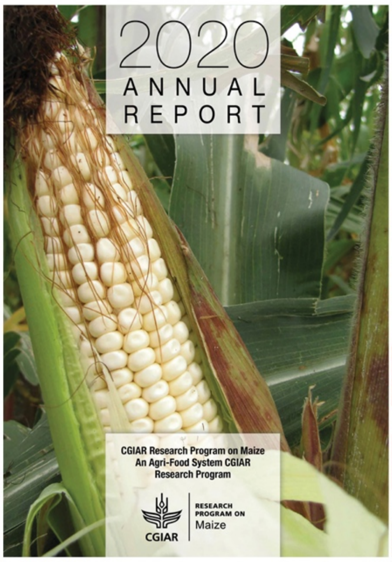
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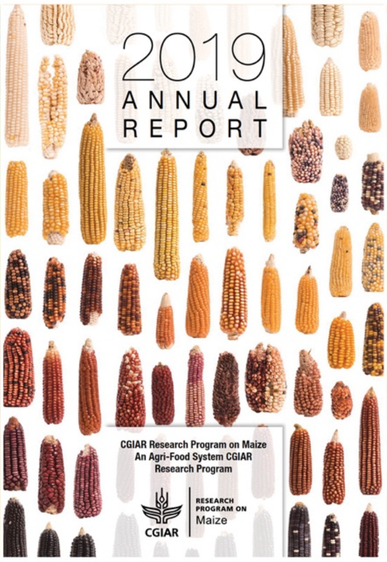
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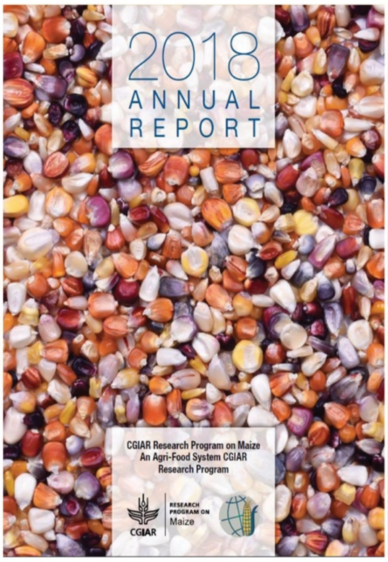
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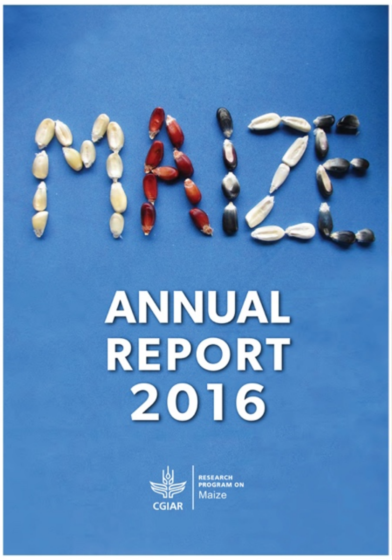
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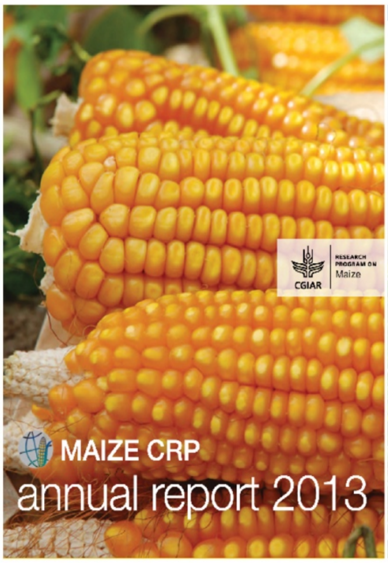
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Acronym list

