2019 ANNUAL REPORT

RESEARCH PROGRAM ON Wheat

CGIAR

CGIAR Research Program on Wheat
An Agri-Food Systems CGIAR Research Program

Name of the CRP: **Agri-Food Systems CGIAR Research Program for Wheat**
Name of the Lead CGIAR Center: **CIMMYT**

Flagship lead institutions (CGIAR Centers or lead partners)
Flagship 1: CIMMYT
Flagship 2: CIMMYT & ICARDA
Flagship 3: CIMMYT
Flagship 4: CIMMYT
Other participating CGIAR Centers: **ICARDA –** plus management partners **ACIAR (AU) BBSRC (UK), ICAR (India) –** and platform partners **BARI (Bangladesh), INIA (Bolivia), JAAS (China), EIAR (Ethiopia), KALRO (Kenya), INRA (Morocco), IRESA (Tunisia), INIAF (Uruguay) –** and international partners **G-20 Wheat Initiative, International Wheat Yield Partnership (iwyp.org). The complete list of partners is accessible here.**

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Table of Contents

Contents

EXECUTIVE SUMMARY

Wheat farmers will experience less stable yields from year to year, and more frequent low yields. Most impact research on agriculture to date has focused on impacts of warming >2°C on mean crop yields. Many previous studies did not focus on *extreme events and yield interannual variability*. Using the Agricultural Model Intercomparison and Improvement Project (AgMIP) for Wheat to represent major rainfed and irrigated wheat cropping systems, scientists showed that projected global wheat production will change by −2.3% to +7.0% under the 1.5°C scenario and −2.4% to +10.5% under the 2.0°C scenario[1]. Despite mostly positive impacts on global average grain yields, the frequency of extremely low yields and yield inter-annual variability will increase under both warming scenarios for some high-temperature growing locations, including in the world's second largest wheat producing country, India, which supplies more than 14% of global wheat. The projected global impact of warming <2°C on wheat production is not evenly distributed: it will affect regional food security as in the Global South, well as food prices and trade.

To address climate change and other challenges, WHEAT and national agricultural research system (NARS) partner scientists have built on breeding research with a strong track record, as well as conservation agriculture (CA)-based sustainable intensification practices, including appropriate-scale mechanization, to deliver outcomes and impacts relating to SLO targets 1.1, 1.2 and 2.1. Examples include farmers adopting varieties in Afghanistan and through the International Winter Wheat Improvement Program; genetic gains delivered via elite lines for rainfed environments; income effects of cereal-legume systems; and the poverty reduction, greenhouse gas (GHG) and pollution reduction benefits of climate smart CA practices including laser land levelling and mechanization. – *See Tables 1, 2 & 4.*

WHEAT built new knowledge related to value chains (consumer demand, farmer adoption dynamics), climate smart agricultural practices (zero tillage, water management and precision fertilizer) and nutritional quality. The majority of 2019 innovations are in the social sciences or breeding domains and just under half are at stage 3 (ready for uptake) – *see Table 4*.

Part A: NARRATIVE SECTION

1. Key Results

1.1 Progress Towards SDGs and SLOs

Breeding for farmers: Impacts

Screening operations in wheat rusts led to the release of over 100 Ug99 resistant wheat cultivars globally over last decade *See Outcome impact case report (OICR) & Table 1, SLO 1.1 and 1.2.*

Thanks to work at the International Stem Rust Phenotyping Platform in Njoro, Kenya screening up to 50,000 wheat lines per year from as many as 20 countries, over 100 CGIAR wheat cultivars resistant to the stem rust race Ug99 and its variants have been released globally over the last decade, benefitting smallholder wheat farmers worldwide. The platform also facilitates breeding to identify and develop new resistant lines. Since 2011, 19 varieties have been released in Kenya, benefiting up to 3,000 small scale farmers, accounting for about 20% of total acreage; up to 1,500 medium scale farmers, accounting for about 50% total acreage; and 200 large scale farmers, accounting for 30% total acreage (Cereal Growers Association, Kenya).

Long-standing collaboration between the Ethiopian Institute for Agricultural Research (EIAR) & WHEAT supports Government of Ethiopia (GOE) efforts to boost and expand wheat production

CIMMYT's partnership with Ethiopia dates from the early 1980s. When the Ug99 race of stem rust fungus was identified in the country in 2005, CIMMYT and national partners implemented an

[1] Compared to a baseline of 1980–2010, when considering changes in local temperature, rainfall, and global atmospheric CO_2 concentration, but no changes in management or wheat cultivars.

aggressive variety replacement program. By 2017, according to DNA fingerprinting technology, 90% of all varieties grown in Ethiopia were CGIAR-derived (e.g. CIMMYT or ICARDA, see p.30).

In 2019, a delegation of WHEAT scientists met with Ethiopian researchers and policymakers -- including Ethiopia's Minister of Agriculture and Natural Resources -- to discuss their role in the nationwide effort to boost wheat production. Priority areas identified include: testing advanced lines to identify varieties suitable for irrigated lowlands; developing disease resistant varieties and multiplying good quality and large quantity early generation initial seed; refining appropriate agronomic practices that improve crop, land and water productivity; organizing exposure visits for farmers and entrepreneurs; implementing train-the-trainer and researchers' training; and technical backstopping. As part of this support, WHEAT has developed lines that are resistant to diseases such as stem and yellow rust, stress tolerant and adapted to different wheat agro-ecologies.

1.2 CRP Progress towards Outputs and Outcomes

1.2.1 Overall CRP progress

Synthetic hexaploid wheat. WHEAT work over the past 30 years to develop and use wild grass-derived synthetic, hexaploid wheat is adding novel genetic diversity for heat and drought tolerance, as well as pest and disease resistance to modern bread wheat. Annually, 1.500 new synthetic-derived and other elite wheat lines help farmers worldwide, through WHEAT distribution of more than 350,000 seed packets to over 250 collaborators each year – *see FP2; OICR Table 3.*

Crop residue burning. A WHEAT-authored study in *Science* shows that thousands of wheat farmers in northern India could increase their profits if they stop burning their rice straw residue and adopt no-till practices, which could also cut farm-related greenhouse gas emissions by as much as 78% and lower air pollution. With financial support from the Sonalika Project, WHEAT, Borlaug Institute for South Asia (BISA) and Indian Council of Agricultural Research (ICAR), scientists researched various options for eliminating crop residue burning in 26 selected pilot villages in Haryana state, India, including the Happy Seeder and Super SMS appliances, and zero tillage technology. Happy Seeder and zero tillage technology have been adopted on 0.8 million hectares across in northwest India.

Progress on scaling wheat technologies in Sub-Saharan Africa. Under the African Development Bank-co-funded Technologies for African Agricultural Transformation (TAAT) Wheat Compact led by ICARDA, heat-tolerant varieties deployed as basic, certified and quality-declared seeds came to 30,500 metric tons (MT) for Sudan, 25,438 MT for Ethiopia, 7,600 MT for Nigeria, plus over 2,000 MT for six other countries.

1.2.2 Progress by flagships

FP1: Enhancing WHEAT's research for development (R4D) strategy for impact

Conservation agriculture adoption in India. An ex ante business case for subsidizing water-saving technologies in irrigation-intensive cereal systems farming in India's Indo-Gangetic Plain found that bundling CA farming with sub-surface drip irrigation ("CA+") improved rice-wheat farmers' crop productivity by 11.2%, irrigation water productivity by 145% and profitability by 29.2% compared to farmers' usual practice.

According to a WHEAT-led analysis, Ethiopian farmers planted more rust resistant varieties and/or increased their variety diversity to reduce the effects of rust re-occurrence after a 2010-2011 yellow rust epidemic. Adopting resistant varieties offers Ethiopian farmers a 29-41% yield advantage even under normal conditions, demonstrating the importance of continuing to develop and deploy resistant varieties to help smallholders maintain improved yields under rust challenges.

Strong case for conservation agriculture in Tunisia. Tunisian farmers put 52 ha under CA (zero tillage and/or residue retention) in 1999 and 14,000 ha in 2015, out of a potential 260,000 ha. Using models to examine one semi-arid and one sub-humid region, NARS and WHEAT researchers found that CA-based durum wheat production under climate change conditions enhances wheat yield (15%, through mulching); water use efficiency and soil organic carbon accumulation; and is more effective for soil resilience, preventing water erosion.

No-till adoption challenges in Algeria: A study based on 28 participating smallholder farms in a CA project in North Africa clearly showed that the no-till (NT) system outperformed conventional farming practices, and lowered variable costs (work time and fuel consumption). Still, 71% of farms dropped out of NT adoption, though the researchers believe that local social and technical constraints could be relatively easily overcome.

FP2: Novel tools for improving genetic gains and breeding efficiency

Using synthetic hexploid wheat as a bridge to incorporate more genomes of wild species. Climate change drives a higher occurrence of -- and yield losses to -- wheat diseases. Current practices of relying on chemical protection are not sustainable. NARS and WHEAT scientists studied a set of primary hexaploid synthetic wheat under high disease pressure (powdery mildew, leaf and stem rust, *Septoria tritici* and *S. nodorum*). These novel genetic sources of disease resistance can be applied in breeding most successfully by using the synthetics in back- or top-crosses.

Harnessing genetic potential for nutrition and disease resistance. With support from the UN Food and Agriculture Organization (FAO)'s International Treaty on Plant Genetic Resources for Food and Agriculture, a team of WHEAT scientists and breeders have embarked on a treasure hunt for "lost" varieties. In collaboration with Afghan and Turkish partners, they collected 162 landraces in Turkey and 25 in Afghanistan. After planting and selecting the best performing varieties, with local farmer input, they are returning the best landrace seeds to the original farming communities and providing training on sustainable cultivation.

Primitive tetraploids and wild species to enhance durum heat and drought tolerance. ICARDA continued pre-breeding efforts in durum wheat through more interspecific crosses and evaluation of derived germplasm from the WHEAT genebank. Advanced lines yielded more than their parents and best available checks under drought and heat stresses. 12 ICARDA originated varieties derived from wild relatives have been released by partners (see p.68) and their level of adoption is rapidly increasing. The Hessian fly resistant variety Faraj released in Morocco in 2008 has finally become commercially available in 2019 and was grown on 20,000 ha, based on the resistance allele derived from *T ararticum.*

***Progress on genomic prediction for faster, cheaper and more precise breeding*.** Using the full wheat genome map published by the International Wheat Genome Sequencing Consortium in 2018 combined with data from field testing in multiple countries, an international team of scientists, including WHEAT researchers, identified significant new chromosomal regions for wheat yield and disease resistance and created a freely-available collection of genetic information and markers for more than 40,000 wheat lines. The results will speed up global efforts to breed more productive and climate-resilient varieties of bread wheat and pave the way to apply genomic selection in wheat breeding.

FP3: Better varieties reach farmers faster

CIMMYT invests nearly $700,000 annually to distribute more than 350,000 packages of experimental seed years to over 220 collaborators worldwide from its international wheat for five mega environments targeting a range of input intensities, variable moisture stress and availability, disease threats, and biofortified nutritional and end-use quality-related traits. In 2019, CIMMYT and ICARDA international trials and nurseries went to over 100 countries. A majority of partners returned data voluntarily – *See Table 4.*

At least 50 varieties were released in 2019. For more information, see the table here *and Table 4.*

Wheat varieties released 2019

A rigorous study investigating European winter wheat cultivars bred over five decades showed that breeding for high-input (fertility, water supply, pest/disease control) systems delivered parallel genetic gains and yield stability for low-input systems, underscoring the efficiency of centralized breeding. WHEAT is preparing a similar analysis of its spring wheat to complement existing studies of genetic gain on farmers' fields.

Increasing genetic gain on farmers' fields by improving varietal replacement rates. The rapid replacement of old varieties with new ones allows farmers to exploit genetic gains from plant breeding and increases cost effectiveness. In this review article, Indian partner scientists summarized the institutional, technical, environmental and socio-economical constraints to faster varietal replacement. They argue for a paradigm shift in institutional policy and a 5-point strategy that addresses crop breeding for local adaptation.

Heat and drought lines released in Pakistan (see OICR). Eleven new varieties specifically bred for increased tolerance to heat and drought were released in 2019 in Pakistan.

Use of crop wild relatives in durum wheat. NARS and WHEAT scientists discovered that Crop Wild Relative (CWR)-derived elites can be superior to elite-by-elite lines. Of the 10 most recently released (2016-17) durum wheat varieties, four were derived from top-crosses with CWR and two from landraces. In related research, scientists confirmed that spike fertility and maintenance of green leaves are the most critical traits to drive heat tolerance and should be the primary targets of durum wheat breeders.

Nutritional quality. Grain-based foods — both whole-grain and refined — are a key part of healthy diets, according to WHEAT scientists based on more than 100 research papers and national health recommendations. *For other nutrition-focused research, see FP4.*

At the WHEAT-co-sponsored International Conference of Wheat Diversity and Human Health Maria Itria Ibba, head of CIMMYT's Wheat Chemistry, Quality and Nutrition Laboratory, presented research to improve global dietary fiber consumption through wheat with increased Arabinoxylans (AX) — fiber components associated with reduced risk of diabetes, cholesterol, cardiovascular disease and colon cancer. Preliminary findings suggest that AX content could be identified through molecular markers to effectively select for this trait in the breeding process.

Global Disease Monitoring and Surveillance: NARS partner and WHEAT scientists have identified a growing threat of yellow rust in the Himalayan regions of Pakistan, Nepal and Bhutan and argue for greater research efforts, which would have a global benefit as well. In addition, powdery mildew may increasingly affect the Himalayan region of Pakistan. Regarding stripe rust, crop improvement researchers participating in the Wheat Production Enhancement Program for Pakistan (WPEP) project noted increased the frequency of stripe rust resistance in Pakistan's national breeding program (see Poster 037). More research is needed to bring more resistance-conferring genes into elite lines (*Yr5, Yr10* and *Yr15*). Pakistan is a center of diversity for stripe rust.

