data:

WHEAT-related Open Data Resource content has grown, but in 2017, no *additional* resources or tools were made available to a larger audience. Key challenges to Open Data Access implementation, which also apply to WHEAT, were aptly summarized in 2017. Bilaterally funded Open Data resources include the CSISA Open Data repository, with currently 14 datasets.

In 2017, the CIMMYT data repository that hosts open access WHEAT datasets was migrated to Dataverse 4.7.1. CIMMYT set up a partnership with the Dataverse development team at Harvard University, resulting in the release of version 4.6.2, which was featured during the 2017 Dataverse Community Meeting. ICARDA benefitted from CIMMYT experience in Dataverse and deployed its OA-OD Policy compliant repository (Version 4.7) using the same handle permanent identifier method as CIMMYT. This milestone has been support by the CRP on Livestock and the BigData Platform. ICARDA and the BigData Platform added enhancements to ensure interoperability with the FAO-AGROVOC vocabulary.

Also in 2017, CIMMYT started a full revamp of its digital repositories, including Dataverse, chiefly to make WHEAT's Open Access assets available through the Mexican National Science Repository, which will be harvested by the Latin-American Regional Science Repository "LA Referencia" in the near future.

A growing number of scientists are depositing data sets, and researcher downloads of Open Access datasets grew from 281 to 361— a 28% increase — from May 2017 to April 2018 (35k file downloads) and the trend continues.

1.3.6 Intellectual Assets:

CIMMYT, participating CGIAR centers, and partners manage WHEAT CRP Intellectual Assets ('IA') in accordance with the CGIAR Principles for the Management of Intellectual Assets and the CGIAR Open Access and Data Management Policy. WHEAT is not a legal entity, so IAs are managed across the research portfolio of each Lead or Participating Center, without specific regard to how projects are matched to CRPs (or not) and funded.

Every year, CGIAR centers submit an Intellectual Asset report to the CGIAR System Management Board, in which centers describe the most relevant IA management strategies and practices and a summary that describes in detail intellectual property arrangements for Limited Exclusivity Agreements and Restricted Use Agreements. WHEAT does not duplicate IA Report information in this Annual Report.

During 2017, as WHEAT Lead Center CIMMYT strategically managed IAs generated through WHEAT research projects, with a focus on revising current dissemination pathways for two main outputs: germplasm and research data. With respect to germplasm, CIMMYT updated its germplasm policy (currently under upper management review), to be finalized during 2018. This policy now includes new licensing schemes intended to recoup, under certain commercialization scenarios, a portion of the R&D investment in the development of the germplasm being commercialized, including scaling up and out through IA management. CIMMYT also standardized and maintained transparency of its wheat product allocation principles, referenced in its germplasm policy. With respect to research data, CIMMYT continued to define data management standards that allow dissemination of datasets in the broadest possible way: through public repositories and data sharing agreements. At the same time, these standards respect all Centers' obligations under (i) the International Treaty on Plant Genetic Resources for Food and Agriculture, (ii) the privacy of individuals; (iii) confidential obligations acquired; and/or (iv) intellectual property rights of third parties.

(b) Indicate any published patents and/or plant variety right applications (or equivalent) associated with intellectual assets developed in the CRP and filed by Centers and/or partners involved in the CRP (please fill out or update the Table E);

CIMMYT and ICARDA have not filed, nor have any CIMMYT or ICARDA partners informed CIMMYT of any application, for patent or plant variety protection associated with intellectual assets developed as part of WHEAT.

(c) List any critical issues or challenges encountered in the management of intellectual assets in the context of the CRP.]

Most critical challenges encountered in IA management in the context of WHEAT were identified in the Phase II Full Proposal (listed below for reference). Two additional challenges were added in the light of recent developments, in the field of datasets (related to digital sequence data and datasets with personal, private information):

- Ensure sufficient funding (including sufficient human resources), to implement on a timely basis all actions needed for a proper IA management.
- Lack of IP policies in some NARS; lack of knowledge among NARS of IA management practices at CGIAR centers and/or insufficient capacity to conduct adequate IA management.
- Collecting, exporting and licensing seed in view of the ITPGRFA and the Nagoya Protocol.
- Some IP policies or practices from certain WHEAT partners are not aligned with CGIAR IA management Policies;
- Harmonization of licensing practices to disseminate digital sequence data with the Open Access obligation, in light of concerns raised among some ITPGRFA stakeholders in relation to the use of such datasets;
- The rising bar for Centers' privacy protection and accountability in the context of dealing with datasets, wherein such data include personal information that carry with them accompanying dissemination obligations under Open Access.

2. CRP Effectiveness and Efficiency

2.1 Variance from Planned Program:

- *Program research scope*. No significant change to overall and per FP research scope. In addition to research priorities per FP and 'uplift budget' researchable issues described in the Phase II Full Proposal, WHEAT-MC identified the need to invest more in mechanization (FP4) and soil-borne diseases (FP3), because in next 25-30 years wheat production may well move into more marginal areas. In such areas, access to labor will likely a growing challenge and there will be less or no irrigation. Marginal areas will be exposed to greater climate change effects (heat, drought). Soil borne diseases cause more yield losses in rain-fed and drought-stressed environments, because of the damage done to roots.

- *Program delivery*. Some delays in delivery, as cautious FP-level spending in response to uncertainty about W1&2, for example FP1 Kyrgyzstan, Tajikistan, Uzbekistan Adoption and Impact Study (Methodology Development, Training, Survey and Database).
- *Learning at CRP/FP-levels.* The FP4 Sustainable Intensification Program implemented three regional retreats. The key Lessons Learnt from the South Asia FP4-SIP Retreat in 2017 were 1) Important to offer a basket of technologies and layering of those, 2) all implementing partners need to invest in their own capacity development & 3) a flexible and accommodating approach to partnership and project implementation can make a big and positive difference to impact on the ground. FP4 2017 budget in the region was over $20M or 63% of total WHEAT FP4 budget.

2.2 Use of W1-2 Funding:

WHEAT is guided by the high-level framework for W1&2 deployment shown below, whilst *Table F below (optional for 2017 reporting)* shows in more detail what W1&2 has been used for during 2017. This information is based on W1&2 annual work-plans per FP and per annual reporting templates per major activity.

	Strategic, longer-term research, seed invests	Rapid response (incl flexibility)	Cross-Portfolio, -CRP learning for impact	CRP Gov. & Mgmt.
Discovery (upstream)	FP1, 4: ex ante IA & ex post IA / adoption studies for new knowledge for better targeting, prioritizing; ARI, national partners FP2-4: Generate new knowledge for R-to-D pipeline: New alleles for heat and drought, other climate change-related traits identified; GS models using high throughput phenotyping and / or environmental data; Biological Nitrification Inhibition	FP3 new diseases & pests: Wheat blast in S-Asia	FP2-3: Germplasm improvement methodologies, methods, data mgmt (e.g. Genetic gain, cross-crops) FP4: Research on scaling out, innovation pathways	WHEAT-ISC, WHEAT-MC. SMB Member (DG), CRPs Rep in SMB, MEL CoP co-leadership
Validation	FP3: New traits into elite lines: Heat and Drought. Precision Phenotyping Platforms with NARS partners; expanded yield testing		FP4: Country coordination, systems research approaches	
Scaling out (down-stream)	FP1, 4: Research on adoption dynamics, scaling out, targeting, prioritizing, M&E approaches FP3: Research on farmer adoption, seed systems innovation	FP3-4: post-conflict emergency support	FP3.7, 4.4: Country coordination, companion crops into wheat-based systems, capacity development	
CGIAR-SRF Cross-cutting themes	Gender / social inclusion applied to 2 to 4 WHEAT innovation pipelines and assessments rapid value chain assessments with proper gender lens		FP1, 4: AFS-CRPs & CCAFS FP3: WHEAT & A4NH on improved nutrition Inter-CRP: How to improve gender mainstreaming into research	

2.3 Key External Partnerships:

New and emerging partnerships include i) The Foundation for Food and Agriculture Research (FP2, bilateral),which launched the "Crops of the Future Collaborative," to accelerate crop breeding to meet global food demand 20-50 years in the future; ii) greater collaboration on scaling-out with the Nature Conservancy (FP4) and iii) a number of Advanced Research Institute partners in the domain of sustainable intensification outcomes indicators, trade-off analysis and remote-sensing supported targeting or prioritizing (FP4) – *see Table G*.

WHEAT intends to perform learning activities across its FPs with regard to developing and shaping partnerships at multi-project level in 2018/19.