CGIAR System Institutions and Processes

AFS	Agri-food systems
AGG	Accelerating Genetic Gains in Maize and Wheat
A4NH	CGIAR Research Program on Agriculture for Nutrition and Health
CASI	Conservation Agriculture for Sustainable Intensification
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CGIAR	A global research partnership for a food-secure future
CIMMYT	International Maize and Wheat Improvement Center
CoA	Cluster of Activity
CSISA	Cereal Systems Initiative for South Asia
CRP	CGIAR Research Program
DTMA	Drought Tolerant Maize for Africa
EiB Platform	Excellence in Breeding Platform
EMT	Executive Management Team
FCDO	Foreign, Commonwealth & Development Office
FP	Flagship project
GENNOVATE	Global Comparative Gender Norms Research Initiative
Harvest Plus	A program that is part of the CGIAR Research Program on Agriculture for Nutrition and Health
HIC	Higher Income Country
IA	Impact Assessment or Intellectual Asset
IDO	CGIAR Intermediate development outcome
IEA	Independent Evaluation Arrangement
IITA	International Institute of Tropical Agriculture
IMIC-Africa	International Maize Improvement Consortium Africa
IMIC-Asia	International Maize Improvement Consortium Asia
IMIC-LATAM	International Maize Improvement Consortium Latin America
ISC	Independent Steering Committee
LMICs	Lower-and Lower-Middle Income Countries
MAIZE	CGIAR Research Program on Maize Agri-food Systems
MARLO	Managing Agricultural Research for Learning and Outcomes
MC	Management Committee
MEL	Monitoring, Evaluation & Learning
MEL CoP	Monitoring, Evaluation & Learning Community of Practice
MELIA	Monitoring, Evaluation, Learning and Impact Assessment
OICR	Outcome impact case report
OPV	Open Pollinated Varieties
POWB	Plan of Work and Budget
R4D	Research-for-Development
SIMLESA	Sustainable Intensification of Maize and Legume Systems for Food Security in Eastern and Southern Africa
SLO	System Level Outcome
SMB	System Management Board
SMO	System Management Office
SRF	Strategy and Results Framework
STMA	Stress Tolerant Maize for Africa
TAMASA	Taking Maize Agronomy to Scale in Africa
ToC	Theory of Change
W1, W2, W3/bilateral	CGIAR Windows 1, 2 and 3/bilateral
WHEAT	CGIAR Research Program on Wheat Agri-food Systems

Research and Development Partners

AFSTA	African Seed Trade Association
BARI	Bangladesh Agricultural Research Institute
CAAS	Chinese Academy of Agricultural Sciences
DArT	Diversity Arrays Technology, Australia
DR&SS	Department of Agricultural Research & Support Services (Zimbabwe)
ICAR	Indian Council of Agricultural Research
EIAR	Ethiopian Institute of Agricultural Research
FCDO	Foreign, Commonwealth & Development Office, UK
ICTA	Agricultural Science and Technology Institute
JHI	James Hutton Institute, UK
INIFAP	Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (Mexico)
KALRO	Kenya Agricultural & Livestock Research Organization
KIT	Royal Tropical Institute, the Netherlands
NARC	Nepal Agricultural Research Council
NARO	National Agricultural Research Organization, Uganda
USAID	United States Agency for International Development
WUR	Wageningen University, the Netherlands

Miscellaneous

AIPs	Agricultural Innovation Platforms
CA	Conservation agriculture
CSA or CSAPs	Climate smart agricultural practices
DH	Doubled haploid
DTMV	Drought Tolerant Maize Varieties
DOI	Digital Object Identifier
DT	Drought tolerant
FAW	Fall armyworm
GP	Genomic Prediction
GS	Genomic selection
IP	Intellectual Property
ISI	International scientific indexing
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
MLN	Maize lethal necrosis
M&E	Monitoring and Evaluation
NARS	National agricultural research system
QTL	Quantitative Trait Locus
SNP	Single Nucleotide Polymorphism
SSA	Sub-Saharan Africa
SDGs	Sustainable Development Goals
WTP	Willingness to pay
Zn	Zinc

Statistical analysis applications

CERES-Maize	Crop model. Part of the Decision Support System for Agro technology Transfer

COVER PAGE

Name of the CRP: MAIZE
Name of the Lead CGIAR Center: International Maize and Wheat Improvement Center (CIMMYT)
Flagship lead institutions (CGIAR Centers or lead partners)
Flagship 1: CIMMYT & IITA
Flagship 2: CIMMYT & IITA
Flagship 3: CIMMYT & IITA
Flagship 4: CIMMYT & IITA

Other participating CGIAR Centers: IITA, plus key partners: **ICAR (India), IDS (UK), KIT (NL), DArT (AU), JHI (UK), Bayer, Corteva Agriscience, Syngenta, KALRO (Kenya), NARO (Uganda), EIAR (Ethiopia), DR&SS (Zimbabwe), NARC (Nepal), BARI (Bangladesh), INIFAP (Mexico), African Seed Trade Association (ASTA) and WUR (NL).**

A complete list CRP partners is available here.