Progress in wheat blast resistance. Four wheat blast resistant varieties - one in Bolivia and three in India - were released in 2019. As previously reported, the 2NS gene is currently the major resistance factor against blast. Using data from more than six environments, WHEAT scientists have identified three non-2NS lines with moderate resistance to blast – a step towards more resilient blast resistance.

FP4: Sustainable intensification of wheat based-farming systems

Landscape sustainability: Scientists from the Oak Ridge National Laboratory and University of Tennessee partnered with WHEAT scientists through a multi-year WHEAT partner grant to develop and test a systematic approach for measuring progress toward landscape sustainability goals in the Yaqui Valley, a major wheat-based farming system in Mexico. The researchers recommend a six-step assessment of progress toward landscape sustainability to support adoption of better landscape management practices via adaptive management and transdisciplinary research. Stakeholder engagement in, and ultimate ownership of, the process is more important than a specific result or indicator value. This rapid appraisal approach could be applied to a wide variety of communities and landscapes.

Early seeding raises yields in northwest India. Building on previously published analysis, a remote sensing study analyzing a 3-year (2017, 2018, 2019) trend in weekly date of wheat seeding in northwest India showed a progressive increase in acreage under early seeding. Efforts to scale up early seeding wheat using an improved version of the Happy Seeder planter continued and remote sensing monitoring showed significant progressive adoption from 2017-2020.

Raised bed sowing in Egypt, potential for regional scale-up. A water- and labor-saving farming machine, the Raised Bed Machine (RBM), was developed by ICARDA and promoted in Egypt in 2019. Improvements to the machine to make it more versatile and economically efficient – in addition to famer awareness-building efforts and incentives for smallholders -- have encouraged adoption. A 2018 analysis estimated that benefits of mechanized raised-bed wheat production would exceed US$ 4 billion over 15 years for more than one million Egyptian wheat producers, significantly reduce wheat imports by 2025 and increase productivity on more than 200,000 ha of water-starved lands. Potential for scale-up is strong: RBM has a life span of around 12 years, with calculations indicating owners can recoup the initial expense within three years.

Mechanization. The Mexico-CIMMYT MasAgro program continued to facilitate access to and availability of scale-appropriate mechanization options. In total, the program has developed over 50 machine prototypes for different scales of operation (manual, animal-drawn, two-wheel tractors and four-wheel tractors) and on-field and off-field activities, trained local metalworkers and delivered standardized construction plans and technical sheets. In 2019, the program conceptualized and constructed four prototypes with local manufacturers and its Smart Mechanization Unit established a network of 19 builder workshops in eight different Mexican states.

A WHEAT-led assessment of scaling success of Mechanization Service Provider Models (MSPMs) in Mexico, Zimbabwe, and Bangladesh offered important implications for development interventions aimed at increasing smallholder access to mechanization services at scale. Despite some positive examples of integration and alternate funding sources, sustained benefits are hampered by insufficient support for entrepreneurs and high dependency on project funding.

Biodiversity and nutrition. In research involving WHEAT FP4 scientists, authors state that "forest pattern, not just amount, influences the dietary quality in five African countries," providing further evidence that land sparing (segregation of agriculture and biodiversity) may be the best land use model for biodiversity, but not for people's nutrition in rural areas – in this case, consumption of fruits. Innovative and collaborative research led by WHEAT scientists assessed the links between forest cover and dietary diversity in Bangladesh, Burkina Faso, Cameroon, Ethiopia, Indonesia, Nicaragua, and Zambia. Their results were mixed, demonstrating that these mechanisms can vary significantly from one site to another, and highlighting the need for site-specific interventions.

1.2.3 Variance from Planned Program for this year

No research lines were dropped. FPs' impact pathways and Theories of Change (e.g direction) remain unchanged.

CIMMYT and ICARDA maintained their suspension of project operations and offices in Iran, because sanctions made even basic R4D operations impossible.

1.2.4 Altmetric score and Publication highlights

The top 4 Altmetric scored WHEAT co-funded publications concerned:

- farmer-participatory disease surveillance (Mobile And Real-time PLant disEase (MARPLE) diagnostics, a point-of-care disease diagnostics and surveillance tool for complex fungal pathogens);
- marker-assisted breeding (rice in flood-prone rice-wheat systems),
- how agricultural landscapes can best serve multiple purposes - simultaneously maintaining agricultural productivity and conserving biodiversity (Agriculturally productive yet biodiverse: human benefits and conservation values along a forest-agriculture gradient in Southern Ethiopia) – and
- Genome editing, gene drives, and synthetic biology: will they contribute to disease-resistance crops, and who will benefit? (MAIZE and WHEAT).

1.3 Cross-cutting dimensions (at CRP level)

1.3.1 Gender

Important research outputs are: *Leaving no one behind: how women seize control of wheat–maize technologies in Bangladesh*. Researcher findings suggest that a relatively simple empowerment process – training in wheat–maize technologies through a women's organisation – has started to enable women to secure access to innovations and start making important choices in their lives. – *see also section 1.3.2 below.*

From working in the wheat field to managing wheat: women innovators in Nepal. Wheat farming increasingly feminised with respect to labour and more women are exerting managerial competencies, supported by their husbands / extended families. But they face many constraints stemming from weak institutional recognition of women as wheat farmers. Agricultural institutions are failing to recognise the changes in gender relations and the implications for their practice.

Gender and agricultural innovation in Ethiopia - From innovator to tempered radical: The concept of tempered radicals, developed originally to interrogate change processes in organizations, can be applied in rural agricultural settings. Innovation is happening and that there are windows of opportunities for supportive interventions, but change is small, incremental, and faces resistance regardless of the gender. Strategies to support (women) innovators must be strongly context & gender-specific. Single women, existing on their society's margins, are more likely to be innovators. Thus, there is scope for developing strategies to support women-headed households and for methodologies aiming to strengthen intra-household bargaining processes.

Gender Norms and Poverty Dynamics in 32 Villages of South Asia. Gender norms exercise significant influences on poverty transitions. Across the study contexts, the possibility of families to move out of poverty is deemed to depend on men's roles. Over time some women have negotiated substantial roles in small-scale commercial agricultural enterprises and moved their family out of poverty. In relatively few villages, however, are such practices widely recognized or encouraged.

Methods or tools: Gender Integration Monitoring System (GIMS) was finalized and approved for institutional implementation in CIMMYT and shared with CGIAR Gender Research Community of Practice.

Capacity Development: As of the second quarter of 2019, Hom Gartaula joined CIMMYT's gender and social inclusion team under CoA 1.3, based in New Delhi. Having a member of the team based in the region significantly increases the capacity for integrating gender and social inclusion considerations in the project portfolio in South Asia.

Outcomes from the GENNOVATE (Enabling Gender Equality in Agricultural and Environmental Innovation) research initiative continue to grow. Examples include explicit integration of gender and social inclusion dimensions in adoption and impact studies (CoA 1.2); integration of gender norms in the discourse on gender in the CGIAR, and increased appreciation of qualitative research; and four PhD candidates working with GENNOVATE data.

***Important findings that have influenced the direction of the CRP's work, and how things have changed*:** One CGIAR discussions and ongoing restructuring processes have considerable transaction costs. Fundraising for gender, like other areas of research, is challenging as donors are waiting for clarity before committing new resources.

Have any problems arisen in relation to gender issues or integrating gender into the CRP's research? One project in the portfolio with a focus on gender in wheat-based livelihoods ended, was not renewed. No other funding was available to cover the staff member who led the project, who subsequently left. For the CoA 1.3 team this meant a significant reduction in PhD level staff.

1.3.2 Youth and other aspects of social inclusion / "Leaving no one behind[2]"

GENNOVATE research in Bangladesh showed that indigenous Santal women are obtaining access to and benefiting from wheat–maize innovations, enabling low-income Muslim women to benefit as well. In this case study, WHEAT partnered with a large NGO, Rangpur Dinajpur Rural Service (RDRS), active in hundreds of communities across northern Bangladesh. WHEAT researchers piloted wheat–maize innovations in 2013 and rolled out the project in 2014/2015 to more farmers with improved wheat and maize varieties, inorganic fertilizer and machinery including the power tiller operated seeder (PTOS). The study authors found that the establishment of the Union Federation -- an outreach platform specifically to reach women farmers -- and the channeling of technical training to women was the precondition for both Santal and low-income Muslim women to effectively express their agency, allowing them to secure a range of achievements. It appears that even in circumstances of very low access to assets and services, weak political voice and identity-based marginalization, women's agency is a powerful mechanism for overturning all of these, to a greater or lesser degree.

ICARDA implemented a six-month DFID-funded FAO project to rehabilitate the self-sustaining food production capability of the farming communities affected by the civil war in Syria. 40.3 tons of quality certified seed of improved crop varieties were produced, enough to cover 350 ha of agricultural land in 2020 (cereals and legumes). At an estimated yield of 2.5 tons/ha, those 350 ha will produce 875 tons of quality seed, enough to cover 7,000 ha of crop land with high quality seed, derived from WHEAT germplasm under development. Based on an estimated land holding size of 5 ha per farmer, about 1,400 farm households will get access to high quality seed and 60 tons of straw produced provide feed for 300 head of sheep during the critical feed shortage periods of December 2019 to March 2020. Most importantly, this intervention will contribute in the recovery of the agriculture sector by replenishing the quantities of certified wheat seeds available over the next two to three years.

[2] Leaving no one behind is a key facet of the SDGs.

1.3.3 Capacity Development

See also Table 8: Common Reporting Indicator on Individuals Participating in CapDev #C3.,

WHEAT continued to implement its capacity development strategy by 1) developing courses in cooperation with universities for young scientists, 2) providing training and research opportunities in key areas, in collaboration with leading universities, NARS, private sector, and advanced research institutes; 3) supporting a culture of learning and collaboration through the implementation of the Learning Management System (LMS; co-funded by WHEAT and MAIZE) within CIMMYT and CGIAR; and 4) funding seminars, learning events, workshops and projects that develop knowledge and learning resources across WHEAT Flagship projects.

Co-funding AWLA (formerly Tamkeen) Program. Together with the Bill & Melinda Gates Foundation and the Islamic Development Bank, WHEAT co-funded the Arab Women Leaders in Agriculture (AWLA) program, led by the International Center for Biosaline Agriculture (ICBA). Targeting women scientists in the MENA countries, the AWLA program will help to improve their research and leadership potential to become future leaders in agricultural science. Two wheat scientists participated in this one-year blended learning program with online and classroom courses. WHEAT will continue to co-fund participants in 2020.

1.3.4 Climate Change

Resource-conserving technologies. WHEAT scientists (in press) presented a framework for mainstreaming climate smart agriculture (CSA) into government policy and planning in India, using climate-smart villages to generate an evidence base for local adaptation plans of action and state and national action plans. The authors found that irrigation time in rice-wheat systems of Punjab and Haryana is reduced by almost 70 hours per hectare in laser-levelled fields compared to traditionally-levelled fields, and that state government policies, such as a subsidy for zero-till (ZT) machines and laser land levelers, have favored CSA adoption.

The provincial governments of Punjab and Haryana, as well as Government of India have initiated policies and programs to save water in agricultural production, given the region's speedily depleting groundwater resources. In India, 90% of all fresh water withdrawals go to into agriculture (for 2008-2012 study period). Those policies and programs would benefit from recent scientific studies that show the **farm profitability and environmental benefits of bundling various complementing agronomic innovations** including subsurface drip irrigation, applied to cereals-based farming systems. This 2-year research field study makes the case for greater crop and farm profitability, irrigation water savings, lower nitrogen use, and increased nitrogen use efficiency. Subsidizing or not subsidizing subsurface drip irrigation set-up does not make a significant difference to farm profitability.

The CIMMYT-Henan Innovation Center, a new partnership with Henan Agricultural University that focuses on research and training, is **studying the impact of climate change on wheat**. See more detail in section 2.2.1.

In a Nature comment, also published in Thomson Reuters Foundation News, CCAFS and WHEAT scientists revealed that **food-related GHG emissions -- from food production, related land-use changes, processing, consumption and management of food waste -- range from 21-37% of all human-induced emissions**. To combat this, a complete food systems approach is needed, and many agricultural practices can increase yields and resilience to climate change while also reducing greenhouse gas emissions, such as leaving behind stems from harvested crops, or using livestock manure for fertilizer. The dynamics of dietary change and their linkage to climate and health also need to be better understood. Finally, it is essential to find actionable ways to increase adoption of key adaptation and mitigation practices, for example, rigorous testing of the role of incentives and rapid development of innovative techniques such as circular economies.

2. Effectiveness and Efficiency

2.1 Management and governance

The WHEAT-Independent Steering Committee (WHEAT-ISC) recommended some **evolutionary and some revolutionary -- or out-of-the-box -- future research areas** (e.g. GMO for gene stacking, strategic rust resistance; more investment in station management for higher quality data international trials; sub-soil perspective for breeding) **– to consider when shaping the 2022+ WHEAT-relevant part of the CGIAR Portfolio**. WHEAT-ISC also recommended that WHEAT **no longer budget for research on hybrids**, while remaining open for funded bilateral collaborations, with the primary aim to understand more about genetic groups. However, WHEAT should no longer invest in creating pre-competitive space for PPP consortia; private sector players should do so.