2.4 Cross-CGIAR Partnerships (other CRPs and Platforms):

- WHEAT has joined the newly established CCAFS Platform on Soil Carbon Sequestration.
- The Big Data Platform's 2017 Inspire Challenge winners included 2 proposals involving CIMMYT/WHEAT scientists: Real Time Diagnostics for Wheat Rust: Use of mobile gene sequencers to drastically cut diagnosis time, resulting in faster treatment of devastating wheat rust pathogens in Ethiopia; and IVR (Interactive Voice Response) Marketing Service : Which will increase linkages between individuals in the value chain, no matter their literacy level and language, enabling farmers to report their harvest, locate product, and also connect the underemployed with work.
- Genebank Platform and AFS-CRPs' collaboration on Germinate 3.
- WHEAT scientists' participation in the Advisory Committees that are developing the 5 modules of the Excellence-in-Breeding Platform.
- Collaboration with HarvestPlus, under A4NH, resulted in initial high zinc wheat farmer adoption successes in Pakistan and India.
- Bottom-up collaboration between FTA and WHEAT scientists on agro-forestry and wheat-based systems
- Scoping of future collaboration domains between WLE and WHEAT/MAIZE.
- Proposal development collaboration with CCAFS and GIZ. As part of a multi-year effort, CCAFS, MAIZE and WHEAT have invested in multi-partner/stakeholder planning of a Climate-Smart Agriculture scaling-out proposal, together with GIZ Southern Africa. The aim is to have GIZ**, an accredited agency, take the proposal to the Green Climate Fund in 2018.**

See also Table H.

2.5 Monitoring, Evaluation, Impact Assessment and Learning (MELIA):

FP4 invested (W1&2) in several regions-based learning exercises, as well as a workshop to re-think systems analysis, which brought together FP1 and FP4 scientists, MAIZE, WHEAT, CCAFS, BIG DATA and advanced research partners.

CGIAR collaboration: MAIZE/WHEAT provided co-leadership MEL CoP; CRPs Representative in SMB, contributed to practicable harmonized indicators, POWB and AR designs and definitions, helped generate consensus across the CRPs/PFs.

Due to budget restrictions, WHEAT and MAIZE did not commission a planned evaluation of FP2: Novel Tools and Diversity. This has been re-scheduled for 2018, budget permitting. However, the CIMMYT spring bread- and durum wheat programs were externally evaluated, based on the Breeding Program Assessment Tool (BPAT; a follow up to the 2015 BPAT evaluation; bilaterally funded). Both programs received excellent marks.

WHEAT continued to build capacity in terms of project management, conducting 5 four-day trainings at regional offices and at HQ in 2017. These trainings include sections to strengthen project-level monitoring, evaluation and learning and feed into institutional decision making and learning.

WHEAT reviewed and reflected on FP theories of change at the end of 2017 based on performance data collected and lessons learned. Best practices have been taken into account for next year. In 2017, FP teams came together to collectively develop indicators, targets, data sources, data collection frequencies and data collection responsibilities for each output, outcome and assumption for the duration of Phase-II.

WHEAT has also conducted regular follow-ups on evaluation recommendations from the 2015 Evaluation of the CGIAR Research Program on Wheat and the 2014 IEA Review on CRP Governance and Management, in compliance with the CGIAR Policy for Independent External Evaluation. WHEAT has fully implemented all but one of the recommendations.

In 2017, MAIZE and WHEAT rolled out use of the MARLO platform (Managing Agricultural Research for Learning and Outcomes) to strongly link individual projects and areas of research to 2022 outcomes and the WHEAT impact pathway, as well as to easily plan and budget its work, monitor research progress, and report on CRP results in coming years.

2.6 Improving Efficiency:

WHEAT scientists have provided examples of efficiency improvements at project and unit/department levels across CIMMYT-ICARDA, via the MARLO platform. Aggregation of such information will be provided in the Annual Report 2018.

3. CRP Management

3.1 CRP Management and Governance

CRP FP and CoA leadership role and functions should be well integrated into Center-based management structures and associated reporting lines. In effect, this represent a matrix organization, though FP and especially CoA Leads act on a peer-to-peer leadership principle, as they do not necessarily have formal unit or department leadership functions as defined by the employing Center – and FP/CoA Lead roles end with closure of the CRP. Even in a 2-Participating Center CRP, this is not easy. In collaboration with WHEAT-MC, CoA Leads reviewed their terms of reference in 2017. Due to W1&2 funding volatility, WHEAT-MC withheld a dedicated, small budget to facilitate CoA leadership activities, but has opted to resume with deploying it, at the discretion of FP Leads, in 2018, not least to ensure progress towards the CIMMYT and ICARDA Board of Trustees' endorsed One CGIAR Global Wheat Program.

FP and CoA Leads participated in a bottom-up prioritization exercise of W1&2 funding per FP that was the basis for WHEAT-MC allocations in 2018.

WHEAT- and MAIZE-MCs decided to re-structure their shared CRPs-PMU effective 1st January 2018, aiming to better streamline routine work processes and associated methods and tools.

WHEAT-ISC recommendations to the CRP Director/WHEAT-MC and the Lead Center Board of Trustees' Program Committee were fully followed up in 2017 and several WHEAT-ISC members engaged in 'Ambassador' functions and regional scientific events with WHEAT research partners. John Roy Porter took over from Tony Fischer as WHEAT-ISC Chair.

3.2 Management of Risks to Your CRP

(see the **CGIAR Risk Management Guidelines**).]

During Phase I, WHEAT applied a risk management matrix to regularly assess and manage risks related to delivery of results. The three major risks identified remained unchanged during Phase II:

- W1&W2 budget insecurity and delayed transfer of W1&2 funds, which directly affects CRP research and development operations;
- Unfulfilled obligations by the partners for commissioned and competitive grants;
- Lack of a systematic and integrated approach for monitoring and evaluation at the outcome level.

To mitigate risk (1), the W-MC gives priority to multi-year investments of centers and partners, and uses the issuing of new partner grants as the most flexible component of the budget. WHEAT continues to sign only one-year partner grant contracts, to manage partner expectations and minimize any delays of payments to them. For risk (2), WHEAT regularly monitors the fulfillment of obligations by partners and intervenes when necessary to ensure proper completion of grant requirements. As for risk (3), MAIZE and WHEAT counts with the support of a shared Senior Monitoring, Evaluation and Learning Specialist to strengthen the CRP monitoring and evaluation system. A number of CIMMYT/WHEAT initiatives also contributed to minimizing risk, including the implementation of MARLO.

3.3 Financial Summary:

Throughout the year, WHEAT-MC remained committed to the 2017 budget of $11.154 (75% of SC-endorsed 14.8M), also when the DFID contribution was confirmed in December 2017. WHEAT-MC then took decisions about the deployment of unanticipated carry-over under the 2018 budget. For more details, see Table J.

W1&2	2017 75%
CRP Management incl ICARDA	1,350,000
	154,840
ICARDA	2,023,654
CIMMYT	6,774,840
Partners	851,506
Total	11,154,840

TABLES

Table A: Evidence on Progress towards SLOs

Table A-1: Evidence on progress towards the SLOs (sphere of interest)

***From WHEAT Phase II Proposal:* Table 4. WHEAT contributions in view of SRF commitments, estimated relative to the importance of wheat for poor producers and consumers and to proposed core budget (see also PIM Table A).**

SRF targets (2022/2030)		WHEAT (2022)	WHEAT (2030)	Assumptions
1.1	100/350 M more farm households have adopted improved varieties, breeds or trees, and/or improved management practices.	17.5M	36 M	Improved varieties released by NARS 2015-2030; 169 M farm households producing wheat (of 570 M farms in developing world; FAO 2014) in low-middle income countries; 15-30% adopting new WHEAT innovations (dependent on country income level); based on global impact study (Lantican et al. 2016). Estimates will be refined through further ex post impact studies for specific geographies (FP1.2) and updated global variety release and adoption data (uploaded in wheatatlas.org).
1.2	30/100 M people, of which 50% are women, assisted to exit poverty.	5.7M	12 M	Based on $1.25/day purchasing power parity (World Bank); number of poor (producers & consumers) in wheat growing areas categorized by the relative importance of wheat (share in food crop area); assumed poverty effect (0-15%) of stratified adoption (15-30%), both dependent on country income level (low-middle income countries).
2.1	Improve the rate of yield increase for major food staples from current 1% to 1.2-1.5% / <2% to 2.5% per annum (pa)	1.4% pa	2.5% pa[4]	Global average yield growth rate, broken down to WHEAT target geographies, based on reported farmers' yields in official statistics; 2022 target already implies 40% increased annual gains; 50% gains each (0.7%) from germplasm (genetic gains) & from crop management; assumes maintenance breeding translates into avoided losses (Lantican et al. 2016).
2.2	30/150 M more people, of which 50% are women, meeting minimum dietary energy requirements	10M	55 M	Based on FAO World Hunger Map (SOFI 2014), WHEAT target regions and on average 20% of daily calories for 1.2 bn wheat-dependent poor ($2/day) producers and consumers. Wheat kCal contribution per capita has been constant over past decades; and will continue to account for a substantial share of human energy needs (kcals) for a growing world population in 2050 (Wageningen FSC, 2016); assuming affordability, access.
2.4	10%/33% reduction in women of reproductive age consuming less than the adequate number of food groups.	3M	10 M	Indirect impact of maintaining low staple food (wheat) prices for poor consumers, thereby able to spend more of their income on other diverse non-staple foods; consumption of Zn/Fe enriched wheat varieties (see also A4NH/Harvest+); assuming affordability, access.
3.1	5%/20% increase in water and nutrient (inorganic, biological) use efficiency in agro-ecosystems ...	5M ha	20 M ha	20% wheat area in target geographies, equivalent to ca 100 M of global 240 M ha sown to wheat.
3.2	Reduce GHG emissions related to agriculture by 0.2/0.8 Gt CO_2 yr^{-1} (15%) compared with a business-as-usual scenario in 2030.	5%	Between 5%-20%	Agri emission intensities reduction in select target regions, in terms of % change from 2015 baseline in fertilizer N consumption, NUE and soil carbon; Biological nitrification inhibition (BNI) varieties on farmers' fields.
3.4	2.5/7.5 M ha of forest saved from deforestation	0.18 M ha	0.5 M ha	Indirect effect of net land savings (Stevenson et al. 2013).