Acknowledging our funders:

In **2021, MAIZE received US$2.08M W2** support from Australia (ACIAR) and UK (FCDO) and $7M W1 from Australia, Belgium, Canada, France, India, Japan, Korea, Netherlands, New Zealand, Norway, Sweden, Switzerland, UK and the World Bank. Total new W1&2 income was $9.08M, up from $8.543M (2020). As in 2020, USAID shifted earlier W2 contributions to W3, linked to the AGG and Crops to end Hunger bilateral projects. Bilateral funder support is documented in the MAIZE Annual Financial Report and in the **CGIAR Financial Dashboards.**

EXECUTIVE SUMMARY

Part A: NARRATIVE SECTION

Maize is projected to overtake wheat as the most widely grown crop in the world in the coming decade. By 2030, researchers project there will be 227 million maize farms globally, a 5% increase over 2020 figures (Erenstein et al., 2021). While the low and lower-middle Income countries (LMICs) have more than four times as many farms and twice the rural population as high-Income countries (HIC), they have half the agricultural area and an average farm size one tenth of that of HICs. Only 32% of maize is produced in the LMICs. These farm number estimates and the associated indicators merit more attention in efforts towards global sustainable development and economic and rural transformation - *see MELIA 4457.*

One fact remains clear: Farms will remain the foundation of rural development. The CGIAR Research Program on Maize (MAIZE) not only carried on its diverse portfolio of R4D work to benefit resource constrained smallholders in the world's tropical and subtropical regions through its final operating year, it has guided foresight and targeting processes for the recently launched OneCGIAR Initiatives and the redesigned research portfolio.

CGIAR's 50 years of investment in research on abiotic stress tolerance underwrote significant yield gains and the development of genetic sources of stress tolerance and disease resistance used by national maize breeding programs (*Byerlee and Edmeades 2021, p.18*). By 2020, over 230 improved *hybrid and open-pollinated v*arieties (OPVS) with drought tolerance and other key adaptive traits were released, and many were rapidly adopted by smallholders (*Byerlee and Edmeades, p.17*). Combining tolerance to abiotic stresses, Striga and major maize diseases resulted in further adoption of improved varieties. In 2015, the aggregate yearly economic benefits of using CGIAR-related maize varieties released after 1994 were estimated to be between US$ 0.66-1.05 billion, after accounting for the CGIAR parentage share (i.e. *80.5%; Krishna et al., 2021, p.vi*) - *see SLO 1.1, Table 1.*

During 2011-2021 MAIZE and partners focused on Conservation Agriculture-based (CA) Climate-smart Agriculture (CSA) innovations in southern Africa in a systematic, rather than a single commodity technology approach. They generated scientific evidence and enhanced local stakeholders' capacity, which informed policy change by several governments towards smallholders' sustainable intensification (see *feasibility study confirming business case*) - *see Table 3, OICR4479*.

MAIZE and its lead Center CIMMYT were key knowledge providers to the Government of Zimbabwe for its "Pfumvudza" scaling concept. *By July 2021, the Ministry of Agriculture announced it had reached 2.2 million farmers,* which made the country food secure for the first time in several decades. This success prompted the government to engage MAIZE and CIMMYT in an Alliance on Smallholder Mechanization, which aims to help 1 million smallholders access mechanization services by 2025. Adoption of CSA practices *in Malawi,* Zambia, and Zimbabwe positively impacted farmers' food security and household income. To date, farmers have adopted CA systems in the three countries *on >627,000 ha* (Kassam et al., 2019); and *more than 3 million farmers have benefited from large governmental investment*. Studies have shown that the impact of adoption was positive and significant - *see SLO 1.1, Table 1*.

MAIZE and its partners looked at interactions between farmers and agro-dealers and their impact on maize seed choices, challenges faced by retailers and seed companies to expand maize hybrids sales, and the effects of remoteness and competition on seed prices and choice (Rutsaert, P et al., 2021). This multi-year research has generated growing donor and investor interest in seed marketing and distribution research – *see Table 3, (4465).*

MAIZE and WHEAT researchers also published findings based on gender-transformative research and methods with clear policy implications for Ethiopia, Malawi and Tanzania, underlining the significant gender gaps associated with agricultural technologies' adoption. In gender-intentional maize breeding in sub-Saharan Africa (12: 2021,),MAIZE researchers evidenced gender-differentiated preferences for maize varieties and proposed changes in research approaches and priorities.