W1&2 unpredictability remained an issue in 2019, mainly because of in-year donor W2 shifts away from WHEAT and the risk that total W1 target might not be reached. WHEAT-MC maintained a buffering reserve, based on a so-called midi-scenario, until October 2019, when CGIAR-SMO confirmed W1&2 budget, with the good news that lower-than-planned W2 would be compensated by the Stabilization Fund. WHEAT-MC decided to use the buffer budget to fund more partner grants.

Both WHEAT-ISC and WHEAT-MC had **One CGIAR / 2030 Plan** on their agendas. A common concern was the lack of an evidence-based rationale for organizational change (e.g. move to One Board, merge Centers) and the need to ensure stability, continuity and thus current CRPs' delivery during the change or transition process.

In September, CIMMYT and ICARDA counterparts revisited the progress made towards **One CGIAR Global Wheat Program (OWP)** and options for fully implementing it, following a WHEAT-ISC request (July). They reached agreement on a OWP that is supported by all scientists from CIMMYT and ICARDA, and that will be reflected in the future collaboration from gene-banks to pre-breeding to breeding, including inter-disciplinary teams to tackle specific challenges –e.g. transfer a major gene into an elite line to stacking minor genes for Fusarium head scab resistance. This should position the OWP well for a future One CGIAR, no matter in which direction it will take.

2.2 Partnerships

2.2.1. Highlights of External Partnerships

See also Table 9 & Common Reporting Indicator on External Partnerships #C2.

A study in *Science* conducted by a global team including **WHEAT scientist ML Jat and partners from The Nature Conservancy, the Indian Council of Agricultural Research (ICAR), the Borlaug Institute for South Asia (BISA) and the University of Minnesota**, compared the costs and benefits of 10 distinct land preparation and sowing practices for northern India's rice-wheat cropping rotations. The direct seeding of wheat into unplowed soil and shredded rice residue was the best option — it raises farmers' profits through higher yields and savings in labor, fuel, and machinery costs while cutting greenhouse gas emissions from on-farm activities by as much as 78% and helping lower air pollution. The findings complement and support Indian government policies including a US$166 million subsidy to promote mechanization such as the Happy Seeder to manage crop residues **(see OICR).** This research builds on earlier policy advocacy efforts and successes in Punjab (Happy Seeder adoption on 700,000 ha). The study compares the costs and benefits of 10 distinct land preparation and sowing practices for northern India's rice-wheat cropping rotations. Direct seeding of wheat into unplowed soil and shredded rice residue was the best option — it raises farmers' profits through higher yields and savings in labor, fuel, and machinery costs.

The CIMMYT-Henan Innovation Center, a new partnership with Henan Agricultural University that focuses on research and training, is **studying the impact of climate change on wheat**. The Center began work in 2018 with the posting of two WHEAT senior scientists, now increased by two post-docs and an intern, funded by **National Science Foundation (NSF) China, the Chinese Academy for**

Agricultural Sciences (CAAS), CIMMYT and the CGIAR Platform on Big Data in Agriculture. Climate change is not only a global problem for wheat, but also a concern for Henan province, as Center analysis revealed that average March temperatures in Henan have increased by 4.5ºC over the last 30 years. Linking this analysis with genomics will facilitate the selection of new varieties that perform well in a warmer environment. Other Center collaborators include research teams at the University of Florida, CAAS, the Chinese Academy of Sciences, China Agricultural University, and the private weather company meteoblue. Results have been published in high impact publications including *Nature Plant*, *Nature Food* and *Field Crop Research.*

The FAO-TAGEM-WHEAT-co-sponsored International Conference on Wheat Diversity and Human Health convened experts from the region and the globe to examine the link between wheat and human health, making a strong, scientifically supported case for a range of health benefits from wheat, its countless varieties and the foods made from them.

WHEAT scientists participated in most of the 11 Expert Working Groups of the G20 Wheat Initiative, the only crop/cropping system-focused initiative to better coordinate and prioritize research at an international scale. WHEAT scientists are junior partners in several International Wheat Yield Partnership (IWYP) projects.

Precision Wheat Phenotyping Platforms (PWPP). WHEAT and co-investing national partners managed seven platforms, with China joining in 2019:

Septoria in durum wheat (Tunisia): This PWPP plays an important role in establishing linkages among research institutions, universities, farmers' organizations, regional extension services and private organizations. Major activities in 2019 included field screening, a fully functional Septoria laboratory, a regional training course, collaboration with eight graduate students, and completing six publications.

Septoria leaf blotch, leaf rust, and Fusarium head blight (Uruguay): The platform evaluated around 2,000 wheat accessions for the three diseases under field conditions. Accessions came from 13 institutions (public and private) from seven countries; capacity development activities included a regional workshop.

Wheat blast (Bolivia). Evaluating under both natural and artificial inoculations, 4,000 accessions were tested under two planting dates in two cycles (summer/winter). The INIAF-Okinawa variety was released, and a Field Day was held with scientists from China and India. ***Wheat blast (Bangladesh)****:* The platform assessed wheat blast reaction of elite germplasm from Bangladesh and beyond, identified sources of resistance and selected agronomically superior resistant/tolerant lines. Achievements included training of research scientists, multi-location trials of promising wheat blast resistant/tolerant lines for disease and varietal release tests, and a socioeconomic benefits study.

Heat/drought tolerance (Morocco): A new drip irrigation system was installed for field trials and 265 accessions from CIMMYT were planted under rainfed and irrigated conditions (15 Dec 2019), together with lines from the ICARDA breeding program and INRA-Morocco. The newly installed rainout shelter lysimeter will complement high quality phenotyping data on heat and drought stress with new molecular selection technologies, to generate precise prediction values for developing improved germplasm. Through the WHEAT Bottom-Up grant assigned to the platform, the first experiment to measure night evapotranspiration will be performed next summer.

Stripe rust resistance and race analysis of rust pathogens (Turkey): Rust surveillance was conducted by the Regional Cereal Rust Research Center for Lebanon, Iraq, Iran, Morocco, Uzbekistan, Azerbaijan, Georgia, and Egypt. Surveillance data were provided to the RustTracker online database system. In total 317 rust samples were typed using differential sets. The platform conducted precision rust resistance phenotyping for bread and durum wheat lines, held a national training course, and hired four PhD interns.

Fusarium head blight (China): CIMMYT signed an agreement letter with the Jiangsu Academy of Agricultural Sciences (JAAS) in November for collaboration on FHB phenotyping, deployment of FHB resistance genes/QTL in Chinese and CIMMYT germplasm and wheat breeding activities. The platform is in one of the country's most important FHB epidemic regions.

2.2.2. Cross-CGIAR Partnerships (Centers, other CRPs and Platforms)

New collaborative research by Indian NARS (Chaudhary Charan Singh Haryana Agricultural University -CCSHAU, ICAR) and CIMMYT, supported by WHEAT, CCAFS and Bayer CropScience, finds, in addition to the CA benefits to yield, water, income, and soil, each hectare of CA-based sustainable intensification can help meet the protein requirements of eight additional persons, compared to a conventional system.

Through a country-level analysis, CCAFS and WHEAT scientists reported that adoption of climate-friendly technologies has the **potential to cut 18% of India's annual GHG emissions arising from agricultural sector**: efficient nitrogen fertilizer management, zero-tillage farming and improved water management being the major mitigation measures. The government of India has recognized some of these technologies as scalable innovations, to increase agricultural production in the face of climate change, as stipulated in "Agricultural Policies and Action-Plans for a Secure and Sustainable Agriculture in India." Appropriate government policies, incentive mechanisms and institutional setup are required for wide-scale adoption of these climate-friendly technologies.

Under Harvest+ (A4NH), wheat scientists continue to work to **fight "hidden hunger" and meet micronutrient needs** while reducing agriculture's environmental impact. To date, more than 12 biofortified high zinc wheat varieties have been released, reaching close to 1 million households in target countries such as India and Pakistan.

MAIZE, WHEAT & Excellence-in-Breeding: A functional **Enterprise Breeding System ("EBS")** version 1 was deployed at CIMMYT for use by maize and wheat breeders. Germplasm data migration will be completed in 2020. Early adopter breeders participate in the ongoing software development process to ensure viability and compatibility. Though delayed into 2020, ICARDA and IITA breeders will be able to start using EBS in 2020.

2.3. Intellectual Assets

Note: Further information can be found here. Have any intellectual assets been strategically managed by the CRP (together with the relevant Center) this year?

CIMMYT and ICARDA reviewed their relevant policies to support greater transparency including in partnerships and results dissemination to ensure they are in line with the CGIAR Principles

WHEAT is not a legal entity. The management of legal assets relevant to the CRP is managed by WHEAT Lead and participant centers. WHEA Lead Center (CIMMYT) and Participant Center ICARDA annually prepare and submit a detailed and confidential intellectual asset report to the System Management Board and the information contained therein is not repeated here. Flagship projects, WHEAT and CIMMYT-PMU do not, on their own, manage intellectual assets without consulting with the Lead Center's legal department; the same applies to ICARDA. The legal department reports intellectual assets management for CIMMYT in its annual IA report, which may include information from the CRPs FPs, if not separately discussed elsewhere in the IA report; the IA report would not specifically reference the term "flagship" projects.

(b) **If relevant**, 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, giving a name or number or link to identify them.

CIMMYT has not filed, nor has any CIMMYT partner informed CIMMYT, of any application for patent or plant variety protection associated with intellectual assets (IA) developed under WHEAT.

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

Critical issues and challenges identified in the proposal and the 2019 report are currently:

- Ensure enough funding and adequate 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 intellectual property 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, considering 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.

2.4 Monitoring, Evaluation, Impact Assessment and Learning (MELIA)

WHEAT FP1: 2019 ex ante studies that generate new knowledge are listed in the innovations table. Ex post studies and impact assessments are featured in SLO Targets Table 1.

WHEAT is fully utilizing MARLO to link individual projects and areas of research to FP theories of change and to monitor research progress. MARLO helps the CRP collect important lessons across projects and incorporate these in program decision making and institutional learning.

WHEAT reviewed its FP theories of change at the end of 2019, based on performance data collected and lessons learned. Best practices were taken into account for next year. In addition, WHEAT has considered lessons learned from the performance management standards pilot and is making improvements accordingly to strengthen processes and better document decision making.

WHEAT participated in the MEL CoP steering committee for another year, where it contributed to the finalization of a CGIAR MEL Glossary, the interoperability of two planning and reporting systems, the refinement of a quality assurance process for annual reporting, the establishment of a CGIAR MELIA support pack, progress on how to implement the projected benefits indicator, agreement on streamlining planning and reporting on MELIA studies, and the creation of new sub-groups to tackle issues in 2020.

WHEAT continued its efforts to build project management capacity, conducting 4 trainings, at headquarters and in regional offices. They included sections to strengthen project monitoring, evaluation and learning.

Lastly, WHEAT commissioned an external review of MEL systems in a sample of projects from FP4. Management agreed with all recommendations and has developed a plan including timelines and responsibilities to respond to these recommendations.

2.5 Efficiency

CIMMYT has implemented multiple tools from the Microsoft 365 platform **to increase efficiency and information security** and will continue to do so in 2020, including access to the tools managed via Azure Active Directory allowing adequate control over access; cloud-based solutions that are available even if CIMMYT HQ IT infrastructure were damaged; and centralized backup solutions for all information.

To date, 243 CIMMYT staff have been trained in Project Management and Monitoring, Evaluation and Learning tools for projects as part of the **PM@CIMMYT initiative**. Staff have access to the Teamwork project management tool to support task management, communication and collaboration within projects. We consistently track around 100 active users each month who are uploading files, adding comments, and assigning and completing tasks; and more than 200 users to date who have accessed the platform over 15 times. CIMMYT also launched the **PM Minimum Expectations**, which guide project leaders on the good practices and tools for projects of different sizes, in alignment with the

CGIAR Performance Management Standards. Due to this intervention, the participating projects' completion rates have continually improved over the course of 2019. CIMMYT-PMU staff share their experiences with the CGIAR-MEL-Community of Practice.

2.6 Management of Risks to Your CRP

The three major risks remain 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 (sub)-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), the SMO led a quality assurance of annual reporting, with a focus on outcomes and impacts reporting and CGIAR-Advisory Services commissioned a pilot assessment of the six Performance Management standards. On both counts, WHEAT performed well.

2.7 Use of W1-2 Funding

WHEAT is guided by the high-level framework for W1&2 deployment shown below, while Table 12 shows in more detail where W1&2 has been invested during 2019, based on the 96 work packages in the W1&2-per-FP annual work plan that cuts across CIMMYT and ICARDA scientists and their implementation partners.

	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	

3. Financial Summary

In 2019, WHEAT received US$6.7M W2 support from Australia (ACIAR), UK (DFID) and USA (USAID) and $6.1M W1 from Australia, Belgium, Canada, France, India, Japan, Korea, Netherlands, New Zealand, Norway, Sweden, Switzerland, UK and the World Bank. Bilateral funder support is documented in the WHEAT Annual Financial Report and in the CGIAR Financial Dashboards.

Initial CGIAR Financial Plan for 2019 was set at $14.08M, then lowered to $13M.

During 2019, WHEAT-MC

- Agreed to work with a $12.74M W1&2 budget and withhold $2.46M to cover for the risk of lower USAID W2 that would not be compensated by the Stabilization Fund, as well as the risk of lower total CGIAR W1 income (e.g. World Bank contribution reduced).
- By Oct, based on updated figures from SMO, agreed to reduce the buffer and spend on prioritized partner grants and bottom-up multi-FP scientists' small innovation projects.
- Invested over $2.4M in ongoing and new WHEAT partner grants, equivalent to 19% of 2019 new income received.
- Noted with satisfaction that 2019 actual new W1&2 income ($12.49M) was equivalent to 98% of System Council-approved (net of CSP) and that SMO income and cashflow predictions have become more accurate since the start of Phase II.