[4] Note that this figure refers to a basket of CGIAR mandate crops and not to wheat on its own.

SLO Target (2022)	Brief summary of new evidence of CGIAR contribution to *relevant* targets for this CRP (with citation)	Expected additional contribution before end of 2022 (if not already fully covered).
1.1. 100 million more farm households have adopted improved varieties, breeds, trees, and/or management practices	CSISA adoption dynamics study on zero-till service providers, Bihar, shows significant growth rates (2012: 733, 2016: 2909). Greater adoption of Reduced/Zero Till on Eastern Gangetic plains needed and feasible: Only 44% of sample households knew about ZT technology, with substantial scale bias in favor of larger scale farmers with respect to awareness and adoption. Both the adoption behavior and characteristics of the respondents' network members influenced their own awareness and adoption of ZT, particularly among smallholders. Farmers valued the time-saving potential of ZT, especially under conditions of increasingly unreliable monsoon rains resulting in a delayed rice crop and, consequently, late establishment of wheat, which reduces yield. Project/scientist-derived, ex post: New evidence about farmer adoption in 2017: 79 CGIAR-derived winter varieties, released between 2008 and 2017 grown on 2.5M ha in West & Central Asia. More than 70 wheat and other cereal varieties developed and released during 2000-2017 by KASIB grown on ca. 6M ha (wheat only). Ethiopia: Emergency seed multiplication gave 271,000 rural households (1.6M individuals) access to improved varieties, which they grew on 100k ha. Ex ante study indicates wheat production can be expanded in a number of divisions in Bangladesh by facilitating and encouraging farmers to produce wheat. This can have positive impacts on the poverty reduction efforts, by allowing resource-poor farmers to grow one additional high-value crop. A recent study by Gumma *et al*. (2016) demonstrates more than 1.90 M ha of land that farmers keep as winter fallow. By bringing this land into short-duration wheat cultivation, Bangladesh could boost its domestic supply of wheat, and lessen its import burden. Ex ante study: Adoption NW India of combine concurrent use with Turbo Happy Seeder so far estimated at 5,000 ha. 80% of NW India rice-wheat production relies on rice residue burning. Replacing residue burning with mechanized harvesting and no-till on 2M ha would offer major gross income, cost, and GHG reduction benefits. Requires updated ex post adoption study: Afghanistan partners have developed and released 12 high-yielding and disease resistant bread wheat varieties, as well as 3 varieties of durum wheat, 2 of barley and 3 of maize; more than 9,000 new wheat and maize lines introduced into the	No (e.g. no expansion of WHEAT 2022 target 17.5M) WHEAT sub-IDOs focus: Enhanced genetic gain *on-farm* (1.4.3) More efficient inputs use (1.3.4 & 1.4.2, 1.4.4)

	country since 2012. (2017 workshop reports; no update to impact assessment publication since 2013.	
1.2. 30 million people, of which 50% are women, assisted to exit poverty	Ex ante: the durum varieties (resisting 35-40 °C) could generate 600,000 tons of new food and help drive out of poverty 1 million smallholder farmer families that live along the River[5]. Research received Olam Prize. Emergency seed support 2016-17: 1.6M people (217,000 HH) reached in 4 Ethiopian regions. Ex ante, **CSISA scaling out / mainstreaming partnerships (KVK)**: Promoting early sowing for 1.5 million hectares of wheat using zero tillage represents a potential $255 million in additional profits for the region from sowing wheat 5 days earlier. Ex-ante (currently in press): study shows that, under conservative scenario of 5-10% wheat blast production damage in single season in likely affected areas, wheat grain losses would amount to 0.89-1.77 million tons worth $180 – 350 million. Ex post impact, donor-funded, Enhancement of Food Security in the Arab Region (EFSAC) project (2011-2018): Average yield increase of 28% across all demonstration sites, noting trend continued during 2nd phase (2015-2018). US$5.3 million invested during the initiative generated "in-pocket gains" of US$54.2 million for farmers in Egypt, Tunisia, and Jordan (Phase I, 2011-14).	No (e.g. no expansion of WHEAT 2022 target) WHEAT sub-IDO focus: Reduced prod. risk (1.1.2 & (1.4.1)
2.1. Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	DNA fingerprinting, Ethiopia, 2016-17: Evidence of rapid expansion of newly released varieties (2016 vs 2014); **91% of varieties detected and 87% of area sampled** from CIMMYT germplasm. DNA fingerprinting Afghanistan (to be published 2018): 94% of grown varieties detected with high-density genotyping. Majority of improved varieties grown are CIMMYT varieties. Caveat: Sampling only representative of 'demo' villages and assuming finding is representative for all Afghanistan, link to yield growth must be shown. Ex ante, Pakistan: Participatory varietal selection research showed the potential for food security of smallholder farmers through new high-yielding varieties, which gave an additional 0.3 –0.5 tons of grain per ha.	No (e.g. no expansion of WHEAT 2022 target) Enhanced genetic gain *on-farm* (1.4.3)

[5] Estimate to be reviewed during Phase II.

2.2. 30 million more people, of which 50% are women, meeting minimum dietary energy requirements		WHEAT did not provide a target, because this falls under A4NH/Harvest+
2.3. 150 million more people, of which 50% are women, without deficiencies in one or more essential micronutrients	WHEAT: No target, feeds into A4NH outcomes Agriculture Innovation Program (Pakistan): 21 producer groups also in remote areas of Pakistan produce quality high zinc seed, most popular with farmers in 2016 trials. HarvestPlus: Zinc wheat will reach at least 100,000 farming households in Pakistan by 2018. Ex post, project report (HarvestPlus, A4NH): High zinc wheat, India, 50,000 farmers adopted.	No (e.g. no expansion of WHEAT 2022 target) WHEAT reports via A4NH
3.1. 5% increase in water and nutrient efficiency in agroecosystems	http://www.cimmyt.org/study-reveals-new-opportunities-to-cut-greenhouse-gas-emissions-in-india/ Cited here: Optimum fertilizer application in wheat using optical sensors such as the GreenSeeker can reduce national emissions in India by 0.14 to 2.5 million Mg CO_2e without compromising yield (Basak 2016).	No (e.g. no expansion of WHEAT 2022 target) Agri systems diversified, intensified in ways … (3.2.2 & 1.3.4) Enhanced capacity to deal with climatic risks & extremes (A.1.4)
3.2. Reduction in 'agriculturally'-related greenhouse gas emissions by 5%	Ex ante study revealed importance of considering both on farm management and socioeconomic factors when developing high-yield low-emission pathways for cereal production systems. All mitigation-related interventions require investment decisions at the household level. Scientists explore the options that can help to reduce agricultural emissions, whilst raising production and in a region of global importance in relation to the food-climate nexus; highlights the contribution that improved cropland management can make to India's INDC of emissions reduction to UNFCCC.	No (e.g. no expansion of WHEAT 2022 target) (A.1.4)
3.3. 55 M ha degraded land area restored	Ex ante, proxy: Field scale, a 3-seasons experiment, Ethiopia: *F. albida* trees increase soil mineral N, wheat water use efficiency, reduce heat stress, increasing yield significantly.	No (e.g. no expansion of WHEAT 2022 target)
3.4. 2.5 M ha forest saved from deforestation		

Table A-2: List of New Outcome Case Studies from This Reporting Year (Sphere of Influence)