Part A: Impacts of Covid-19 on farming systems

MAIZE scientists carried out qualitative research to understand the immediate impacts of COVID-19 and governments' response on farming systems in Central America and Mexico. They found that larger corporate farming systems (with vertical market integration and high levels of control or coordination within the supply chain), as well as smallholder or subsistence farming systems (focused on production for self-consumption and with little external input use), were both relatively less impacted and showed greater adaptive capacity than the medium and small entrepreneurial farming systems, which are dependent on agriculture as their primary income and have less control over the upstream and downstream parts of their supply chain.

In Asia, researchers employed a mixed-methods approach to assesses the initial responses of major farming and food systems to COVID-19 in 25 countries. The study found that rural livelihoods and food security were affected primarily because of disruptions to local labor markets (especially for off-farm work), farm produce markets (notably for perishable foods), and input supply chains (i.e., seeds and fertilizers). The overall effects on system performance were most severe in the irrigated maize wheat-based system and least severe in the hill mixed system, the latter case being associated with greater resilience and diversification and less dependence on external inputs and long market chains.

1. Key Results

1.1 Progress Towards SDGs and SLOs

Sustainable Intensification: In sub-Saharan Africa, the average adoption rates of various Sustainable Intensification (SI) technologies varied from 23% (soil and water management practices) to 48% (organic fertilizers). These figures include both CGIAR-led (e.g., DTMA, SIMLESA) and non-CGIAR efforts (Jones-Garcia, et al., 2021). The environmental benefits of sustainable intensification were found to be substantial. However, studies fail to question the suitability of a given technology for the underlying sociocultural and agroecological realities - *see Table 1, SLO 1.1*

Long-term maize breeding research impacts in Nepal: Using the economic (producer and consumer) surplus approach, NARS scientists estimated the internal rate of return (IRR) on maize research in Nepal over the last 20 years to be 87%. Farmers planted modern varieties on 92% of the maize area in Nepal—nearly 24% of which were released after 2004 (Timsina, Krishna, et al., 2021). Average varietal age is 20.5 years. The majority of hybrids grown are CGIAR-derived. Within the past two decades, production and yield increased from 126,000 to 2,185,000 metric tons and 1.0 to 3.0 ton/ha respectively, due to introduction, development and release of CGIAR-derived varieties (MoALD, 2021)Significant challenges to closing the yield gap and reducing maize grain-for-poultry imports (US$130 million p.a.) remain; maize productivity, hybrid maize area, and seed replacement still remain below the projected figures in Nepal's' National Seed Vision – *see Table 1, SLO 2.1*

Successful management of MLN in Africa: MAIZE researchers continued their intensive efforts to help effectively manage maize lethal necrosis disease (MLN) in sub-Saharan Africa (Prasanna et al., 2020), including breeding and deploying MLN resistant improved maize varieties, administering a checklist for MLN-free commercial seed production, strengthening the capacity of national plant protection organizations for MLN diagnostics and surveillance, etc. MAIZE researchers also investigated the role of MLN infested soil in disease transmission, confirming the need for soil and residue management to effectively manage MLN. A comprehensive technical manual on MLN management was brought out for the benefit of stakeholders.

1.2 CRP Progress towards Outputs and Outcomes (spheres of control and influence)

1.2.1 Overall CRP progress

In 2021, MAIZE continued to progress on both of its research strategies: developing and deploying stress-resilient and nutritious maize varieties and supporting the sustainable intensification of maize-based farming systems.

In total, 65 improved maize varieties derived from germplasm from CIMMYT and IITA were released through MAIZE partners in 2021. These include 47 in sub-Saharan Africa, 12 in Latin America and 6 in Asia. Besides high and stable yield potential, some of the special traits stacked in these varieties include drought tolerance, nitrogen use efficiency (NUE), Tar Spot Complex (TSC) resistance, Quality Protein Maize (QPM), increased provitamin A content (in partnership with HarvestPlus under A4NH), ear rot resistance, and Turcicum leaf blight resistance.

MAIZE's Sustainable Intensification impact pathway, led by FP4, can point to progress on foresight (e.g. predicting adoption of sustainable intensification), targeting (joint research with CCAFS on water footprints), better understanding adoption dynamics, Climate-smart Agriculture practices piloting and validations, and research methods innovation, as documented in Outcome and Impact Case Reports 4479 and 17 MELIA studies - *see Tables 3 & 10*.