Part B. TABLES

Table 1: Evidence on Progress towards SRF targets (sphere of interest) (Report Table)

Please complete this table as best you can, based on solid evidence, such as findings of published adoption or impact studies.

SLO Target (2022)	Brief summary of new evidence of CGIAR contribution	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	**An ex post study** on diffusion of zero tillage (ZT) wheat among the smallholders of the eastern Indo Gangetic Plains indicated that the technology has become more accessible to marginalized categories of farm households over time. With an average landholding size of 0.39 hectares, most farmers of the study area (Bihar state, India) were found relying on custom-hiring services to access the technology. The ZT technology awareness increased from 47% to 84% between 2012 and 2015 and the share of farmers who use the technology on farm increased from 32% to 40%. The authors found a strong initial scale bias in ZT use, which declined substantially as awareness of the technology grew and the service economy expanded. The quality of service provision improved over time. **Ex post, behavioral change impact assessment** (3 years panel data, 184 farm households, Haryana, India): Conservation agriculture-based wheat production system (CAW) can serve as an *ex ante* measure to minimize loss due to climate risks (e.g. extreme rainfall during the wheat production season). This study examined whether farmers learn from their past experiences of exposure to climate extremes and use the knowledge to better adapt to future climate extremes. The analysis shows that most farmers who had applied CAW in the year 2014-2015 (a year with untimely excess rainfall during the wheat season) have continued to practice CAW and have increased the proportion of land area allocated to it. Many farmers shifted from conventional tillage-based wheat production system (CTW) to CAW in 2015-2016. **Ex post impact assessment:** The International Winter Wheat Improvement Program (IWWIP) was established in 1986 between the Government of Turkey and CIMMYT with 3 objectives: (1) develop winter/facultative	

	germplasm for Central and West Asia, (2) facilitate global winter wheat germplasm exchange, and (3) train wheat scientists. ICARDA joined the program in 1991. Germplasm developed by IWWIP as well as the winter wheat cultivars and lines received from global cooperators assembled into international nurseries, are offered annually to public and private entities and distributed to more than 100 cooperators in all continents. IWWIP impact: ✓ New winter wheat cultivars combining broad adaptation, high yield potential, drought tolerance and disease resistance. 93 cultivars released in 11 countries, occupying annually an estimated 2.5–3.0 Mha; ✓ An entirely new area of zinc biofortification began in the early 2000s; ✓ Led to improvement in wheat production and grain nutritional quality in Turkey and neighboring countries; ✓ Inventory of **wheat landraces** in Turkey in 2009–2014 led to **discovery of novel genes** contributing to grain yield under moisture stress and other agronomic traits. Since 2014, targeted crossing to improve drought tolerance & disease resistance, currently at yield test stage. Work on wheat landraces led to further regional projects (Afghanistan, Iran and Turkey), to utilize the landraces in breeding and to expand on-farm wheat diversity - **Spring wheat synthetics** developed at CIMMYT by crossing durum and *Aegilops tauschii* proved to be an **important genetic resource for a number of traits**. **An assessment** of wheat varieties grown in farmers' fields in Afghanistan, with the help of DNA fingerprinting of 560 samples collected during the 2015–16 cropping season, found that only 19 wheat varieties were grown in the sampled provinces, of which 9 were direct releases from CGIAR; others had CGIAR parentage. About 75% of all varieties were released after 2000. A CIMMYT advanced line (MUQAWIM-09) is one of the most prominent wheat varieties grown in the study region. However, due to a few past interventions of CIMMYT and ICARDA in this region (e.g., on-farm demonstrations), these results are not necessarily representative of entire rural Afghanistan.	
1.2. 30 million people, of which 50% are women, assisted to exit poverty	**An ex ante integrated biophysical and economic modeling study** on climate smart agriculture (CSA; particularly integrated soil fertility management) and input-intensive technologies in Ethiopia's cereal systems indicated that adopting CSA on 25% of Ethiopia's maize and wheat land increases annual gross domestic product (GDP) by an average 0.18% (US$49.8million) and reduces the national poverty rate by 0.15 percentage points (112,100 people). CSA was found more effective than doubling fertilizer use on the same area, which increases GDP by US$33.0 million and assists 75,300 people out of poverty. The study showed that, although not a panacea for food security concerns in the country, greater adoption of CSA could deliver economic gains but would need substantial tailoring to farmer-specific contexts in Ethiopia. **Ex post, quantitative & qualitative adoption study**: Appropriate-scale mechanization adoption pathways in South Asia: Spread of smaller scale engines and equipment in some South Asian countries has been an essential technology behind many of the different South Asian green revolutions. Authors call for cost-effective empirical studies of what has been happening on the ground in recent years … by 2019, a range of government and donor	

	projects actively promoting "scale appropriate" technology … the Cereal System Initiative South Asia (CSISA) … and an Australian funded project (FACASI) … for some countries in Africa. Authors concentrate on spread and use of small single cylinder diesel and petrol engines in rural areas - mainly in Asia. With an estimated market of 3000 per year and a lifespan of 4 years, there may well be over 12,000 or more of these small machines in Nepal. … These "good enough" and mostly Chinese-made two-wheel tractors in South Asia … approx. 800,000 in Bangladesh and close to 40,000 in Nepal now. … Thus far all agree that the single household/family-based entrepreneur selling services of 1–2 or 3 machines is, by far, the most wide-spread business model.	
2.1. Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	**Ex post, genetic gains impact assessment** *and by implication farmer adoption impacts*: Impact of High Rainfall Wheat Screening Nursery (HRWYT) (received June 2019, published February 2020) that go to more than 100 collaborators worldwide within the International Wheat Improvement Network (IWIN): This type of evaluation is imperative…, *given that 70% of cultivars grown in target countries are either direct CGIAR releases or used as parents* (Lantican et al., 2016). … The grain yield (GY) analyzed data set belongs to HRWYTs distributed and grown from 2007 to 2016 at 360 locations in 53 countries. … Our study shows reliable genetic progress for GY over time when the data is expressed as genetic progress *per se* or as a percentage of local checks. The trends observed in the high-rainfall environment were very consistent, exhibiting regression slopes highly significant ($p \leq 0.001$) and genetic rates of 3.8 % and 1.17 % for genetic progress and local checks, respectively. Similar genetic progress *per se* has been observed in some countries located in high-rainfall environments. For example, in Ethiopia, the national production showed an annual yield gain of 6.4 % considering the same period analyzed in this study (FAO, 2019). … . Although HRWYT germplasm targets high rainfall environments, we also found genetic progress in the low-rainfall environment for the local checks (GYLC). In this environment, the genetic progress was lower. Interestingly, the parentage base of the best performing lines common in both environments included CIMMYT lines as well as the European winter wheat lines. Those CIMMYT genotypes have been widely reported to maintain stable and superior performance over a range of low, intermediate and high yield environments, irrespective of irrigation or drought stress. The European lines, meanwhile, contribute to increased resource use efficiency together with stable and high yields under different environmental conditions. This result supports previous conclusions that CIMMYT breeders successfully broadened the genetic diversity of the elite germplasm through the incorporation of materials from all over the world as well as via primary synthetics into the breeding program. **An impact evaluation of research investment on wheat research in Nepal** from 2005 to 2016 indicated that the share of operational budget in the national research-for-development programs was lower for wheat research than appropriate, given that it remains the third-most important crop. **The pace of increment of wheat production and productivity was driven by improved wheat investment and technologies.** About 60% of varieties released during the study period had CGIAR parentage. The authors found negligible spillover effect from neighboring countries. A huge gap between yield potential and average national productivity remains.	

	An ex ante field research study on the effects of tillage and crop establishment methods on productivity, profitability and soil physical properties in a rice–wheat system estimated the impact of six conservation agriculture technologies in the rice-wheat systems of South Asia. The study revealed that **zero-till direct-seeded rice with residue retention followed by zero-till wheat with residue retention gave 30% greater grain yield** than the conventional system. This technology combination also **increased the net returns and soil properties** (fastest mean infiltration rate, lowest bulk density at 15–20 cm soil depth). Authors concluded that conventionally tilled and transplanting of rice could be successfully replaced by adoption of the profitable double zero tillage rice-wheat system.	
2.2. 30 million more people, of which 50% are women, meeting minimum dietary energy requirements	**An ex post impact evaluation of sustainable intensification of wheat systems with legume rotation in Morocco** indicates that the practice has significant economic advantages over cereal monocropping. Rotations provide higher yields, gross margins, and consumption of wheat and faba beans. This study employs two-year data from a large sample of 1230 farm households and their 2643 fields cultivated with different varieties of wheat and faba beans in the wheat-based production system of Morocco. The two-year average gross margin was 48% higher (US$537/ha extra) than wheat monocropping. Contrary to common expectations, adopters of wheat-faba bean rotation did not use lesser amounts of nitrogen fertilizer than those monocropping wheat, thereby undermining the ecological benefits of the rotation.	
2.3. 150 million more people, of which 50% are women, without deficiencies in one or more essential micronutrients		
3.1. 5% increase in water and nutrient efficiency in agroecosystems	**An empirical study to assess the impacts of laser-land-leveling technology** in Iran identified factors influencing perception regarding laser-land-leveling technology impacts. The most important impacts of laser-land leveling were uniform germination of the crop, uniform distribution of water, decrease of soil erosion, increasing positive competition, and increasing net income. In addition, the results revealed that adopters of laser-land leveling benefitted more than the non-adopter group. Farmers emphasized that "about 50 percent of water consumption was cut down" and that "before laser land leveling water waste was high due to being low and high and improper slope" and "water flow forward was doubled."	
3.2. Reduction in 'agriculturally'-related greenhouse gas emissions by 5%	**An ex post / ex ante study on residue-burning in India** showed that Happy Seeder–based systems are on average more profitable than alternative farming practices, being about 10% more profitable than the most profitable burning option (with zero-till seeders) and about 20% more profitable than the most common burn system (ex post). However, the largest potential of the technology is with respect to GHG and air pollution reductions: Happy	

	Seeder adoption would eliminate air pollution from residue burning and reduce GHG emissions per hectare from on-farm activities by more than 78% relative to all burning options, thereby lowering agriculture's contribution to India's GHG emissions (ex ante). **Ex ante assessment of energy-efficient cropping systems practices in the Eastern Gangetic Plain (3 countries)** Researchers tested improved management practices against a conventional practices baseline in over 400 on-farm trials. Improved management practices significantly reduced the total energy used in rice-wheat cropping systems. Similar savings in total energy used were observed in rice-maize and rice-lentil cropping systems; additionally, energy use was significantly more efficient under improved management in all 3 cropping systems: Between 5% and 11% - and reduced CO_2-equivalent emissions between 11% and 16%, compared to emissions from baseline systems. A similar study focusing on Bihar, India, compared 6 cropping systems options/treatments varying in tillage, crop establishment method, residue management, crop sequence and fertilizer and water management, using a cropping systems model under current (1980–2009) and future (2030 and 2050) climate scenarios for Bihar. All new cropping system treatments had a positive yield implication under the current climate *but did not contribute to adaptation under the future climate* **except future conservation agriculture-based maize–wheat intensive cropping system (FCS-2) in wheat.** *Adaptation to future climate must integrate both cropping system innovations and genetic improvements in stress tolerance*.	
3.3. 55 M ha degraded land area restored		
3.4. 2.5 M ha forest saved from deforestation		

Table 2: Condensed list of policy contributions in this reporting year (Sphere of Influence)

Title of policy, legal instrument, investment or curriculum	Description of policy, legal instrument, investment or curriculum	Level of Maturity	Link to sub-IDOs (max. 2)	CGIAR cross-cutting marker score				Link to OICR or link to evidence (e.g. PDF generated from MIS)
				Gender	Youth	Cap Dev	Climate Change	
384 - Roadmap for Agricultural Development in North-Eastern Hill (NEH) Region, India	NEH region of India consisting 7 states is a hilly terrain with severe land degradation problems and low productivity. In this policy brief we enlisted the strategies and technological options	Level 1	• Agricultural systems diversified and intensified in ways that protect soils and water	1 - Significant	1 - Significant	1 - Significant	1 - Significant	OICR3286
395 - DNA Fingerprinting for Tracking Bread Wheat Varieties in Ethiopia: Policy Implications	The policy brief presents a study conducted on tracking released bread wheat varieties using DNA fingerprinting complemented by the conventional farmer recall survey.	Level 1	• Adoption of CGIAR materials with enhanced genetic gains • Increased conservation and use of genetic resources • Enhanced institutional capacity of partner research organizations	1 - Significant	? - Too early to tell	1 - Significant	? - Too early to tell	Policy brief communicated to national stakeholders and policy makers through a policy workshop & mailing list. The brief is available here
474 - Government of West Bengal mandating CA machinery as part of any Custom Hire Centre and	Government of West Bengal (Department of Agriculture) utilized Conservation Agriculture findings created though SRFSI	Level 1	• Agricultural systems diversified and intensified in ways that protect soils and water • Closed yield gaps through improved	0 - Not Targeted	0 - Not Targeted	2 - Principal	2 - Principal	Evidence: Email response confirming the Dep't of agriculture accepted a proposal to work with SRFSI to integrate CA findings in subsidy