Title of outcome case study	No. of Sub-IDO	Links to evidence*	Space for additional, very brief details, including on cross-cutting issues
Identifying high-yield low-emission pathways for the cereal production in South Asia	A.1.4 *(go to POW B 2017 below)*	Sapkota, Tek B. et al. 2017. Identifying high-yield low-emission pathways for the cereal production in South Asia. Ali, A., and O. Erenstein. 2017. Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. Ali, A., et al. 2017. Impacts of changing weather patterns on smallholder well-being: evidence from the Himalayan region of Northern Pakistan. Rahut, D.B., and A. Ali. 2017. Coping with climate change and its impact on productivity, income, and poverty: Evidence from the Himalayan region of Pakistan.	
Can Sub-Saharan Africa Feed Itself?"	C.1.1.	van Ittersum, M.K., et al. 2017. Can sub-Saharan Africa feed itself?	Focused on 10 countries where cereals make up half of calories in human diets and half the cropland that are part of the Global Yield Gap Atlas, developed using local data to estimate food production capacity on existing cropland. 7 of the 10 countries lack land area to support expansion. Except in Ethiopia and Zambia, cereal yields in most countries are growing more slowly than population and demand, while total cropland area has increased 14% in the last decade. Except for Ethiopia, the countries lag in crop production intensification.
Changing Food Consumption of Households in Developing Countries: A Bangladesh Case	C1.1.	Mottaleb, K.A., et al. 2017. Changing Food Consumption of Households in Developing Countries: A Bangladesh Case.	Using information from more than 29,000 households, this study demonstrates that increased incomes and urbanization are leading consumers in Bangladesh increasingly to substitute wheat for the traditional rice, both in rural and urban areas, a finding that questions the prevailing premise that, with increasing income, households switch from staple cereals to high food-value items.
Conservation Agriculture practices impact on air pollution in India	C.1.1	The Evergreen Revolution See also section 1.1 and 1.2 above	Burning rice straw significantly worsens air pollution in India, especially in Delhi and the national Capital. An economical, scalable and sustainable solution is use use of straw management systems on combine harvesters and direct sowing of wheat seed in unplowed soils and rice residue.

Impacts of Conservation Agriculture practices in South Asia	D.1.1	Ali, A., et al.2017. Implications of less tail end water on livelihoods of small farmers in Pakistan. Keil, A., et al. 2017. Zero-tillage is a proven technology for sustainable wheat intensification in the Eastern Indo-Gangetic Plains: what determines farmer awareness and adoption? Krishna, V., et al. 2017. Conservation tillage for sustainable wheat intensification: the example of South Asia. In: Langridge, P. (Ed.), Achieving sustainable cultivation of wheat Volume 2.	
Gender and innovation processes in wheat-based systems. GENNOVATE Report to the CGIAR Research Program on Wheat. GENNOVATE Research Paper.		Badstue, L.B. et al. 2017. Gender and innovation processes in wheat-based systems.	This report illuminates how gender norms and agency work together to shape access to, adoption of, and benefits from agricultural innovation at the local level. The findings are based on the perspectives and experiences of approximately 2,500 women and men who live and work in 43 villages of Afghanistan, Bangladesh, Ethiopia, India, Morocco, Nepal, Pakistan, and Uzbekistan, where wheat is a key crop.

*Please submit outcome case studies in MARLO, MEL or other MIS, and provide links, using the outcome case study template.

See also adoption and impact studies at annex, below.

Table B: Status of Planned Milestones

Note: All WHEAT researchers deliver an annual report of W1&2-funded activities (internal template). WHEAT CRP Management makes use of available bilateral annual progress reports, to the extent available. Some bilateral projects do not follow the CGIAR Financial Year.

FP	Mapped and contributing to Sub-IDO	2022 CRP outcomes (from proposal)	Milestone*	2017 milestones status (Complete, Extended or Cancelled)	Provide evidence for completed milestones** or explanation for extended or cancelled
1	C1.1	1.9 Last mile provider (extension partners, farmer organization, community-based organizations, private sector) increased access and promotion of technologies to farmers	Ex-ante impact assessments identify potential opportunities, threats and game changes for WHEAT to support outcomes 1.1, 1.2, 1.3	Complete (some delay)	Publications list, internal synthesis report (by 6/2018); see also Tables A-1, A-2, Annex 1 below Ali, S., Hodson, D., 2017. Wheat Rust Surveillance: Field Disease Scoring and Sample Collection for Phenotyping and Molecular Genotyping. Ali, S. et al, Yellow Rust Epidemics Worldwide Were Caused by Pathogen Races from Divergent Genetic Lineages. Asseng, S., et al, 2017. Hot spots of wheat yield decline with rising temperatures. Bueno-Sancho, V. et al, 2017. Pathogenomic Analysis of Wheat Yellow Rust Lineages Detects Seasonal Variation and Host Specificity. Chowdhury, A.K. et al, 2017. Occurrence of wheat blast in Bangladesh and its implications for South Asian wheat production. Gbegbelegbe, S. et al, 2017. Baseline simulation for global wheat production with CIMMYT mega-environment specific cultivars. Haile, M.G.et al, 2017. Impact of Climate Change, Weather Extremes, and Price Risk on Global Food Supply. Hyman, G. et al, 2017. Improving agricultural knowledge management: The AgTrials experience. Meyer, M.et al, 2017. Large-Scale Atmospheric Dispersal Simulations Identify Likely Airborne Incursion Routes of Wheat Stem Rust Into Ethiopia. Meyer, M.et al, 2017. Quantifying airborne dispersal routes of pathogens over continents to safeguard global wheat supply. Patpour, M. et al, 2017. First Report of Virulence to Sr25 in Race TKTTF of Puccinia graminis f. sp. tritici Causing Stem Rust on Wheat.

	1.3.4.	1.8 National and regional policy makers improved policy-making and increased investment based on evidence	Adoption and impact studies on technologies– rolling plan based on progress of technologies along the theory of change	Complete (some delays)	Publications list (see also Table A2), see also Annex 1 below
	B.1.3	1.10 Farmers have greater awareness and access to, and increased adoption and adaptation of improved technologies	Gender / social inclusion lenses will be applied to 2 to 4 WHEAT innovation pipelines and assessments	Complete	Technical support & contributions to data analysis, drafting and outreach activities; 4 resources tailored to specific CRP gender opportunities finalized, published electronically; Communication materials Badstue, L. et al, 2017. Gender and innovation processes in wheat-based systems. GENNOVATE Report to the CGIAR Research Program on Wheat. Drucza, K.L. et al, 2017. Gender transformative methodologies in Ethiopia's agricultural sector: A review. Farnworth, C.R. et al, 2017. Integration of gender considerations in Climate-Smart Agriculture R4D in South Asia: Useful research questions. GENNOVATE resources for scientists and research teams. Rahut, D.B.et al, 2017. Occupation choice in the agricultural and non-agricultural sectors by the rural youth and females in Bhutan. Ripoll, S. et al, 2017. Rural transformation, cereals and youth in Africa: What role for international agricultural research?
	B1.3.		Preparation and roll-out of rapid value chain assessments with proper gender lens conducted to identify opportunities and bottlenecks in WHEAT	Complete (10% in 2018)	Gender Capacity Development program Roll-out; Meta-analysis done; IA/adoption study Central Asia (delayed March '18)
2	1.4.4	2.4 Crop researchers worldwide increased use of novel germplasm and tools for validation, refinement and development of products	Increased use of open-access databases to store and share WHEAT data.	Complete	WHEAT-related Open Data Resources; Research Data & Software Repository Network; GIS data (ICARDA); int'l conferences, training WS
	1.4.3		New alleles for heat and drought, other climate change-related traits identified, validation	Complete	CIMMYT, ICARDA scientist KPI reporting; breeding mgmt. software development; DNA Sample Tracker deployed

			work initiated, and incorporated into the breeding pipeline		
	1.4.3		Improved precision of GS models using high throughput phenotyping and/or environmental data	Complete	Publications list; Research data on Dataverse; biometrics and model outputs (8 new tools)
	1.4.3	2.5 Breeders develop improved varieties more efficiently through greater access and use of documented germplasm and tools	Greater number of experimental, pre-bred germplasm lines, incorporating enhanced drought, heat and yellow rust tolerance or resistance, available for evaluation and use by partners.		CIMMYT, ICARDA scientist KPI reporting; Genotypic data analysis, interpretation and scientific publications;
3	1.1.2	3.6 National regulators of crop variety release improved enabling environment to speeding-up release of improved varieties (merge with 3.5 National partners increased improved variety release)	**No 2017 milestone, but 2018** is: National regulators of variety release and seed supply provide enabling environment to speed up release of improved varieties and farmers' access to quality seed, in 2-3 target countries		
	1.4.1	3.12 Non-and – subsistence farmers adopted improved varieties	**No 2017 or 2018 milestone, but 2019** is: Greater farmer adoption of released varieties (based on CGIAR research) in specific WHEAT target countries, compared to 1994-2014 average		List of CGIAR-derived variety releases; adoption & IA studies
	1.4.1	3.3 Partner breeding teams improved breeding processes by adopting new technologies, methodologies, genetic resources	**No 2017 milestone, but 2018 is:** Improved knowledge of genetic basis of climate change adaptation on global scale thru combination of GS, platforms, unified databases		
	1.4.3	3.2 Partner breeding teams increased multidisciplinary and multi-institutional collaboration (merge	Initiate Global Pests & Diseases Observatory with user inputs, to monitor, assess	Complete	Rust Tracker development; Mechanistic modelling framework developed;