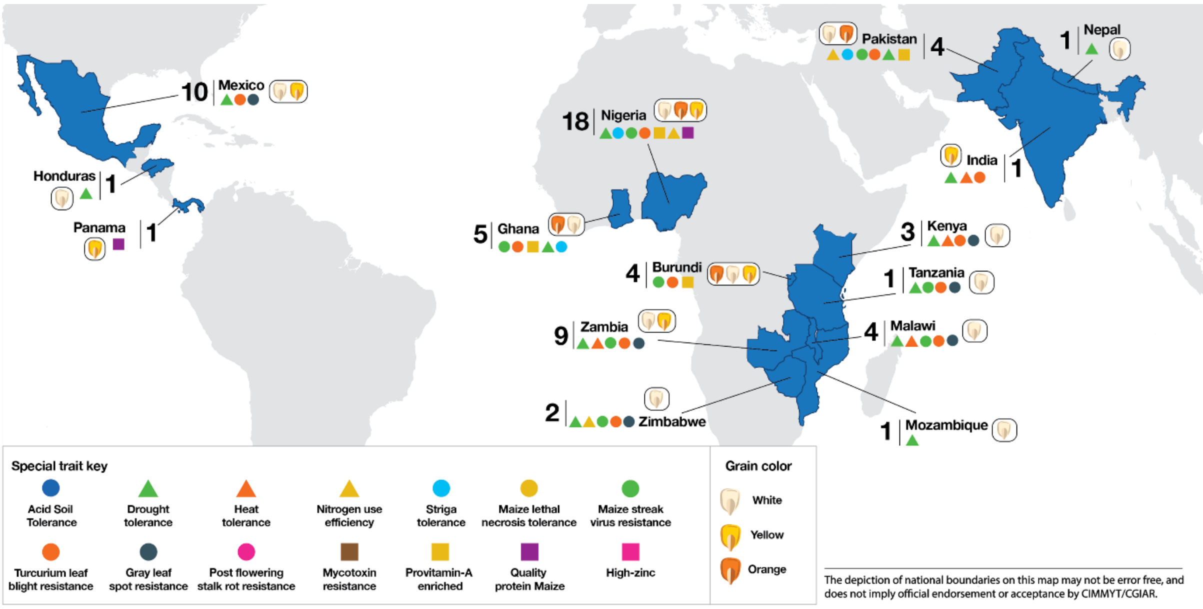

Figure 1: Elite maize varieties released by MAIZE CRP partners in 2021, with depiction of key traits.

1.2.2 Progress by flagships

FP 1 Enhancing MAIZE's R4D Strategy for Impact

Staple cereals will provide 50% of daily calories in 2050; and higher nutritional value too - *see MELIA 4455*. Staple cereals will remain critical for adequate and affordable intake of calories and proteins in Africa and Asia. Diverse diets call for complementary investments across food groups (including fruits and vegetables) and food system transformation (Ulrike G. et al., 2021). In addition, developing multi-nutritional attributes of maize varieties, rather than single-nutrient biofortified cultivars, is a promising near-term solution for improving nutrition - *see MELIA 4405*. Studies also show that such interventions should account for the geographical disparities in micronutrient availability at the subnational scale (Gashu, D. et al., 2021) - *see MELIA 4533.*

To adapt to climate change, farmers in eastern and southern Africa have adopted a variety of practices. Long-term Conservation Agriculture (CA) systems research in Malawi, Zambia, and Zimbabwe has generated scientific evidence regarding CA's productivity, profitability, as well as environmental, social, and human impacts. These are widely used by National Governments to adapt policies for more climate-smart agriculture interventions, leading to CA adoption on >627,000 ha and yield benefits of 30-50% (up to 140%) under drought stress (Mutenje et. al., 2018). A Study conducted in 2021 concluded that Conservation Agriculture can reduce some of the detrimental effects of heat stress for maize on cropping-system yields, which is pertinent to the looming challenges of climate stress facing farmers.

DNA fingerprinting based maize varietal adoption analysis in Ethiopia: Maize grain samples of barley, maize and sorghum were collected in six regions of Ethiopia. Varietal identification was assessed by matching the samples to the DNA fingerprint reference library. Data were part of a study documenting the reach of CGIAR-related germplasm in Ethiopia. A study indicates that rate of maize adoption estimates from the DNA fingerprinting technology differs from farmer perceptions. According to the household survey 43.75% of the farmers used improved maize varieties during the study main cropping season, whereas, based on DNA fingerprinting analysis 97.16% of the respondents used improved maize varieties. The difference was statistically significant ($p<0.01$) and highlights the importance of the DNA fingerprinting technique compared with farmer self-identification. Adoption estimates of maize varieties based on Data from the DNA fingerprinting technology approach showed that that 97.16% of the farmers used improved maize varieties, of which 72.06% adopted hybrids and the remaining 25.10% used improved OPV varieties.