supporting through subsidies to do so.	project and integrated this into their subsidy program for agricultural mechanization (custom hire centers) and converged with decentralized agricultural extension activities (e.g. ATMA) across the entire state.		agronomic and animal husbandry practices • More efficient use of inputs					program across the state; memo from the governor confirming the allocation of government funds to farm mechanization schemes; extensive guidance. Evidence is here.
475 - Roadmap for Agricultural Development in North-Eastern Hill (NEH) Region, India	CIMMYT produced a roadmap for agricultural development in the NEH region of India. The brief was written in collaboration with the Indian Council of Agricultural Research, the National Academy of Agricultural Sciences, and the Indian Association of Hill Farming.	Level 1	• Agricultural systems diversified and intensified in ways that protect soils and water	0 - Not Targeted	0 - Not Targeted	2 - Principal	2 - Principal	Policy brief published and drafted in concert with the Indian Council of Agricultural Research. The document is available here.
476 - The Government of Nepal provided a 50% subsidy to farmers for farm mechanization, with emphasis on labor-saving	The Government of Nepal (through the Prime Minister's Agricultural Modernization Project in Banke's Rice Super Zone) provided a 50% subsidy to farmers for	Level 1	• Technologies that reduce women`s labor and energy expenditure adopted	2 - Principal	2 - Principal	2 - Principal	1 - Significant	The linked document (in Nepali) are guidelines issued by the Government of Nepal, through the Prime Minister's Agriculture Modernization Project (PMAMP). They illustrate

mechanical weeders that are ergonomic and easy to use for women farmers	farm mechanization, with emphasis on labor-saving mechanical weeders that have been demonstrated to be ergonomic and easy to use by women farmers.							the provision of a 50% subsidy on farm mechanization, including those promoted by CSISA. Provinces are drafting their specific farm mechanization policies, but overall these fall under the linked Government of Nepal guidelines.
477 - Nepal provincial governments (Sudurpashchim and Province 5) started to subsidize the purchase of efficient fertilizer hand-crank spreaders by providing a 50% subsidy for farmers groups, cooperatives and private firms.	An Agricultural Mechanization Subsidy Program was approved by MoAD, and this included technologies from CSISA project, such as efficient fertilizer hand-crank spreaders.	Level 1	• Agricultural systems diversified and intensified in ways that protect soils and water • Closed yield gaps through improved agronomic and animal husbandry practices	1 - Significant	1 - Significant	1 - Significant	0 - Not Targeted	Sudurpashim province has begun subsidizing purchase of agricultural machinery, which includes efficient fertilizer hand-crank spreaders, a technology supported by CSISA.Link available here.
478 - Climate-smart agriculture framework and	The climate-smart agriculture framework and the draft	Level 1	• Closed yield gaps through improved agronomic and animal	0 - Not Targeted	0 - Not Targeted	1 - Significant	1 - Significant	The climate-smart agriculture framework for Zimbabwe was influenced

Draft Mechanization and Irrigation Policy for Zimbabwe influenced by FACASI and PROGRESS	Mechanization and Irrigation Policy for Zimbabwe was influenced by FACASI and PROGRESS and refers to the 4 pillars of our small mechanization approach: two-wheel tractor, conservation agriculture, service provision by rural entrepreneurs, and small irrigation.		husbandry practices • Agricultural systems diversified and intensified in ways that protect soils and water					by FACASI and PROGRESS and refers to the 4 pillars of our small mechanization approach: CIMMYT scientists are referenced several times, notably in the section on "Evidence and Insights on CA in Zimbabwe". The Draft Mechanization and Irrigation Policy for Zimbabwe was also influenced by FACASI and PROGRESS. Evidence is here.

Table 3: List of Outcome/ Impact Case Reports from this reporting year (Sphere of Influence)

Title of Outcome/ Impact Case Report (OICR)	Link to full OICR	Maturity level	Status
OICR2524 - Conservation Agriculture in South Asia	Link	Level 2	New Outcome/Impact Case
OICR2525 - Women empowerment and food security in wheat systems of Madhya Pradesh, India	Link	Level 1	New Outcome/Impact Case
OICR3284 - CGIAR synthetic wheat breeding strategy successfully transfers valuable diversity from wild goat grass to modern wheat, providing farmers with climate-resilient, pest and disease-resistant wheat.	Link	Level 3	New Outcome/Impact Case
OICR3285 - Screening operations in wheat rust phenotyping platforms (Kenya, Ethiopia) led to release of over 100 Ug99 resistant wheat cultivars globally over last decade	Link	Level 3	New Outcome/Impact Case
OICR3286 - Factors driving large-scale adoption of sustainable intensification practices in the Indo-Gangetic Plain (Cereal Systems Initiative for South Asia - CSISA)	Link	Level 2	Updated Outcome/Impact case at same level of maturity
OICR3296 - Heat and drought-resistant wheat varieties in Pakistan help farmers combat climate change stress and is success of physiological breeding approach	Link	Level 2	Updated Outcome/Impact case at same level of maturity

Table 4: Condensed list of innovations by stage for 2019 – NEXT 3 PAGES

Title of innovation with link	Innovation Type	Stage of innovation	Geographic scope (with location)
1165 - 51 new pre-breeding wheat lines with high yield potential and climate resilience for Mexico's growing regions.	Genetic (varieties and breeds)	Stage 1: discovery/proof of concept (PC - end of research phase)	National, Mexico
1166 - 17 new wheat varieties multiplied in collaboration with seed producers located in strategic growing areas of Mexico.	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	National, Mexico
1167 - Two wheat lines selected in collaboration with INIFAP proposed as variety release candidates.	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	National, Mexico
1168 - 24 CIMMYT advanced lines with high yield potential, good grain quality and disease resistance.	Genetic (varieties and breeds)	Stage 2: successful piloting (PIL - end of piloting phase)	National, Mexico
1169 - Re-designing irrigated intensive cereal systems through bundling precision agronomic innovations for transitioning towards agricultural sustainability in North-West India	Production systems and Management practices	Stage 1: discovery/proof of concept (PC - end of research phase)	Regional, Southern Asia
1174 - New protocol developed to measure spike photosynthetic rates under European conditions	Research and Communication Methodologies and Tools	Stage 3: available/ ready for uptake (AV)	Regional, Western Europe
1227 - 2 new wheat varieties	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	National, Spain
1256 - High-throughput assays for polyphenol oxidase (PPO) activity and phytic acid content developed. Molecular markers associated with PPO activity and phytic acid have been identified in genome-wide association studies.	Other	Stage 1: discovery/proof of concept (PC - end of research phase)	Global
1265 - Use of modeling tools to simulate the impact of climate change on wheat and barley production	Research and Communication Methodologies and Tools	Stage 1: discovery/proof of concept (PC - end of research phase)	Global

1273 - Climate services for resilient cropping systems	Production systems and Management practices	Stage 3: available/ ready for uptake (AV)	National, Bangladesh
1274 - Cultivar mixtures to reduce wheat blast	Production systems and Management practices	Stage 1: discovery/proof of concept (PC - end of research phase)	National, Bangladesh
1278 - Wheat blast resistant and tolerant cultivars	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	National, Bangladesh
1279 - Wheat straw reaper-bailers to improve livestock feeding practices	Production systems and Management practices	Stage 1: discovery/proof of concept (PC - end of research phase)	National, Nepal
1286 - Economic benefits of blast-resistant biofortified wheat in Bangladesh: The case of BARI Gom 33	Social Science	Stage 3: available/ ready for uptake (AV)	National, Bangladesh
1322 - Averting wheat blast by implementing a 'wheat holiday': In search of alternative crops in West Bengal, India.	Social Science	Stage 3: available/ ready for uptake (AV)	National, India
1323 - Alternative use of wheat land to implement a potential wheat holiday as wheat blast control: In search of feasible crops in Bangladesh.	Social Science	Stage 3: available/ ready for uptake (AV)	National, Bangladesh
1325 - Adapting irrigated and rainfed wheat to climate change in semi-arid environments: Management, breeding options and land use change	Biophysical Research	Stage 1: discovery/proof of concept (PC - end of research phase)	National, Mexico
1326 - Satellite data and supervised learning to prevent impact of drought on crop production: Meteorological drought	Social Science	Stage 1: discovery/proof of concept (PC - end of research phase)	Global

1398 - Assessing the long-term impact of conservation agriculture on wheat-based systems in Tunisia using APSIM simulations under a climate change context.	Social Science	Stage 1: discovery/proof of concept (PC - end of research phase)	National, Tunisia
1400 - Modelling farmers' responses to irrigation water policies in Algeria: An economic assessment of volumetric irrigation prices and quotas in the Jijel–Taher irrigated perimeter.	Social Science	Stage 1: discovery/proof of concept (PC - end of research phase)	National, Algeria
1401 - Analysis of the competitiveness of wheat and orange farming in Tunisia under water shortage scenarios	Social Science	Stage 1: discovery/proof of concept (PC - end of research phase)	National, Tunisia
1402 - Climate change and agriculture in South Asia: adaptation options in smallholder production systems	Production systems and Management practices	Stage 3: available/ ready for uptake (AV)	Regional, Southern Asia
1438 - Different uncertainty distribution between high and low latitudes in modelling warming impacts on wheat	Biophysical Research	Stage 1: discovery/proof of concept (PC - end of research phase)	Global
1440 - Crop season planning tool: Adjusting sowing decisions to reduce the risk of extreme weather events	Biophysical Research	Stage 1: discovery/proof of concept (PC - end of research phase)	Global
1469 - Distribution of International trials and nurseries	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	Global
1481 - Agvisely/"Climate Information Service Advisories for Major Field Crops of Bangladesh"	Production systems and Management practices	Stage 3: available/ ready for uptake (AV)	National, Bangladesh
1486 - ETBW8003 rust resistant elite line	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	National, Ethiopia
1487 - Jawahir 19 rust-resistant elite line	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	National, Afghanistan

1489 - Sharq 19	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	National, Afghanistan
1490 - Imam 1	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	National, Nigeria
1493 - Salvarti	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	National, Azerbaijan

Innovation 1469: Details next page

International Wheat Improvement Nursery Innovations

Target	Crop	Mega-environment	Description	CIMMYT GWP Nurseries	% of annual IWIN distribution	Annual prep & distribution costs (USD)*
Optimum environments	BW	ME1	Irrigated, low rainfall environment, represents the optimally irrigated, low rainfall areas of the world. Diseases: Mainly rusts; Karnal bunt. Area: Primarily throughout Asia, in Africa and Mexico	ESWYT, IBWSN	20	134000
High rainfall environments	BW	ME2	High rainfall environment. Temperate environments with an average of more than 500 mm of rainfall during the cropping cycle. Diseases: Stripe and leaf rust, Septoria tritici, Fusarium head blight (FHB), BYDV, bacteria, powdery mildew and the root disease complex. Area: Concentrated in West Asia and North Africa (WANA), Ethiopia, Kenya, the Southern Cone and Andean Highlands of South America.	HRWYT, HRWSN	11	73700
High temperature environments	BW	ME5	Warmer area environment Mean temperature of the coolest month is above 17.5^{0}C. Diseases: Helminthosporium sativum, leaf rust. Area: Primarily located between 23^{o}N -23^{o}S, below 1000 masl, Egypt, Bangladesh, India, Pakistan, Paraguay, Sudan.	HTWYT	11	73700
Drought prone environments	BW	ME4	Low Rainfall / Drought environment. Less than 500 mm of water available during the cropping cycle. Diseases: Rusts, Septoria, root rots, nematodes, and bunts. Area: Syria, North Africa, Southern Cone, India.	SAWYT, SAWSN	17	113900
Wheat Physiology	BW	Heat, Drought, Yield Potential	Global spring bread wheat, Stress Adaptive Traits, Wheat Yield Consortium	SATYN, WYCYT	11	73700
Best-of-best	BW	Broad adaptation	Collaborative Wheat Evaluation Network	CWEN	2	13400
Strategic diseases	BW	Prevalent global wheat diseases	Pre-bred materials for Fusarium Head Blight, Karnal bunt, Stem Rust Resistance, Wheat Blast, Septoria diseases and Helminthosporium diseases	FHBSN, KBSN, STEMRRSN, BLASTSN, ISEPTON, HLBSN	18	120600
High quality durum	DW	ME1, ME4	Irrigated and low rainfall durum wheat where leaf rust, stem rust, Septoria tritici are major constrains, with amber, highly pigmented grain.	IDYN, IDSN	10	67000
TOTAL						670,000

* Based on 2019 IWIN (100%), SHL (50%), SDU (50%) charge back costs, & shipment charges.