		with: Partner breeding teams improved breeding processes by adopting new technologies, methodologies, genetic resources)	races/biotypes of key diseases and pests		
	B.1.2	3.8 Farmer organizations increased access, promotion, adoption of improved varieties to farmers (gender and other social identities as customer attributes in relation to seed diffusion interventions, including varietal promotion and replacement)	**No 2017 milestone, but 2018 is:** Develop wheat with enhanced healthy properties: reduce chronic diseases risk (incl high content dietary fiber to address obesity)	Extended (delayed, bilateral funding challenge)	New SNP KASP assays for industrial quality and nutritious wheat (Zn, Fe concentrations); Improved knowledge of the genetic control of quality traits.
	A.1.4	3.3 Partner breeding teams improved exchange and utilization of germplasm and data	All molecular markers linked to traits of agronomic importance converted onto SNP-based platforms. SNP-based low and high-density genotyping hubs established. NARS partners are involved.	Complete	low density genotyping hub at Intertek has been pilot tested and is functional; High-throughput genotyping service (HTPG) functional;
	B.1.2	3.7 & 3.8 Extension partners (universities, national /state / provincial governments) increased access and promotion of adoption of improved varieties to farmers, and increased investment in emerging private sector circumstances	New options, approaches piloted to fast track release of varieties, accelerated seed multiplication and dissemination	Complete	Ethiopia emergency seed support; SARD-SC/WHEAT seed multiplication.
4	1.4.2	4.7 Actors in SI increased participation in feedback loops via monitoring, evaluation and sharing of lessons learned 4.8 Actors in SI increased consideration and integration of gender and social inclusion into policies, processes and practices	Multi-criteria assessments taking into account environmental and social acceptability aspects, based on standardized protocols for multi-criteria 'step' assessments of advanced crop management packages	Extended	Landscape and field-level remote sensing-based assessments (Mexico, Malawi); soil erosion modelling & scenario-building (Mexico); wheat-based nutrition sensitive landscapes; long-term trials (4); Farming System Analysis using FarmDesign Model; Strategic research on G x E x M in wheat systems
	3.2.2		Build skills necessary to monitor soil, crop parameters (evaluate	Complete	PhD/MSc student supervision; NARS

			crop management practices)		workshops; farmer field demonstrations;
	D.1.1	4.6 Private sector (and public sector) increased provision of services to smallholder farmers to increased their ability to adopt SI practices and products 4.4 NARS increased use of participatory approach in system research, enhanced capacity and knowledge to create awareness and develop improved technologies	Increased adoption of combinations of SI strategies, resource and labour-saving technologies in specific target geographies compared to 2016	Complete	Ex ante studies, Policy briefs (3, S. Asia); Mechanization trials; CSISA, Bihar, early sowing scaling p'ship; scaling new tools for precision nutrient management (S. Asia, Mexico);
	C.1.1		Existing scaling approaches including public/ private partnership and context specific business models evaluated in target geographies leading to improve scaling models and critical scaling factors defined	Complete	PPP projects (MasAgro; CSISA); Scaling tool development & training; Scaling CoP set up;

* Milestones include both outputs, output use and outcomes along the impact pathways.
** Provide link to any relevant open accessible document.

Table C: Cross-cutting Aspect of Outputs

Cross-cutting	Number (%) scored 2 (Principal)	Number (%) scored 1 (significant)	Number (%) scored 0	Total overall number of outputs
Gender	5.08%	24.44%	70.48%	315
Youth	1.27%	21.59%	77.14%	
CapDev	10.16%	40.95%	48.89%	

Table D: Common Results Reporting Indicators

Table D-1: Key CRP Results from 2017, in Numbers

Sphere	Indicators	Data	Comments
Influence	I1/I2*. Projected uptake (women and men) /hectares from current CRP investments (for innovations at user-ready or scaling stage only – see indicator C1)	n/a	n/a
	I3. Number of policies/ investments (etc) modified in 2017, informed by CGIAR research	13	
Control	C1. Number of innovations by phase - new in 2017	• 8 innovations at proof of concept • 4 piloted successfully • 15 available for uptake (includes policy recommendations) • 11 taken up by next users (includes policy change), see Table D-2	
	C2. Number of formal partnerships in 2017, by purpose (ongoing + new)	Research partnerships (Discovery/proof of concept): 111 Piloting partnerships: 18 Scaling up and out partnerships: 69	
	C3. Participants in CGIAR activities 2017 (new +ongoing)	18,609 (16% women) 'end-users' in on-farm trials, farmer field days and similar 1158 (20% women) 'next users' in innovation platforms, policy workshops and similar	See below
	C4. People trained in 2017	Long term: 72 (39% women) Short term: 28,464 (13.5% women)	See below
	C5. Number of peer-reviewed publications	197	
	C6. Altmetrics	Not yet operational at CIMMYT	

*Please note: I = Sphere of Influence and C = Sphere of Control

Comment: Because bilateral annual reporting timetables vary, not all C3 participants and C4 People trained were included in the above table. This also applies to the 271,000 Ethiopian households mentioned on p.1 of this Annual Report.

Table D-2: List of CRP Innovations in 2017 (From indicator #C1 in Table D-1) *(OPTIONAL)*

Title of innovation (minimum required for clarity)	Phase of research *	Novel or adaptive research	Contribution of CRP (sole, lead, contributor)	Geographic scope: for innovations in phases AV* or USE* only (one country, region, multi-country, global)
Linear selection indeces for use in modern plant breeding (open access book completed 2017; will publish in 2018)	PIL	Novel	Contributor	Global
High throughput genotyping technology called DArTseq, LIMS, DArTsoft, DArT toolbox and visualization tools (Flapjack and CurlyWhirly)	AV and USE	Adaptative research	contributor	Multi-country
Low-density genotyping hub	AV/USE	Adaptive research	Lead for CIMMYT-WHEATCRP	Multi-country
Haplotype based GS for grain yield	PC	Novel research	Lead for CIMMYT-GWP	One country
Galaxy data analysis pipeline development (within GOBII)	PIL	Novel product	Lead for CIMMYT-GWP	Multi-country
High throughput assays for photosynthate sugars	PC	Novel	Lead	AV and USE across CG Centers
Data management tool development: Cross assistant (within GOBII)	PC	Novel product	Lead for CIMMYT-GWP	Multi-country
Spatial META-R Spatial Multi-Environment Trial Analysis. BGLRR Bayesian Generalized Linear Regression for prediction in genome selection. BIO-R Molecular biodiversity. STAD-R Descriptive statistics of experimental designs. RIndSel Calculate phenotypic and molecular selection indices. ADEL-R Generate and analyze standard experimental designs. PED-R Calculate parentage coefficient and pedigree analysis. ACBD-R Generate and analyze augmented designs.	AV and USE. Software delivered, continuous improve-ments.	Novel	Sole and lead	Global
Electronic data capture and bar coding devices (HW)	AV	Adaptive	Partial	Mexico and India
Newly designed small tent houses for A- line multiplication (HW)	AV	Novel	Partial	Mexico
Molecular markers for Restorers (HW)	PIL	Adaptive	Partial	Mexico
11 new QTLs identified against cyst nematodes	completed	Novel	Sole	Global

31 new QTLs identified against crown rot caused by *F. culmorum* and root lesion nematodes	Completed/ongoing	Novel	Sole	Global
2 new endophytic fungi were identified (promising biocontrol agents)	Completed	Novel	Lead	Global
Speed breeding (winter wheat)	PC	Novel	contributor	Central Asia
Drought field phenotyping.	AV	Adaptive	Contributor	Dryland of Central Asia.
Synthetic wheat	USE	Novel	Lead	Global
Novel wheat blast resistant germplasm	AV	Adaptive	Lead	South Asia
Utilization of Fhb1/Sr2 recombinant in breeding	AV	Adaptive	Sole	Global
Fungicide for YR and STB	AV	Adaptive	Sole	Mexico
Low-cost mini-breadmaking test	PC	Adaptive	lead	Global
Plant height estimation on Wheat through RS	PC	Novel	Sole	Global
Yield and grain protein content assessment from wheat farmers fields through hyperspectral high resolution images	PC	Novel	Sole	Global
Wheat strip tillage using a 2WT and a 2BFG (Mechanical row planting of wheat and fertilizing in a single pass, without prior land preparation)	AV	Novel	Lead	Wheat and teff growing areas of Ethiopia, smallholder wheat growing areas of sub-Saharan Africa
Adaptation of wheat planter to teff	PIL	Adaptive research	Contributor	Ethiopia
Portfolio of practices to address food-water-energy nexus	AV	Novel	Contributor	India/South Asia
Innovative, viable and scalable solutions for residue management to eliminate burning	USE	Novel	Contributor	India/South Asia
Scaling tool	PC		lead	USE, Global
Raised bed technology	AV	adaptive		USE mostly in one country and at adaption stage in others.
Irrigation scheduling based on Short Messaging Systems (SMS) technology	AV and USE	adaptive		USE in one country

* Phases: PC - proof of concept, PIL - successful pilot, AV - available/ready for uptake, USE - uptake by next users.