Lessons on Sustainable Intensification (SI) adoption: MAIZE researchers reviewed the empirical literature on the determinants of farmers' SI adoption and found that more attention is needed on the attributes of given technologies and their socio-institutional contexts. A case study in Ghana concluded that promoting the integration of legumes into maize cropping systems and the use of stress-tolerant varieties, as well as improving farmers' access to the varieties, can be a **useful strategy to reduce farmers' vulnerability to weather-related shocks in northern Ghana**. Introducing weather-index-based crop insurance schemes, which are tailored to smallholder farmers, can reduce the risk-aversion of farmers thereby enhancing their willingness to try new technologies.

FP 2 Novel diversity and tools for improving genetic gains

Preserving and leveraging genetic diversity: Researchers analyzed the drivers of continued in-situ maize diversity in Latin America, and found that increased diversity is associated, among other variables, with smallholder farming, farmer control of the farming system, and persistence of traditional culinary and agricultural practices. Recommendations include strengthening market opportunities for maize landraces and OPVs, supporting participatory maize breeding, and improving access to quality landrace and OPV germplasm. Maize landrace diversity is an important reservoir for traits needed to adapt to future crises and challenges: a 2021 study using a maize landrace introgression panel identified chromosomal regions associated with drought tolerance. In Mexico, researchers showed that ex situ and in situ genome-wide diversity was similar via a comparison of two sample groups. They also identified several loci under selection when comparing in situ and ex situ seed lots, suggesting ongoing evolution in farmer fields. These results have implications for ex situ collection resampling strategies and the in-situ conservation of threatened landraces.

Increasing the rate of genetic gains: In a review article, researchers find that advances in genome sequencing technologies combined with efficient trait mapping procedures accelerate the availability of beneficial alleles for breeding and research. Enhanced interoperability between different omics and phenotyping platforms, leveraged by evolving machine learning tools, will help provide mechanistic explanations for complex plant traits. Targeted and rapid assembly of beneficial alleles using optimized breeding strategies and precise genome editing techniques could deliver ideal crops for the future. MAIZE scientists also presented an "enviromic assembly approach" to predictive breeding, which uses ecophysiology knowledge in shaping environmental relatedness into whole-genome predictions (GP) for plant breeding (referred to as enviromic-aided, E-GP). They observed that E-GP outperforms benchmark GP in all scenarios, especially for smaller training sets.

Noting that molecular breeding efforts have been constrained in developing countries' NARS and smaller companies by a lack of high-throughput and cost-effective genotyping platforms that can be shared across the community, MAIZE and CAAS scientists developed a new SNP array in maize that can be captured in solution, increasing the marker loci from 20K to 40K. The system was validated in terms of its power for DNA variation detection and genome-wide association study (GWAS). The technologies and protocols developed for maize can serve as a model for similar systems in other plants.

***Striga* resistance mechanisms in maize:** *Striga hermonthica* causes up to 100% yield loss in maize production in sub-Saharan Africa. Genome-wide association revealed that resistance to *Striga hermonthica* is influenced by multiple genomic regions with moderate effects. The results demonstrated the polygenic nature of resistance to *S. hermonthica*, and that implementation of GP in *Striga* resistance breeding could potentially aid in increasing genetic gain for this important trait. Breeding maize for Striga resistance is challenging due to the scarcity of resistant sources in cultivated species. Another possibility is to develop high yielding maize genotypes with resistance to Striga using genome editing of SLs genes, which are responsible for Striga germination and attachment. Further exploration of closely related QTL gene markers related to Striga will help in the effective trait pyramiding gene actions that can contribute to maize effective production. Some effective molecular docking approaches such as CRISPR/Cas9 genome editing of strigolactone genes, which are responsible for *Striga* germination and attachment could also be considered for the development of high yielding maize genotypes with resistance to Striga.

FP 3 Stress tolerant and nutritious maize

CIMMYT and the University of Agricultural Sciences, Bangalore (UAS Bangalore) **opened the Doubled Haploid (DH) facility** in December 2021. Its construction was co-funded by MAIZE, as part of an effort to complement the African and Latin American facilities. It will offer maize doubled haploid production services to public and private sector partners in South Asia.