Varietal releases derived from breeding research (CIMMYT, 2019)

Bread wheat-Spring (36 Varieties)

Bolivia	INIAF OKINAWA
Ethiopia	Bondena (ETBW6188), ETBW8260, Hadis (ETBW6463), Hibist (ETBW7690)
India	DBW 222, DBW 252, HD 3249, HI 1621, HI 1628, HUW711, NIAW 3170, VL Gehun 967
Iran	Kelateh, Mearaj, Torabi
Jordan	Ghweir 1
Kenya	Kenya Jacana, Kenya Kasuku
Mexico	Hans F2019
Pakistan	Aghaz-2019, Akbar-19, AZRC-Dera, Bhakkar Star, Fahim-19, Ghazi-19, Ghulzar-19, Markaz-19, NIFA Awaz, Pirsabak-19, Umeed-e-Khas2019
Spain	Setenil
Turkey	Hilar, Kirve, Polathan, Serince

Durum wheat (5 Varieties)

Iran	Yet to be named
Mexico	ISABELLA ORO C2019
Spain	DON FERNANDO
Turkey	Cudi 63, Ilkhan

Varietal releases derived from breeding research (ICARDA & IWWIP)

Durum wheat-Spring (1 Variety)

Jordan	Rabba 1

Bread wheat-Winter (8 Varieties)

Afghanistan	Jawahir 19, Mirdad 19, Sharq 19
Ethiopia	ETBW8003
Iran	Rahmat
Turkey	Tugra, Yavuz
Uzbekistan	Gallakor 2016

Table 5: Summary of status of Planned Outcomes and Milestones

FP	FP Outcomes 2022	Sub-IDOs	Summary narrative on progress against each FP outcome this year.	Milestone	2019 milestones status	Provide evidence for completed milestones	Link to evidence
1	FP1 Outcome: 1.8 National and regional policy makers improved policy-making and increased investment based on evidence	Increase capacity of beneficiaries to adopt research outputs	Ex-ante/spatial assessments (incl foresight and targeting) assess how major drivers (like climate change, biotic stresses, and rural transformation) will alter WHEAT in the developing world. Highlights of foresight/targeting studies to inform policy: - Ex ante assessment of potential impact of blast-resistant biofortified wheat in Bangladesh using the case of BARI Gom 33 (1), and possible alternatives to wheat in Bangladesh (2) and West Bengal, India (3) - wheat disease monitoring and decision-making tools: An early warning system in Ethiopia now predicts and mitigates wheat rust diseases (4) and cross-continental predictive dispersal simulations (5). - Climate change adaptation analysis: Assessing options to adapt irrigated and rainfed wheat to climate change in semi-arid environments in Mexico (6). -review of potential of crop pest/disease modeling (7) - Crop modeling applications to assess	2019 - Ex-ante/spatial assessments (incl foresight and targeting) assess how major drivers (like climate change, biotic stresses, and rural transformation) will alter WHEAT in the developing world	Complete	9 papers + 1 bookchapter 1.Crop Protection 123, 45-58 2.Land Use Policy 82, 1-12. 3.PlosOne 14, e0211410. 4.Environmental Research Letters 14, 115004 5.Phytopathology 109, 133-144 6.EJA 109, 125915. 7.Bookchapter. 8.Science of the Total Environment 692, 1223-1233 9. Agricultural Economics 50, 101-111 10.Arabian Journal of Geosciences 12, 355 11.IrrigationDrainage 68, 507-519	1.https://doi.org/10.1016/j.cropro.2019.05.013 2. https://doi.org/10.1016/j.landusepol.2018.11.046 3. https://doi.org/10.1371/journal.pone.0211410 4. http://dx.doi.org/10.1088/1748-9326/ab4034 5. https://doi.org/10.1094/PHYTO-04-18-0110-R 6. https://doi.org/10.1016/j.eja.2019.125915 7. http://dx.doi.org/10.19103/AS.2019.0061.07 8. https://doi.org/10.1016/j.scitotenv.2019.07.307 9. https://doi.org/10.1111/agec.12469 10. https://doi.org/10.1007/s12517-019-4527-5 11.https://doi.org/10.1002/ird.2327

			long-term impact of conservation agriculture on wheat-based systems in Tunisia (8) - Case studies to assess competitiveness implications of water shortage scenarios in Tunisia (9) and farmers' responses to irrigation water policies in Algeria (10) -synergies between CRP WHEAT foresight/targeting and CRP PIM (including Foresight Report) and Big Data Platform re-enforce role of (a)biotic stress monitoring and big-data.				
	FP1 Outcome: 1.10 Farmers have greater awareness and access to, and increased adoption and adaptation of improved technologies		Highlights to enhance adoption/impacts: - WHEAT Impact assessment strategy released (1) and potential implications for technological change rethought (2). - Review of remote sensing opportunities for monitoring adoption dynamics (paper submitted, under review). - Tool development for global assessment of sustainable intensification (for rollout in 2020). - wheat germplasm adoption studies highlight smallholders' coping mechanisms with wheat rust epidemics in Ethiopia (3) and modest varietal turnover in Morocco (4) - Adoption studies highlight prospects of increasing social inclusion with zero-tillage wheat in eastern India (5) and factors associated with agricultural mechanization in Bangladesh (6) - Studies assesses trade-offs of fertilizer	2019 - Adoption and impact studies on technologies- rolling plan based on progress of technologies along the theory of change	Complete	7 papers, 1 report + 1 bookchapter 1. Report 2. Outlook on Agriculture 48, 169-180. 3. PlosOne 14, e0219327. 4. bookchapter 5. World Development 123, 104582. 6. World Development Perspectives 13, 1-9. 7. Sustainability 11, 5161. 8. Utilities Policy 59, 100930. 9. Energy Strategy Reviews 24, 236-243	1.https://repository.cimmyt.org/handle/10883/20221 2. https://doi.org/10.1177/0030727019864978 . 3. https://doi.org/10.1371/journal.pone.0219327 4. https://hdl.handle.net/20.500.11766/8505 5. https://doi.org/10.1016/j.worlddev.2019.06.006 6. https://doi.org/10.1016/j.wdp.2019.02.002 7. https://doi.org/10.3390/su11195161 8. https://doi.org/10.1016/j.jup.2019.100930 9.https://doi.org/10.1016/j.esr.2019.03.005

			subsidy (7) and energy in Pakistan (8, 9)Highlights to enhance gender/social-inclusiveness: - Study assesses how changing roles make women wheat innovators in Nepal (10) - Ethiopian case studies highlight potential of gender audit to assess potential for gender research in NARS (11) and role of gender norms, agency and innovation in wheat-based systems and livelihoods (12) - review assesses the need for a gender focus in agricultural extension (13) - study assesses the role of caste in farmers' access to quality information in India (14) - Study untangles gender differentiated food security gaps in Bhutan (15)				
				2019 - Cross-regional assessment of the influence of gender norms and agency on men/women's capacity to innovate in WHEAT AFS-based livelihoods	Complete	5 papers + report 10. The European Journal of Development Research 31, 293-313 11. Gender, Technology and Development 23, 55-75. 12. Report 13. Journal of Gender, Agriculture and Food Security (Agri-Gender) 4, 1-10 14. PlosOne 14, e0210721 15. Review of Development Economics 23, 782-802	10.https://doi.org/10.1057/s41287-018-0153-4 11. https://doi.org/10.1080/09718524.2019.1616361 12.https://repository.cimmyt.org/handle/10883/19931 13.http://dx.doi.org/10.19268/JGAFS.422019.1 14. https://doi.org/10.1371/journal.pone.0210721 15.https://doi.org/10.1111/rode.12566

	FP1 Outcome: 1.9 Last mile provider (extension partners, farmers organizations, community-based organizations, private sector) increased access and promotion of technologies to farmers	Increase capacity of beneficiaries to adopt research outputs	Market/value chain development refines the understanding of agri-food systems and develops a strategic nutritional agenda for WHEAT to support identification of priorities and effective interventions. Highlights of markets/value chain studies to enhance last mile linkages: - Using Mexico as case study research examined consumer access to processed wheat products in high and low income areas of Mexico City and consumers' willingness to pay for healthier bread in low income areas (papers submitted, under review). - Book provides comprehensive assessment of the seed system and its political economy in Morocco (1). - Using case of blast resistant BariGom 33 in Bangladesh study documented its development process and scaling implications (2). - Two studies looked at input supply dimensions – including willingness to pay for scale-appropriate mechanization in Nepal (3) and the role of fertilizer traders as agricultural extension agents in Bangladesh (4). - Study assesses value chain losses for wheat in Jordan (5). - Study assesses gender-differentiated impacts of food market shocks in Bangladesh (6)- Ongoing review with visiting fellow assesses	2019 - Selected WHEAT value chain studies to support identification of priorities and effective interventions	Complete	6 journal papers + 1 book + 1 bookchapter 1. Book 2. Acta Agrobotanica 72 3. Technology in Society 59, 101196 4. Agricultural Water Management 222, 242-253 5. Journal of Agribusiness in DevelopingEmerging Economies 9, 109-124. 6. Food Security 11, 1009-1027 7. Women's Studies International Forum 76, 102272 8. Bookchapter	1.https://hdl.handle.net/20.500.11766/8505 2.https://doi.org/10.5586/aa.1775 3.https://doi.org/10.1016/j.techsoc.2019.101196 4.https://doi.org/10.1016/j.agwat.2019.05.038 5.https://doi.org/10.1108/JADEE-08-2017-0078 6.https://doi.org/10.1007/s12571-019-00962-7 7.https://doi.org/10.1016/j.wsif.2019.102272 8.https://doi.org/10.1016/B978-0-08-100596-5.21540-0

			nutritional opportunities for WHEAT (in progress for 2020)				
FP 2	FP2 Outcome: 2.4 Crop researchers world-wide increased use of novel germplasm and tools for validation, refinement and development of products	Adoption of CGIAR materials with enhanced genetic gains		2019 - Phenotypic, genotypic, and genealogical data from the previous three years published for novel germplasm in accordance with the data management policy			
				2019 - Gene editing successfully implemented for Lr67 and/or MLO genes to develop tolerance to wheat diseases			
				2019 - Novel diversity available for yield potential, drought and heat tolerance in lines from crossing bank accessions with elite lines			
				2019 - Demonstrated use of genomic prediction to save			

				phenotyping costs via 'sparse testing'			
	FP2 Outcome: 2.5 Breeders develop improved varieties more efficiently through greater access and use of documented germplasm and tools	Adoption of CGIAR materials with enhanced genetic gains		2019 - Centralized breeding data management system and associated tools deployed to provide breeding teams with better access to germplasm, genealogical, and phenotypic data			
				2019 - Centralized genotypic data management system deployed to provide breeding teams with better access to genotypic data			
				2019 - The effects of Mendelian sampling in cross performance evaluated using phenotypic and genomic data from lines, crosses, and their progeny			
3	FP3 Outcome: 3.2 Partner breeding teams increased multidisciplinary and multi-	Enhanced institutional capacity of partner research organizations	CIMMYT and ICARDA shared 1000 improved spring and winter bread wheat and durum wheat candidate varieties to over 200 National partners in 60 countries through international trials and nurseries for growing during	2019 - sustainable seed system optimised in 2-3 countries (pilots, with scaling-out potential)	Extended	Progress on scaling wheat technologies in Sub-Saharan Africa: TAAT-Wheat Compact; heat-tolerant varieties deployed as basic,	Early warning system involves daily automated data flow between two continents during wheat season in Ethiopia. The framework utilises expertise and environmental research infrastructures from biology, agronomy, meteorology, computer science and

	institutional collaboration		the 2019-20 crop season. Partners completed growing of wheat trials and nurseries received during 2018-19 crop season. Multi-site within country and across country data analysis identified superior yielding wheat lines with disease resistance and quality. Partners retained the selected wheat lines for further testing as required in each country for the release of variety for cultivation by farmers. Also selected wheat lines are being used by partners in their own breeding program. From previously provided wheat lines at least 50 new varieties were released by partners in key wheat growing countries in Asia, Africa and Latin America. Partners have also multiplied several tons of seed and provided to seed multiplication agencies. The Turkey-CIMMYT-ICARDA led winter wheat breeding program will close down in 2020 due to insufficient funding. This will affect the provision of new candidate varieties for East and Central Asia region.			certified and quality-declared seeds came to 30,500 MT for Sudan, 25,438 MT for Ethiopia, 7,600 MT for Nigeria, plus over 2,000 MT for 6 other countries. Farmers in Nigeria grew 500,000 hectares of wheat within the last three years. Seed production is continuous exercise and task is too large in wheat, as more than 80% seed moves from farmers to farmers.	telecommunications. Successfully provided timely information to assist policy makers to decide about allocation of limited stock of fungicide during the 2017 and 2018 wheat seasons.
				2019 - pest, disease-resistant varieties adopted and less chemicals used in 3-6 target countries/sites	Complete	New disease resistant varieties are released each year by National partners. The milestone is therefore recurring each year. A total ofat least 50 new varieties, directly selected from CG germplasm, released in different countries. https://repository.cimmyt.org/bitstream/handle/1	List of new released varieties in each partners country is available. We are in the process of creating a link to this file. Map of varieties will be included in 2019 Annual Report.