Table E: Intellectual Assets

Year reported	Applicant(s) / owner(s) (Center or partner)	Patent or PVP Title	Additional information*	Link or PDF of published application/ registration	Public communication relevant to the application/registration

Table F: Main Areas of W1/2 Expenditure in 2017

[Optional:) some funding fits more than one category; we apportion funding to its principal use; however, percentages do not add up to 100% **]**

Expenditure area *	Estimated percentage of total W1/2 funding in 2017**	Space for your comments [please remove notes below]
Planned research: principal or sole funding source	60	Synthesis of previous foresight studies, for future priority-setting Continued genotypic characterization of genebank accessions and pre-breeding material Further develop high-throughput phenotyping tools Develop gene editing capability and apply in specific genomic environments; continue R4D on genomic selection to integrate molecular approaches in breeding Provide data migration and curation support and software training, bioinformatics/statistics support to scientists; analytical and decision tools to help breeders, Open Data/Access Resources maintenance and improvements Breeding research: Winter wheat, Central Asia, CWANA, wheat precision phenotyping platforms, pre-breeding spring/winter wheat all agro-ecological zones, durum wheat, all pests and diseases of global/regional importance except rusts, marker-assisted breeding/ molecular research SI Indicators and metrics at landscape level, use of geospatial information for better baselining and impact assessment of SI technologies
Planned research: Leveraging W3/bilateral funding	15	Ex-ante impact assessments Proposal development for Foresight and Impact Assessment projects Completion and dissemination of value chain potential study (Rwanda & Zambia) Proposal development, partnership building: Sustainable Intensification North Africa, value chains/market interventions Generate science based evidence on how CA based SI contributes to simultaneously address a number of SDGs, to help governments on their investment prioritization; Develop partnerships and collaboration with large scaling actors
Catalyzing new research areas	15	Rural transformation and evolving food dietary patterns in South Asia

		Development of genetic engineering capacity for gene discovery and creation of novel diversity; Introgress new genetic diversity from wheat wild relatives for priority traits Innovations in early detection of wheat diseases Develop & adapt scalable smallholder precision input management technologies, tools, techniques, strategies and innovations
Gender	10	Coordination and strengthening Gender and Social Inclusion portfolio, synthesis of Gender case studies (builds on GENNOVATE), thematic gender study Gender monitoring and capacity strengthening in WHEAT AFS
Youth	5	Scoping WS/paper on comparative advantage of WHEAT/MAIZE focusing on youth; on quantitative gender and youth in cereal-based AFS
Capacity development	15	Development of Learning Management System (LMS), co-funding of participants in short-/long-term trainings and scientific conferences A Capacity enhancement on scaling with partners in Mexico.
Start-up or maintenance of partnerships (internal or external)	*Cannot be distinguished, extracted*	Partnerships and collaboration with large scaling actors
Monitoring, learning and self-evaluation	*100% overlap with first 2 categories above*	Synthesis of previous foresight studies, for future priority-setting Make MARLO Platform operational for WHEAT, including staff trainings Annual CRP reporting on indicators Project Management tools and staff training Scaling Scan tool developed to better self-evaluate scalability of interventions
Evaluation studies and Impact Assessment studies	5	Ex-ante impact assessments Compilation of impact/adoption R4D under WHEAT; impact assessments for Central Asia/variety adoption, S Asia/Sustainable Intensification
Emergency/contingency	0	WHEAT-MC approved a 2017 W1&2 budget at 75% of System Council-endorsed. The 25% difference acted as contingency.
Other		
TOTAL FUNDING (AMOUNT)	10,192M spend	13,292M budgeted (L-Series, see Table J)

*Use these categories wherever possible, delete unneeded rows and add rows if none of these are suitable.
**We recognize that (i) some funding may fit more than one category but please try to apportion funding to its principal use and (ii) percentages may not add up to 100%.

Table G: List of Key External Partnerships

FP	Stage of research*	Name of partner	Partner type*	Main area of partnership*
1	ongoing	InSTePP at UMN	Academic	research
1	Collaborative project completed, looking for new opportunities	Wageningen Economic Research (WEcR)	ARI	research
1,3	Ongoing with MAIZE, opportunities for wheat in future	Wageningen University – Food Quality and Design	Academic	research
1	ongoing	Wageningen Environmental Research (WEnR)	ARI	Research, research data and services development
1,3	ongoing	Johns Hopkins University, USA	Academic	research
1	ongoing	CAAS, China, Beijing	Academic	joint labs, staff, research
1	Collaborative project completed, looking for new opportunities	PEP, Kenya, Nairobi	ARI	research
1	Renewed collaboration	Hohenheim University, Stuttgart, Germany	Academic	research
1	Ongoing collaboration	University of Florida	Academic	Research
1	Ongoing	University of Central Asia Kyrgyzstan, Tajik Agricultural Academy of Sciences, The Scientific Research Institute of Agricultural Economics	NARS	Adoption and Impact Study in 3 countries, Central Asia
1	AV	University of Jordan, University of Natural Resources and Life Sciences (BOKU), University of Waterloo, Canada, University of Western Ontario, Canada	University	Co-advising PhD / MSc students
1	AV	INRA, Morocco, ARC, Egypt, ARARI, Ethiopia	NARS	Capacity building, data collection, analysis, publications
2	Early	DowDuPont, now Corteva AgriScience	Commercial	Gene Editing
2	Early	FFAR, USA	PPP	Gene discovery (starting with maize)
3.2	Ongoing	Jiangsu Academy of Agricultural Sciences, China	Project based	Association mapping for FHB and blast
3.2, 3.3	Ongoing	Chinese Academy of Agricultural Sciences, China	Joint research	QTL mapping for FHB and blast screening
3.4	Ongoing	Field Crop Development Centre, Alberta, Canada	Project based	Germplasm and information exchange for FHB, YR and scald
3.4	Ongoing	USDA-ARS and Kansas State University, USA	Project based	Wheat blast screening in greenhouse in the USA
3.4	Initiating	CAPECO, Paraguay	Project based	Wheat blast screening in Paraguay
3.2, 3.3	Initiating	Norwegian University of Life Sciences	Joint Research	Genetics of wheat resistance to Septoria nodorum blotch
2	Ongoing	John Hutton Institute, UK	Project based	Genotypic / phenotypic data visualization platforms; public data warehouses;