How much damage has Fall Armyworm (FAW) done in Ethiopia between 2017 and 2019? – *see MELIA4499*. Using a combination of an agroecology-based community survey and nationally representative data from an agricultural household survey, authors found that over 3 years, FAW caused an average annual loss of 36% in maize production, or 0.67 M tons (0.225 M tons p.a.), equivalent to 2.54% of maize production. Total economic loss was estimated at US$ 200 million, or 0.08% of gross domestic product. Lost production could have fed 4 million people with maize. Governments and development partners need to invest more in sustainable FAW control strategies. Researchers also found that insecticides to control FAW have significant and greater toxic effects on the environment than on humans. The efficacy of a synthetic insecticide-based management strategy is not guaranteed, as FAW has developed resistance to many active ingredients from different classes of insecticides. This calls for the development, validation and scaling of integrated pest management (IPM) based innovations for sustainable FAW management.

MAIZE scientists examined the scalability of drought tolerant maize varieties (DTMVs) in Kenya using household survey data from eight counties. Results showed that the 2018 DTMV adoption rate of 26% could potentially be increased to 56% if seed access constraints are addressed, and even rise to 60% if seed affordability constraints are lifted. The use of electronic media appears to be a key success factor in creating awareness of DTMVss but could exclude more marginalized households and communities. This highlights the need for multi-pronged strategies, including enhanced awareness, and stimulation of demand. Scalability also calls for public-private partnerships to foster a sustained supply of seed to the farming communities at competitive prices.

Quality protein maize: Importance, genetics, timeline of different events, breeding strategies and varietal adoption. Wider adoption of nutritious maize remains a considerable challenge. Aggressive marketing can capitalize on several opportunities for the more widespread uptake of nutritious maize to alleviate malnutrition. A functional seed system and a profitable business model need to be in place to fast-track the deployment of the technology.

MAIZE scientists found that the soybean, maize and chicken value chains were interconnected in Tanzania. Chicken feed is an important entry point for integrating the three value chains. Enhancing local sourcing and adequate processing of soybean, and better connecting smallholder farmers with other soybean, maize, and chicken value chain actors, offers an important opportunity for improving access to nutritious diets for local people.

Is breeding for maize roots traits impacting soil organic matter mineralization? Two candidate maize genes have been identified by MAIZE scientists as being associated with enhanced soil organic matter mineralization rates. There is potential to target these genes to enhance the release of nutrients from soil organic matter, with possible beneficial effects on nutrient/nitrogen use efficiency, and fertilizer use, consequently lowering negative environmental impacts. – *See Table 10 (4474) & also FP4 on fertilizer practices*.

FP4 Sustainable intensification of maize-based systems for improved smallholder livelihoods

Soil health, nutrient/nitrogen/fertilizer use efficiency, soil carbon sequestration (SOC): A study of physicochemical soil health in 20 trials across diverse agroecologies in Mexico found that under conservation agriculture (CA), organic matter and nitrates were higher in the top (0–5 cm) layer of soil and soil aggregate stability was greater than under conventional practice (CP). For other soil health parameters, such as nutrient content, pH or penetration resistance, most were more determined by local soil type than by management. CA increased maize yields at most sites, on average by 0.85 ± 1.80 t ha^{-1}. A long-term study (2005-2013) of the impact of CA on soil health and crop productivity in northern Ethiopia found two pathways in which CA-based systems contributed to improved productivity: (a) via higher density of bacteria and improved hydraulic conductivity, and (b) via higher density of fungi and increase soil organic carbon content in the topsoil.– *See Table 10 (4415, 4483).*

Based on a review of fertilizer policies and extension efforts in Bangladesh, India, Nepal, and Sri Lanka, MAIZE researchers found two options for rationalizing subsidies for the balanced application of nutrients. One is to allow a gradual increase in the price of urea over the next few years and to transfer the money saved on subsidies to farmers through other channels to garner their support for this change. The second option is to switch to non-distortionary direct cash transfer of fertilizer subsidies. – *See Table 10 (Melia 4495).*

Is there a link between climate-smart agriculture in Zambia and deforestation? In aggregate, smallholder cropland expansion into forests represents about 60% of the estimated 250,000 ha of forests lost per year in Zambia. Most households expanded cropland because they needed to meet subsistence food requirements. The study did not find statistically significant associations between adopting climate-smart agriculture (CSA) practices and cropland expansion in this nationally representative sample. Given the low extent and intensity of CSA adoption, relying only on CSA as a means to spare forests may be risky. – *See Table 10 (4486).*