						0883/19854/59968.pdf?sequence=1&isAllowed=y" style="color: rgb(169, 169, 169); outline: 0px; (Ethiopia since 2010: Variety development, adoption see pp.25, 28-30)	
	FP3 Outcome: 3.3 Partner breeding teams improved breeding processes by adopting new technologies, methodologies, approaches and genetic resources	Adoption of CGIAR materials with enhanced genetic gains	New functional and linked molecular markers validated and KASP markers used by breeding program. Major meta-GWAS analysis conducted and genomic regions associated with various traits identified in CIMMYT wheat breeding programs. High-throughput phenotyping being done routinely at some breeding and testing sites, however use of UAV is becoming difficult due to restrictions posed by countries.	2019 - broad genetic-based germplasm resistant/ tolerant to pests, diseases predicted to become worse with climate change	Complete	Several journal articles published in 2019 documenting the progress. As continuous improvement and knowledge generation is required, we shall be delivering new information each year for improving breeding process.	Some Peer Review Publications documenting the evidence are: 10.15302/JFASE-201926810.1007/s10681-019-2449-7; 10.3389/fpls.2019.00782; DOI: 10.1094/PDIS-05-19-0985-RE; DOI:10.1007/s00122-019-03362-9; DOI: 10.1038/s41588-019-0496-6; DOI: 10.1007/s00122-018-3206-3; DOI: 10.1534/g3.118.200856; DOI:10.3389/fpls.2019.01189; DOI:10.1094/PDIS-10-19-2198-RE
	FP3 Outcome: 3.4 CRP commodities enhanced engagement in joint lobbying for speeding-up release of improved varieties	Increased capacity for innovations in partner research organizations	Rust epidemic in Ethiopia led to faster variety release process. Some cross-border collaboration on release/certification (ASARECA, SADC) - small (!) successes. In general, WHEAT works on this to the greatest extent possible within the limitations of each countries' variety release processes. WHEAT scientists work with national programs and government agricultural and crop representatives on an ongoing basis to ensure that their variety release process is agile enough to respond to emerging pests and diseases, in line	2019 - fully operational, integrated network of 15 precision phenotyping platforms, germplasm exchange between NARS platforms	Extended	See WHEAT Annual Report section 2.2.1 on precision phenotyping platforms: Precision Wheat Phenotyping Platforms (PWPP). WHEAT and co-investing national partners managed 7 platforms, which China joining during 2019. # of platforms not as high as targeted, because W12 co-funding limited and	See WHEAT Annual Report section 2.2.1 on precision phenotyping platforms. Project leader and platform leaderspresented global network concept at several conferences to raise awareness and interest to use the platforms.

			with the improved germplasm made available to them by WHEAT.			spreading such funds too thinly and too briefly would be counterproductive. 'Model' precision phenotyping platform is based on Obregon.	
	FP3 Outcome: 3.6 National regulators of crop variety release improved enabling environment to speeding-up release of improved varieties	Reduced smallholders production risk	WHEAT works on this to the greatest extent possible within the limitations of each countries' variety release processes. WHEAT scientists work with national programs and government agricultural and crop representatives on an ongoing basis to ensure that their variety release process is agile enough to respond to emerging pests and diseases, in line with the improved germplasm made available to them by WHEAT.	2019 - national variety release process 1-3 years shorter in 2-4 WHEAT target countries	Extended	CGIAR more generally and WHEAT specifically have (very) limited influence on politics of national seed business and variety release process. With regard to wheat, key challenge is not legislative or political, but how to tap into farmer-to-farmer saved seeds networks, to encourage faster replacement of obsolete varieties. In general, an ongoing process in line with seed health regulations and variety release processes within each country.	Ad hoc success in Ethiopia, due to rust epidemic, as well as inBangladesh, with fast-track release of BariGom33, a wheat blast-resistant variety.
	FP3 Outcome: 3.7 Extension partners (universities, national/state/provincial governments)		Beyond the capacity of CRP FP3 as Seed Projects require large investment, have always been bilateral and emergency-driven (e.g. rust epidemic); also, public/private sector extension services very limited in many wheat-growing	2019 - improved, documented understanding of specific wheat seed systems (farmer's seed commercial	Extended	Achieving this milestone fully depends on scientists collaborating across FP1, 3 and 4, as well as on bilaterally funded projects with a	Ethiopia: Ongoing policy-maker level engagement to support sustainable self-sufficiency and better understanding smallholder coping mechanisms; ex ante innovative approaches to farmer improved seed

	increased access and promotion of adoption of improved varieties to farmers, and increased investment in emerging private sector circumstances		countries. In each of the target countries, seed production and commercialization being done by the public or private sectors, as soon as new varieties are released. Some cross-CRP and -FP learning generated (FP4-to-FP3) on role of agro-dealers.	behavior, seed demand and marketing, economics of seed production) / 2-3 NARES identified performance gaps, capacity development needs, to identify, realize relevant cap dev interventions at apt levels		multi-Flagship perspective, thus significant multi-year progress in Ethiopia, South Asia (CSISA), Morocco, Turkey, but not elsewhere.	use/adoption (FP34); understanding thepolitical economy of Morocco's seed sector;
	FP3 Outcome: 3.8 Farmer organizations increased access and promotion of adoption of improved varieties to farmers	Technologies that reduce women`s labor and energy expenditure adopted	Whilst farmer organizations play an important part in raising awareness and promotion of improved varieties and improving farmer access, up to now bilateral funding (CSISA, MasAgro, AIP, etc.) has been critical for farmer organizations to expand their role.	2019 - Improve consumer acceptability of high flour extraction rate and whole grain flour	Cancelled	Lack of W3 funding for the milestone and too specific, will instead be incorporated into a larger, diverse and healthy diet linked to whole grains-type milestone.	N/A
	FP3 Outcome: 3.12 Non-and-subsistence farmers adopted improved varieties	Reduce pre- and post-harvest losses, including those caused by climate change	DNA Fingerprint based adoption studies being planned to determine adoption of new varieties.	2019 - Greater farmer adoption of released varieties (based on CGIAR research) in specific WHEAT target countries, compared to 1994-2014 average	Extended	Current evidence (since 2014) is impressionistic and ad hoc. See Bangladesh/wheat blast, Ethiopia/rusts variety release and adoption mentioned in the milestones above. Longer-term assessments make the case for greater farmer adoption under specific circumstances: See OICR <strong xmlns="http://www.w3.o	Longer-term assessments with indirect evidence: Ex post, genetic gains impact assessment and by implication farmer adoption impacts: Impactof High Rainfall Wheat Screening Nursery (HRWYT) that go to more than 100 collaborators worldwide: This type of evaluation is imperative…, given that 70 % of cultivars grown in target countries are either direct CGIAR releases or used as parents (Lantican et al., 2016). … Grain yield analyzed data set from 2007 to 2016 at 360 locations in 53 countries. Study shows reliable genetic progress for GY over time when the data is expressed as genetic progress per se or as a

						rg/1999/xhtml">Screening operations in wheat rusts have led to the release of over 100 Ug99 resistantwheat cultivars globally over the last decade .	percentage of local checks. The trends observed in the high-rainfall environment were very consistent, exhibiting regression slopes highly significant (p ≤ 0.001) and genetic rates of 3.8 % and 1.17 % for genetic progress and local checks, respectively. Similar genetic progress per se has been observed in some countries located in high-rainfall environments.
				2019 - sustainable seed system optimised in 2-3 countries (pilots, with scaling-out potential)	Cancelled	Lack of W3 funding for the milestone.	N/A
4	FP4 Outcome: 4.4 NARS increased use of participatory approach in system research	Enhanced institutional capacity of partner research organizations	With a project portfolio allocating strong attention to participatory methods and farm-site specific management options, our NARS partners are increasingly adapting and adopting R4D methods which in turn increase the relevance and impact of their work.	2019 - Series of training workshops conducted in South Asia and North Africa (with ICARDA)	Extended	Workshop links (milestones) below are self-explanatory and have engaged a wide range of stakeholders/beneficiaries and partners ranging for ARIs, NARS, private sector, farmers.	https://csisa.org/traveling-seminar-on-scale-appropriate-machinery-brings-together-delegates-from-across-asia/ https://csisa.org/new-infographics-illustrate-impact-of-wheat-blast/ https://csisa.org/stempedia-model-fighting-blight-in-lentil-2/ https://csisa.org/digital-warning-system-boosts-resilience-in-bangladesh-brazil/ https://csisa.org/new-policy-brief-highlights-opportunities-to-promote-balanced-nutrient-management-in-south-asia/ https://drive.google.com/open?id=1uxkw2vLMyRu8YKU8hU2h_NTbfJmtJI1E https://drive.google.com/open?i=1ZzA2Q5s07pSwQ7fTq7wYHnQ0gx9yD71 Numerous training occurred in 2019 and covered at https://idp.cimmyt.org/ CAPDEV KPIs

							are reported by all staff in https://academy.cimmyt.org/ If need be additional info can be obtained on request https://www.cimmyt.org/content/uploads/2019/07/Advanced-Course-on-CA-Asia-North-Africa-Brochure-2019-Revised-dates.pdf For FP4 ICARDA/CIMMYT CAPDEV collaboration further info can be obtained from IFAD CLCA project. Also see on-going training efforts on scaling https://www.cimmyt.org/news/scaling-to-new-heights-in-agriculture/
	FP4 Outcome: 4.8 Actors in SI increased consideration and integration of gender and social inclusion into policies, processes and practices.	Technologies that reduce women`s labor and energy expenditure adopted	Research conducted since inception of CRP Phase II on gender and social inclusion has produced to key knowledge generation on SI options and management practices improving work drudgery, well-being...	2019 - increased adoption of combinations of SI strategies, technologies in specific target geographies compared to 2016	Extended	Several key studies were published in peer-reviewed journals and on-going efforts are deployed to use those evidence to positively influenced development efforts and policy related issues.	Baudron, F. et al., 2019. A farm-level assessment of labor and mechanization in Eastern and Southern Africa. Agron. Sustain. Dev. 39, 17. https://doi.org/10.1007/s13593-019-0563-5 Paudel, G.P., KC, D.B., Rahut, D.B., Justice, S.E., McDonald, A.J., 2019. Scale-appropriate mechanization impacts on productivity among smallholders: Evidence from rice systems in the mid-hills of Nepal. Land use policy 85, 104–113. https://doi.org/https://doi.org/10.1016/j.landusepol.2019.03.030 CSISA Phase II annual report: https://drive.google.com/file/d/1jPGZ66oxNiHIUmg7hdkzWZpJrPhDwCKh/view?usp=sharing
				2019 - strengthened ability to synthesize and apply available knowledge related to SI oriented research methodologies (multi-criteria assessments),	Complete	FP4 has been extremely productive generating peer reviewed syntheses paper in 2019. Knowledge and technologies documented in those papers are key for	Aryal, J.P et al., 2019a. Learning adaptation to climate change from past climate extremes:: Evidence from recent climate extremes in Haryana, India. Int. J. Clim. Chang. Strateg. Manag. https://doi.org/10.1108/IJCCSM-09-2018-0065 Balwinder-Singh, et al, 2019a. Taking the climate risk out of transplanted and direct

				management practices, technologies, machinery, in 10-15 partner orgs (Bangladesh, Nepal, Pakistan, India, Mexico, Ethiopia, Rwanda)		targeting and scaling SI technologies and management practices	seeded rice: Insights from dynamic simulation in Eastern India. F. Crop. Res. 239, 92–103. https://doi.org/https://doi.org/10.1016/j.fcr.2019.05.014 Balwinder-Singh, McDonald, A.J., Srivastava, A.K., Gerard, B., 2019b. Tradeoffs between groundwater conservation and air pollution from agricultural fires in northwest India. Nat. Sustain. 2, 580–583. https://doi.org/10.1038/s41893-019-0304-4 Datta, A., et al,, 2019. Carbon mineralization in soil as influenced by crop residue type and placement in an Alfisols of Northwest India. Carbon Manag. https://doi.org/10.1080/17583004.2018.1544830 Gathala, M.K., et al, B., 2019. Energy-efficient, sustainable crop production practices benefit smallholder farmers and the environment across three countries in the Eastern Gangetic Plains, South Asia. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2019.118982 Gebru, A.A. et al, 2019. IMPLEMENTATION of PERMANENT RAISED BEDS CONTRIBUTES to INCREASED CROP YIELD and PROFITABILITY in the NORTHEASTERN TIGRAY REGION, ETHIOPIA. Exp. Agric. 55, 807–817. https://doi.org/10.1017/S001447971800039X Groot, A.E., et al, 2019. Business models of SMEs as a mechanism for scaling climate smart technologies: The case of Punjab, India. J. Clean. Prod. 210, 1109–1119. https://doi.org/10.1016/j.jclepro.2018.11.054 Islam, Saiful, et al, 2019. Conservation agriculture based sustainable intensification: Increasing yields and water productivity for smallholders of the Eastern Gangetic Plains. F. Crop. Res. 238, 1–17.

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	FP4 Outcome: 4.9 Smallholder farmers increased their capacity to adopt and adapt SI practices and products (associated with crosscutting sub-IDO).	Increased access to productive assets, including natural resources	Capacity of smallholder to adopt and adapt SI practices have been the main focus of CSISA, SRFSI, and MASAGRO. It comprises development and diffusion of adapted knowledge products, participatory research, and close collaboration with national extension services and other development partners	2019 - Farmers in 2 WHEAT (irrigated) target regions, using most water-efficient cultivars and optimum agronomy and irrigation systems, achieve water use efficiency of ca 450 l/ kg grain can be achieved (50% water saving over 2015)	Complete	CSISA, MasAgro, SRFSI are extending in 2020 and while some components are more strategic and focused on syntheses there still will be a significant activities related CapDev of farmers involved.	https://csisa.org/technical-publications/ https://csisa.org/newsroom/videos/ https://csisa.org/resources/csisa-phase-i-baseline-data/ https://www.cimmyt.org/projects/sustainable-and-resilient-farming-systems-intensification-in-the-eastern-gangetic-plains-srfsi/ https://idp.cimmyt.org/ https://www.cimmyt.org/work/integrated-development/ https://drive.google.com/file/d/1mPu7ebB99TRuQ4ojIziZRqVBR_L5HaG/view?usp=sharing

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	FP4 Outcome: 4.6 Private sector (and public sector) increased provision of services to smallholder farmers to increase their ability to adopt SI practices and products	Increase capacity of beneficiaries to adopt research outputs	In Mexico several initiatives were taken to with private sector interactions to develop responsible sourcing to smallholder farmers.In South Asia, private sector interactions focused on the development and improvement of service provision related to farm mechanization. WHEAT was central to scale Happy Seeder and Straw Spread Management system on combine harvester in order to reduce rice crop residue burning in North West India. In Bangladesh CSISA-MI have notably expended they reach to small service providers using 2 WT. CSISA-MI was funded last year and will further focus on private sector contribution ustream of farm service provision.	2019 - improved skills and capacities of farmers and extension workers necessary to manage innovation, extension networks	Complete	Large impact of private sector engagement in mechanisation in South Asia presently documented. Responsible sourcing work is further developing in Mexico	http://crreport.kelloggcompany.com/2018-CR-Report-Nurturing-The-Planet https://www.cgiar.org/news-events/vacancy/responsible-sourcing-and-inclusive-farmer-market-linkages-specialist/ CSISA MI: https://drive.google.com/file/d/1mU5lMuC9Z1aeEbHpTldp0vCdjqE06SGc/view?usp=sharing Mottaleb, K., 2019. Understanding clients, providers and the institutional dimensions of irrigation services in developing countries: A study of water markets in Bangladesh. Agric. Water Manag. 222, 242–253. https://doi.org/https://doi.org/10.1016/j.agwat.2019.05.038 Balwinder-Singh, et al, 2019b. Tradeoffs between groundwater conservation and air pollution from agricultural fires in northwest India. Nat. Sustain. 2, 580–583. https://doi.org/10.1038/s41893-019-0304-4 Shyamsundar, P., et al, 2019. Fields on fire: Alternatives to crop residue burning in India. Science (80-.). 365, 536–538.