2	Ongoing	BISA, AARI-Pak, ICAR-India, Kansas State Univ., EIAR (ET)	Project based	Genomic selection, combined GS-HTPTS prediction; testing heat tolerance
2	Ongoing	ORNL-US, TGAC-UK, GOBII (Cornell),	Project based	Genotypic data analysis, computing power, data storage and integration
2	Ongoing	JIRCAS, other CRPs	Project based	High BNI wheat, BNI Consortium
2, 3	Advanced	NIAB (National Institute of Agricultural Botany), JHI (The James Hutton Institute) and EI (Earlham Institute), all partners from UK.	Non CG, Academic	BBSRC project: UK-SeeD Data Analysis Infrastructure.
3	Ongoing	INIA Uruguay, INRA Morocco, IRESA/INAT Tunisia, INIA Bolivia	NARS	Maintain precision phenotyping platforms; field research
3	PC	Moroccan miller federation (FNM)	Industry	Validation of new bread-making tests
2, 3	Ongoing	NIAB, IRTA	ARI	Germplasm exchange
3	Ongoing	Philippe Lonnet (Florimond-desprez)	Industry	Germplasm exchange
3	Ongoing	Kansas State University, Rothamsted, CSIRO, BIMBO, CNR, Wheat Initiative EWG Quality, Quadram Institute	University, ARI, industry	Wheat quality research
3	Discovery-PC	University of Nebraska, Lincoln, USA, Texas A&M University, University of Nebraska, Lincoln, USA	ARI	Discovery of novel genes and their markers for fertility restoration
3	PC, PIL, AV, USE	Syngenta Inc.	Principal Private collaborator	Hybrid wheat technology development
3	Available/ready for uptake	Murdoch University	University	Wheat quality
3	Proof of concept	Agriculture and Agrifood Canada (AAFC)	Government	Wheat disease resistance
3	Available/ready for uptake	CAAS and other 20 Chinese institutes		Adaptation, scaling out
4	AV/USE	Amio	Private sector	Developing machinery, Scaling up through commercialization.
4	AV/USE	METEC, EIAR, MoA (Ethiopia)	Public sector	Developing machinery, commercialization.
4	AV/USE	GIZ	NGO	Developing machinery based on FACASI outputs. Scaling up these pieces equipment through commercialization.
4	PC	Wageningen U, Yale U, U of British Columbia	University	Work on agroforestry and on nutrition in wheat-based systems, nexus soil fertility-grain nutritional quality
4.4	USE	PPPlab, a consortium of SNV, CDI, Erasmus University and Aqua4All	Knowledge (scaling) partner	Development, testing and improvement of scaling tool
4	PC	CINVESTAV	NARS	Soil ecology research
4	PC	UN University Dresden, Germany	ARI	SI based soil and crop management practices on soil water and carbon dynamics
4	PC	Kyoto University, Japan	ARI	Terrestrial carbon sequestration and nutrient release
4	PC	Wageningen University & Research, The Netherlands	ARI	Farming Systems Analysis and Systems modelling
4	USE	International Plant Nutrition Institute (IPNI)	ARI	Scaling precision nutrient management

4	PC/PIL	BISA, India	Int'l Research Center	Strategic research G x E x M interactions, Water-Energy-Food nexus
4	USE	ICAR/NARS	NARS	Long-term research on CA based SI
4	USE	TAAS, NAAS	Policy Think Tank	Policy level engagement
4	USE	Department of Agriculture of the state Governments in India	Government	Scaling

* See instructions in the common results indicators manual (available early 2018).

Table H: Status of internal (CGIAR) collaborations among programs and between the program and platforms.

Name of CRP or Platform	Brief description of collaboration (give and take among CRPs) and value added*	Relevant FP
7 CRPs	GENNOVATE	1
CGIAR Gender & Agricultural Research Platform	CGIAR Gender & Agricultural Research Platform	1
PIM	Collaboration with IFPRI IMPACT team and all other CGIAR centers in the Global Futures and Strategic Foresight project. Strong synergies between PIM CoA 1.1 and MAIZE CoA 1.1	1
PIM	Collaboration with PIM CoA 1.2	1
CGIAR Platform for Big Data in Agriculture	CIMMYT participates in a project led by WEnR to create weather and climate services using the European Space Agency satellites. Module 1: Shared, high quality data management standards to enhance the FAIR management of data	1
Excellence in Breeding	Module 5 collaborative development of software and tools that are crucial for data management; All Modules, Scientific advisory committees	2
Genebanks	Data curation support for the WHEAT Germplasm Bank at CIMMYT via the GRIN-Global database. Under Genebanks Platform, the Seed Health Laboratory to digitalize its data capture and storage efforts	2, 3
Livestock	NIR based modeling expertise and outcomes exchange. New models for straw feeding value and micro-nutrients under testing	3
FTA	Work on agroforestry in wheat-based systems	4
A4NH	Work on dietary diversity in wheat-based systems	4
CCAFS	Validation/scaling of wheat SI technologies/practices using Climate Smart Village (CSV) sites Joint capacity development of researchers, extension agents, service providers and farmers. Organized international training workshops on CA/SI, farming system modelling etc Joint research publications on climate smart/CA based SI practices and technologies in wheat systems Climate Services for Resilient Development (CSRD) Bangladesh project (USAID) Collaboration with IRI @ Columbia Univ.	4
RTB	Knowledge sharing on scaling, with IITA and Wageningen University	4
RICE	CSISA Phase 3	4
CIAT, WorldFish, AfricaRice, IRRI	Through 7 other members of the GIZ task force on scaling	4
Community of Practice on Scaling led by IFAD, MSI	MSI international is leading a multidisciplinary CoP on scaling. Key members are USAID, FAO, IFAD, DFID, GIZ, WorldVision and many others. CIMMYT supports IFAD in leading the working group on agriculture- the CoP will meet in Washington in March 2018	4

*e.g. scientific or efficiency benefits

Table I: Monitoring, Evaluation, Impact Assessment and Learning

Table I-1: Status of evaluations, impact assessments and other learning exercises planned in the 2017 POWB.

Studies/learning exercises in 2017 (from POWB)	Status	Comments

Table I-2: Update on actions taken in response to relevant evaluations (IEA, CCEEs and Others).

Name of the evaluation	Recommendation	Management response – Action Plan	By whom	By when	Status

Please see Annex 1, Table 1, below.

Table J: WHEAT financial report.

	Planned budget 2017			Actual expenditure 2017*			Difference		
	W1/2	W3/bilateral	Total	W1/2	W3/bilateral	Total	W1/2	W3/bilateral	Total
FP1	1,454	4,155	5,609	955	2,645	3,600	498	1,510	2,009
FP2	2,315	7,985	10,300	1,381	6,213	7,594	934	1,772	2,706
FP3	6,662	24,417	31,078	5,338	15,218	20,556	1,323	9,199	10,523
FP4	1,924	15,999	17,923	1,011	12,100	13,111	913	3,899	4,812
Capacity Development	197	0	197	197	0	197	0	0	0
Strategic Competitive Research grant	0	0	0	0	0	0	0	0	0
CRP Management & Support Cost	1,378	0	1,378	1,309	0	1,309	69	0	69
CRP Total	13,929	52,556	66,485	10,192	36,176	46,367	3,738	16,380	20,118

*Source: L-Series Report 2017 including CGIAR Center collaboration

WHEAT W1&2 funding history.

			PHASE I														PHASE II			
			2012		2013		2014		Phase I 2012-2014		2015		2016		Total Phase I		2017		2018	
Million USD	Fund	Funder	Financial Plan	Received 2012	Financial Plan	Received 2013	Financial Plan	Received 2014	Financial Plan	Received 2014	Financial Plan	Received Funds	Financial Plan	Received Funds	Financial Plan	Received Funds	Financial Plan	Received Funds	Fin Plan 18 (SMO Scenario)	Received 2018
WHEAT (In advance)	W1														-	-		0.800		1.544
WHEAT	W1		8.160	2.381	6.840	5.679	8.200	12.192	23.200	20.252	3.140	3.795	1.900	1.939	28.240	25.986	7.096	6.296		
	Total W1		**8.160**	**2.381**	**6.840**	**5.679**	**8.200**	**12.192**	**23.200**	**20.252**	**3.140**	**3.795**	**1.900**	**1.939**	**28.240**	**25.986**	**7.096**	**7.096**	**-**	**1.544**
WHEAT	W2	Australia	1.300		0.630		1.180		3.110		0.970		0.970	0.911	5.050			0.628		
WHEAT	W2	UK							-		5.430		5.430	3.229	10.860			5.956		
WHEAT	W2	USA	3.500	10.609	4.500	6.821	4.500	3.284	12.500	20.714	4.300	10.045	4.300	3.900	21.100	38.878	6.585			
WHEAT	W2	China	0.030		0.020				0.050					0.078	0.050					
WHEAT	W2	Others			0.510		2.750		3.260						3.260					
	Total W2		**4.830**	**10.609**	**5.660**	**6.821**	**8.430**	**3.284**	**18.920**	**20.714**	**10.700**	**10.045**	**10.700**	**8.119**	**40.320**	**38.878**	**6.585**	**6.585**	**-**	**-**
	Total WHEAT		**12.990**	**12.990**	**12.500**	**12.500**	**16.630**	**15.476**	**42.120**	**40.966**	**13.840**	**13.840**	**12.600**	**10.057**	**68.560**	**64.864**	**13.681**	**13.681**	**14.476**	**1.544**
Diff. vs funds received			-		-		*(1.154)*		*(1.154)*		*0.000*		*(2.543)*		*(3.696)*		*(0.000)*			
ICARDA Investment Plan											**1.269**	**1.269**			**1.269**	**1.269**				

2017 WHEAT W1 funders.

Million USD	Received & confirmed, 2017	%	CIMMYT		
			MAIZE	WHEAT	Total
Australia	4.15	4.11	0.282	0.292	0.574
Belgium	0.14	0.14	0.010	0.010	0.019
Canada	7.43	7.37	0.506	0.523	1.028
France	1.42	1.41	0.097	0.100	0.197
India	0.80	0.79	0.054	0.056	0.111
Japan	0.58	0.58	0.039	0.041	0.080
Korea	0.27	0.27	0.018	0.019	0.037
Netherlands	4.65	4.61	0.316	0.327	0.644
New Zealand	3.97	3.94	0.270	0.279	0.549
Norway	12.78	12.67	0.870	0.899	1.769
Sweden	22.44	22.25	1.527	1.579	3.106
Switzerland	8.57	8.50	0.583	0.603	1.186
UK	3.66	3.63	0.249	0.257	0.507
World Bank	30.00	29.74	2.041	2.111	4.152
Total	**100.86**	**100.00**	**6.863**	**7.096**	**13.959**

2017 Gender expenditure (W1&2)

Summary Report - by Flagships or Modules

		2017 Gender Expenses
WHEAT-FP1	FP1 Enhancing WHEAT R4D strategy for impact	761
WHEAT-FP2	FP2 Novel diversity and tools for improving genetic gains and breeding efficiency	398
WHEAT-FP3	FP3 Better varieties reach farmers faster	1,165
WHEAT-FP4	FP4 Sustainable intensification of wheat-based farming systems	1,735
	Capacity Development	-
	Strategic Competitive Research grant	-
	Management and Support Cost	-
	Net	**4,060**

Participating Centers

CIMMYT

		2017 Gender Expenses
WHEAT-FP1	FP1 Enhancing WHEAT R4D strategy for impact	761
WHEAT-FP2	FP2 Novel diversity and tools for improving genetic gains and breeding efficiency	398
WHEAT-FP3	FP3 Better varieties reach farmers faster	1,165
WHEAT-FP4	FP4 Sustainable intensification of wheat-based farming systems	1,735
	Capacity Development	
	Strategic Competitive Research grant	-
	Management and Support Cost	-
	Net	**4,060**

ICARDA

		2017 Gender Expenses
WHEAT-FP1	FP1 Enhancing WHEAT R4D strategy for impact	
WHEAT-FP2	FP2 Novel diversity and tools for improving genetic gains and breeding efficiency	
WHEAT-FP3	FP3 Better varieties reach farmers faster	
WHEAT-FP4	FP4 Sustainable intensification of wheat-based farming systems	
	Capacity Development	
	Strategic Competitive Research grant	
	Management and Support Cost	
	Less CGIAR Collaboration	
	Net	**-**

* ICARDA did not sent gender information based in SMO not reporting confirmation

Annex 1 / Table 1. Technology adoption studies by CIMMYT/ICARDA researchers for wheat production systems, 2008-2017.

Study	Country	Technology	Data sources	Data type	Main result
Abro et al. (2017)	Ethiopia	rust-resistant varieties	household survey (n =2069)	Panel data	Resistant varieties increased effective yields by 8% in comparison to local susceptible varieties
Ali, Erenstein (2017)	Pakistan	climate change adaptation practices	household survey (n =950)	cross-sectional	Three major adaptation practices: adjustment in sowing time (22% households), use of drought tolerant varieties (15%), and shifting to new crops (25%)
Joshi et al. (2017)	Pakistan	new varieties	survey among participating farmers (n = 780)	multiple years	Most of the varieties included in the participatory varietal selection yielded 5–17% more grain than local checks.
Ali et al. (2017a)	Pakistan	irrigation	household survey (n = 950)	cross-sectional	Farmers situated at the head of the water source had higher wheat yields and income. Poverty levels were lower.
Krishna et al. (2017)	India, Bangladesh	conservation tillage	household survey (n = 2480)	cross-sectional	Significant inter-regional heterogeneity of impacts of conservation tillage observed in South Asia.
Keil et al. (2017)	India	zero tillage	household survey (n = 1000)	cross-sectional	44% of households knew about the technology. There was substantial scale bias in favor of larger farmers with respect to technology awareness and adoption.
Rahut, Ali (2017)	Pakistan	NA (impact of perceived weather changes)	household survey (n = 500)	cross-sectional	Farmers with higher levels of education and secured land rights adopt more climate-risk mitigating strategies.
Ali et al. (2017b)	Pakistan	NA (impact of perceived weather changes)	household survey (n = 500)	cross-sectional	Climate change had negative impacts on the income, poverty levels and the wheat yield, and increased farmer dependence on timber and non-timber forest products.
Khatri-Chhetri et al. (2016)	India	improved seeds, laser leveler, zero tillage	household survey (n = 1267)	cross-sectional	Technology combinations could improve crop yields as well as net returns above adoption of individual technologies.
El-Shater et al. (2016)	Syria	zero tillage	household survey (n=621)	cross-sectional	Technology adoption led to 33% increase in net crop income and 34% gain in per capita wheat consumption per year.
Krishna et al. (2016)	India	new varieties	secondary data from public seed sector & household survey (n =323)	time series, cross-sectional	A slowdown in the rate of cultivar turnover, with average varietal age increasing from 9 years in

					1997 to 12 years in 2009. Turnover rates were lowest among marginal farmers.
Mottaleb et al. (2016)	Bangladesh	scale-appropriate machinery	agricultural census (n = 25.35 million) and sub-sample (n = 1.16 million)	cross-sectional	Machinery ownership was positively associated with household assets, credit availability, electrification, and road density.
Ali et al. (2016)	Pakistan	irrigation	household survey (n = 950)	cross-sectional	Use of alternative energy sources for water pumping resulted in the reduction of poverty in the range of 11–20%
Keil et al. (2016)	India	conservation tillage	survey among service providers (n = 277) and household (n = 991)	cross-sectional	Well-educated, large farmers with extensive social networks were most likely to become the service providers.
Ali et al. (2015)	Pakistan	Certified seeds	household survey (n = 367)	cross-sectional	Farmers who had access to certified wheat seed were able to achieve higher crop yields, higher income, and lower poverty.
Keil et al. (2015)	India	zero tillage	household survey (n = 1000)	cross-sectional	The prevailing technology adoption without full residue retention led to a robust yield gain over conventional-tillage wheat
Aravindakshan et al. (2015)	Bangladesh	conservation tillage	household survey (n =328)	cross-sectional	Energy use efficiency of conventional tillage was significantly higher compared to conventional tillage.
Aryal et al. (2015a)	India	laser leveling	household survey (n =198)	cross-sectional	With the adoption of the technology, irrigation time was reduced by 10–12 h/ha/season and yield increased by 7–9 %.
Aryal et al. (2015b)	India	zero tillage	farmers field trials (n = 40)	3-year panel	Farmers can save USD 79 per ha in terms of total production costs and increase net revenue of about USD 98 per with the technology.
Krishna, Veettil (2014)	India	zero tillage	household survey (n =180)	cross-sectional	Significant cost savings (14%) and productivity increase (5%) were associated with the technology adoption.
Shiferaw et al. (2014)	Ethiopia	improved varieties	household survey (n = 2017)	cross-sectional	Adoption increases food security and farm households that did not adopt would also benefited significantly had they adopted new varieties.
Yigezu et al. (2014)	Syria	Improved supplemental irrigation (ISI)	household survey (n =513)	cross-sectional	At the adoption rate of 22%, the technology led to an average conservation of 418 m^3 of irrigation water per hectare per year.
Lobell et al. (2013)	India	time of sowing	satellite imageries	time series	Wheat was sown one-week earlier by 2010 than it was at the beginning of the decade. An overall yield gain of 5% averaged across India was explained by the sow date trend.

Yigezu et al. (2013)	Syria	sprinkler irrigation	farm survey (n=385)	cross-sectional	By technology adoption, farmers were able to obtain their current yields with 9% less irrigation water. The typical farmer exhibited 28% less efficiency than the best irrigation water user in the group.
Erenstein (2010a)	India, Pakistan	conservation tillage	multiple sources, including supply-side surveys (n = 78) and household surveys (n = 858)	cross-sectional	Illustrated the potential of multi-indicator, multi-site and multi-year triangulation.
Erenstein (2010b)	India	conservation tillage	village survey (n = 170)	case-studies	After an initial rapid spread, the zero / reduced tillage area stabilized at between a fifth and a quarter of the wheat area.
Erenstein, Farooq (2009)	India, Pakistan	conservation tillage	household survey (n = 527)	cross-sectional	Technology adoption in the initial diffusion stage was strongly linked to the wealth of the farm household.
Kassie et al. (2009)	Ethiopia	conservation tillage, compost and chemical fertilizers	household survey (n = 130) and plot-level data (n = 348)	cross-sectional	Observed heterogeneity with regard to the factors that influence adoption decisions of the three technologies and the importance of both plot and household characteristics on influencing adoption decisions.
Erenstein (2009)	India, Pakistan	zero tillage	household survey (n =858)	cross-sectional	Technology effects on savings for diesel, tractor time and cost for wheat cultivation were particularly robust. In one of the study states, technology's positive implications for yield and the other financial indicators were statistically robust, but in the second, these were sensitive to specification effects.

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