	FP4 Outcome: 4.10 Smallholder farmers adopted and adapted SI practices and products	Closed yield gaps through improved agronomic and animal husbandry practices	SI Technologies and improved practices are increasingly adopted by farmers within and beyond projects. In order to properly document FP1 has developed an ex post SI assessment framework that is currently tested in few locations and further be deployed in 2020 and 202. Major effort on scaling methodologies took place in 2019	2019 - Smart mechanization lessons learnt routinely applied in other FP4 projects	Complete	Strong global community of practice is now in place in CIMMYT to contribute to include smart mechanization options in new project from design phase.	Refer to work exchange with FAO and GIZ during 2019
				2019 - Continuous scaling up and out through W3 projects in all wheat regions	Extended	FP4 Scaling team has developed a strong community of practice and is helping designing new projects with a more robust scaling plans but also assisting on-going projects to improve their scaling strategy and its implemenation	https://www.cimmyt.org/research/sustainable-intensification/scaling/ https://ppplab.org/2018/11/3223/ Woltering, L., et al., 2019. Scaling – from “reaching many” to sustainable systems change at scale: A critical shift in mindset. Agric. Syst. 176. https://doi.org/10.1016/j.agsy.2019.102652

Table 6: Numbers of peer-reviewed publications from current reporting period

	Number	Percent
Peer-Reviewed publications	112	100.0%
Open Access	39	34.82%
ISI	73	65.18%

Separate Evidence table with full listing of 2019 publications.

Table 7: Participants in Capacity Development Activities

Number of trainees	Female	Male
In short-term programs facilitated by CRP	2,793	10,277
In long-term programs facilitated by CRP	784	2,241

Degrees awarded in 2019	Female	Male
PhD	12	12
MsC	6	4
Bachelor	7	11

Please note that 2019 numbers for Table 7 are generally lower than 2018, as a result of CIMMYT’s transition to a new system for Capacity Development management and reporting, the “Learning Management System (LMS)”. Non- and mis-reporting should be minimal for 2020 annual reporting.

Table 8: Key external partnerships

Lead FP	Brief description of partnership aims (30 words)	List of key partners in partnership	Main area of partnership
FP1	Collaboration on crop modeling for foresight/targeting and gender/social inclusiveness.	• WUR - Wageningen University and Research Centre	• Capacity Development • Research
FP1	Collaboration on rethinking adoption	• IDS - Institute of Development Studies	• Research
FP2	Precision Phenotyping Platforms- WHEAT and co-investing national partners managed seven platforms, with China joining in 2019.	• JAAS - Jiangsu Academy of Agricultural Sciences • INIAF - Instituto Nacional de Innovación Agropecuaria y Forestal • INRA - Institut National de la Recherche Agronomique (Morocco)	• Research
FP3	CIMMYT Henan Innovation Centre	• HAU - Henan Agricultural University • NSF - National Science Foundation (United States) • CAAS - Chinese Academy of Agricultural Sciences	• Research
FP3	International Conference on Wheat Diversity and Human Health	• FAO - Food and Agriculture Organization of the United Nations • TAGEM - General Directorate of Agricultural Research and Policies	• Research
FP3	G20 WHEAT Initiative- WHEAT scientists participated in most of the 11 Expert Working Groups of the G20 Wheat Initiative, the only crop-focused initiative to coordinate and prioritize international research	• G20WI - G20 Wheat Initiative	• Research
FP4	A global team including WHEAT scientists compared the costs and benefits of 10 distinct land preparation and sowing practices for northern India’s rice-wheat cropping rotations	• TNC - The Nature Conservancy • ICAR - Indian Council of Agricultural Research • BISA - Borlaug Institute for South Asia • University of Minnesota	• Research

Table 9: Internal Cross-CGIAR Collaborations

Brief description of the collaboration	Name(s) of collaborating CRP(s), Platform(s) or Center(s)	Optional: Value added, in a few words
Synergies and collaborative work on gender/social inclusiveness; input into new platform	Gender	scientific benefits; resource pooling
Co-funded collaborative work on processed wheat and food systems in Mexico	A4NH	scientific benefits; resource pooling
Synergies re-enforcing role of monitoring and big-data	Big Data	scientific benefits; resource pooling
Synergies and collaborative work on foresight and targeting (PIM FP1); seed systems (PIM FP1); rural transformation (PIM FP2), markets/value chains (FP3) and out-migration/feminization (PIM FP6)	PIM	scientific benefits; resource pooling
Synergies and collaborative work on foresight and targeting (CoA1); adoption/impact (CoA1.2); gender/social inclusiveness (CoA1.3) and markets/value chains (CoA1.4)	Maize	scientific benefits; resource pooling
MAIZE, WHEAT, Excellence-in-Breeding: A functional Enterprise Breeding System ("EBS") version 1 was deployed at CIMMYT for use by maize and wheat breeders. Germplasm data migration will be completed in 2020. Early adopter breeders participate in the ongoing software development process to ensure viability and compatibility. Though delayed into 2020, ICARDA and IITA breeders will be able to start using EBS in 2020.	Maize, EiB	Efficiency benefits
New collaborative research by Indian NARS (Chaudhary Charan Singh Haryana Agricultural University -CCSHAU, ICAR) and CIMMYT, supported by WHEAT, CCAFS and Bayer CropScience finds, in addition to the CA benefits to yield, water, income, and soil, each hectare of CA-based sustainable intensification can help meet the protein requirements of eight additional persons, compared to a conventional system.	CCAFS	Scientific benefits
WHEAT provided $200k to CIMMYT and ICARDA genebanks improvement projects, linked to a Genebank Platform performance assessment and external review of operations. Ongoing in 2020.	Genebank	More efficient and higher quality genebank operations
In addition to ongoing field research and innovation platform (Climate Smart Villages) collaboration, WHEAT, together with all other CRPs, engaged in further co-development of the '2 Degrees Initiative'.	CCAFS	2022+ CGIAR research program design focused on climate change mitigation and adaptation

Table 10: Monitoring, Evaluation, Learning and Impact Assessment (MELIA)

Studies/learning exercises planned for this year (from POWB)	Status	Type of study or activity	Description of activity / study	Links to MELIA publications
S1271 - Impact assessment of the project	Completed	EPIA: Ex-post Impact assessment	**verify farmer adoption of rust-resistant improved varieties in 54 woredas in Ethiopia.**	
S1291 - Report on wheat blast surveillance and monitoring efforts in Bangladesh: Towards early warning systems	On Going	Other MELIA activity	Project is based in Bangladesh. Nepali scientists were also trained in surveillance and monitoring.	
S1571 - Meta-analysis of wheat adoption studies	Extended	Synthesis (secondary) study	None	
S1581 - Adoption of sustainable intensification technology in the wheat-growing area of India	Extended	Ex-post adoption study	In partnership with The Nature Conservancy, verify on-farm impact of joint research and advocacy work (no burning).	
S2471 - Comparative advantage of smallholder wheat production in Tanzania and Mozambique	Completed	Synthesis (secondary) study	Scoping study based on focus group discussion with wheat smallholder farmers in Tanzania and Mozambique	
S2503 - Dynamics of Social Inclusion through mechanized service provision	On Going	EPIA: Ex-post Impact assessment	n/a	
S2504 - Assessing the influence of risk-reducing agronomy and technology targeting on the uptake of DSR	On Going	Ex-post adoption study	n/a	
S2513 - Strengthen South-South cooperation	On Going	Synthesis (secondary) study	Concerns appropriate-scale mechanization. Synthesis study to learn from experiences in 10 countries (S Asia, Africa, Mexico).	
S3243 - DNA Fingerprinting for Tracking Bread Wheat Varieties in Ethiopia: Policy Implications	Completed	Ex-post adoption study	Study quantifies the number of smallholder farmers who have adopted improved bread wheat varieties and the area coverage of the varieties.	

S3246 - Revitalizing the Durum Wheat Sub-sector in Ethiopia	Completed	Ex-post adoption study	This research contributes to quantifying the number of smallholders who adopted improved varieties.	
S3314 - Legume-based rotations have clear economic advantages over cereal monocropping in dry areas	Completed	Ex-post adoption study	Using two-year data, this study analyzed the economic viability of rotation in wheat-based systems. The study is unique as the analysis of gross margins is carried for the whole duration of the rotation cycle – shading new insights.	https://repo.mel.cgiar.org/handle/20.500.11766/10497
S3315 - Ethiopian Agricultural Extension - Where to go?	Completed	Program/project adoption or impact assessment	This RCT-based study analyzes the impacts of introducing improved extension service delivery and divisible quantities of certified seed on adoption of an improved variety of wheat.	https://hdl.handle.net/20.500.11766/10104
S3317 - Where in the value chain are we losing the most food? The case of wheat in Jordan	Completed	Program/project adoption or impact assessment	This study carried an estimation of the level of food loss and wastage across the entire wheat value chain from the farm to the fork. It found that the highest loss happens in the form of food waste at the households.	https://repo.mel.cgiar.org/handle/20.500.11766/10499

Table 11: Update on Actions Taken in Response to Relevant Evaluations

Not applicable. Tracking of 2014/15 Evaluations closed.

Table 12: Examples of W1/2 Use in this reporting period (2019)

	Strategic, longer-term research, seed invests	Rapid response (incl flexibility)	Cross-Portfolio, -CRP learning for impact	CRP Gov. & Mgmt.
FP1 See pp 6-7	Ex post adoption/impact studies Conservation Agriculture practices, Ethiopia, North Africa, South Asia Ex ante impact assessment Biological Nitrification Inhibition (ongoing) Position paper on nutritional priorities in cereal based Agri-food Systems	Ex-ante impact assessment of a new blast resistant wheat in Bangladesh	Collaboration with PIM on foresight Gender Integration Monitoring System GENNOVATE follow-up studies	WHEAT-ISC WHEAT-MC SMB CRPs Rep support CGIAR CoP participation
FP2 See pp 7	strategic genomic characterization of germplasm focusing on the remaining landraces and wild relatives; expand genetic characterization of pre-breeding material Assess usefulness of advanced machine learning techniques to predict phenotypes of genetic resources; screening for new alleles. HeDWIC resource mobilization		Data migration, curation support, software training for wheat scientists High throughput phenotyping methods developed and implemented Gene editing capacity expanded	
FP3 See pp 7--8	IWIN cooperators receive GCIAR wheat germplasm wheat pre-breeding & breeding germplasm evaluated for heat and drought; for quality traits Marker-assisted breeding Elite durum wheats available to cooperators for crossing and to NARS for release	Wheat blast, rusts resistance breeding	Co-funding with NARS: Precision phenotyping platforms (Morocco, Uruguay, China, Turkey) Innovative ideas competition / cross-Center & program Young scientists' training	
FP4 See pp. 8-9	R4D on biostimulants (continued) case studies on optimization of wheat-based farming systems using FarmDesign; Framework/methodology/protocol on remote sensing technology for in-season decision making on input use		2 Integrated AgriFood Systems Initiatives in advanced stages of development Scaling Scan: Integrate into projects Geospatial, remote sensing: Spatial framework, methods and tools, peer-reviewed publications Learning Management System (supports CIMMYT Academy)	

Table 13: CRP Financial Report

6649

CRP on Wheat	Planned budget 2019			Actual expenditure 2019*			Difference		
DESCRIPTION	W1/2	W3/bilateral	Total	W1/2	W3/bilateral	Total	W1/2	W3/bilateral	Total
FP1	1,796	1,465	3,261	1,459	1,303	2,762	338	162	500
FP2	3,172	4,708	7,880	2,426	3,656	6,082	746	1,052	1,798
FP3	6,649	14,404	21,053	5,328	9,863	15,190	1,322	4,541	5,862
FP4	2,129	11,365	13,493	1,789	9,387	11,177	339	1,977	2,317
Cap Dev	107	-	107	100	-	100	6	-	6
Any other main program planned budget outside FPs (if relevant)			-			-	-	-	-
CRP Management & Support Cost	2,283	-	2,283	1,384	-	1,384	899	-	899
TOTAL by Flagship	**16,135**	**31,941**	**48,077**	**12,486**	**24,209**	**36,695**	**3,650**	**7,732**	**11,382**
Less CGIAR Collab Costs:									
FP1	260		260	260	-	260	-	-	-
FP2	620		620	645	-	645	(25)	-	(25)
FP3	1,338		1,338	1,262	-	1,262	76	-	76
FP4	325		325	325	620	945	-	(620)	(620)
Cap Dev	75		75	44	-	44	31	-	31
any other main program planned budget outside FPs (if relevant)			-			-	-	-	-
CRP Management & Support Cost	130		130	150	-	150	(20)	-	(20)
TOTAL CGIAR Collaborators	**2,748**	**-**	**2,748**	**2,686**	**620**	**3,306**	**63**	**(620)**	**(558)**
Total CRP on Wheat (Net without CGIAR Collaborators)	**13,387**	**31,941**	**45,329**	**9,800**	**23,589**	**33,389**	**3,587**	**8,352**	**11,939**

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