Climate-smart agriculture in Zimbabwe: Farmer adoption dynamics and impacts: CSA offers important opportunities for enhancing food security and incomes through increased agricultural productivity. Researchers investigated CSA adoption using cross-sectional survey data collected from 386 households. The econometric results showed that the status of soil fertility in fields, distance to input and output markets, ownership of communication assets, and Total Livestock Units (TLU) had a significant impact on the decision of farmers to adopt CSA, indicating that CSA adoption has a significantly positive impact on farmers' welfare (e.g., income and food security). – *See table 10 (4458).*

New approach for tackling the shortcomings of global food production systems: To support national agri-food system policy processes, the Integrated Agri-food System Initiative (IASI) methodology was developed and validated through case studies in Mexico and Colombia. It is designed to generate strategies, actions, and quantitative, Sustainable-Development-Goals-aligned targets that have a significant likelihood of supportive public and private investment. The methodology is based on successful integrated development projects implemented by CIMMYT in Mexico and Colombia, the latter in partnership with the Alliance Bioversity-CIAT, which engaged multiple public, private and civil sector collaborators in local maize systems enhancement. These initiatives took advantage of sociopolitical "windows of opportunity" that helped build multiple stakeholder consensus around health, nutrition, food security, and development aspirations in both countries.

To quantify progress toward **landscape sustainability** and to help users advance toward shared goals, **WHEAT, MAIZE and partner scientists developed a structured assessment framework that engages stakeholders** to identify essential features of the landscape and determine steps to be taken to attain or maintain beneficial conditions. It was applied to determine progress in two situations: large, high-input, commercial agriculture in northwestern Mexico and small, low-input family farms in the Western Highlands of Guatemala. The two case studies show the importance of local champions, stakeholder engagement, transparency and trust, effective communication, timely monitoring, long-term commitment, and continual improvement.

In side-by-side multi-year comparisons of technologies, maize yields using conservation agriculture (CA) practices were 21% higher than control yields, and maize profitability was 41% higher. A 2019 MAIZE outcomes report (OICR 3322) had evidenced Mexico-wide farmer (ca. 500,000) adoption on 1.3 million ha. Considering future adoption pathways, a 2021 case study (Guanajuato, Mexico) argued for disaggregating CA into smaller component packages that could increase farmer adoption in risky contexts. The ex-ante economic impact model showed that the two-component scenarios with a legume crop outperformed all other CA adoption scenarios (higher average farm net profit).

1.2.3 Variance from Planned Program for this year

A) Have any promising research areas been significantly expanded?

No

B) Have any research lines been dropped or significantly cut back?

No

C) Have any Flagships or specific research areas changed direction?

No

2021 objectives moved forward into 2022:

No deliverables have been moved forward as this is last year of MAIZE CRP.

1.2.4 Communications

Key thematic information campaigns in 2021 were:

https://www.cimmyt.org/news/high-yielding-staple-crops-improve-health-and-prosperity-in-developing-countries/

https://www.cimmyt.org/news/nitrogen-efficient-wheats-can-provide-more-food-with-fewer-greenhouse-gas-emissions-new-study-shows/

https://www.cimmyt.org/news/digital-nutrient-management-tool-reduces-emissions-improves-crop-yields-and-boosts-farmers-profits/

https://www.cimmyt.org/news/unleashing-the-potential-of-plant-health/

https://www.cimmyt.org/blogs/far-reaching-impacts/

Social media and website metrics:

MAIZE Facebook reached 9,042 followers by the end of 2021. MAIZE Instagram attracted 1,008 followers by the end of the year. Final website analytics show that the MAIZE Website had well over 29,000 sessions, attracting over 25,000 unique users.

Legacy website

In December 2021, MAIZE communications launched a new legacy website to celebrate the closing of the CRP and to communicate the impacts of the last 10 years of MAIZE research. To document and share this legacy, the old MAIZE website was redesigned to highlight the accomplishments of the program and to capture its impact across the five main CGIAR impact areas: nutrition, poverty, gender, climate, and the environment: https://maize.org

1.3 Cross-cutting dimensions (at CRP level)

1.3.1 Gender

Main research outputs:

In work informed by GENNOVATE (Enabling Gender Equality in Agricultural and Environmental Innovation Initiative; 2014-2018), MAIZE researchers advanced the understanding of gender dynamics in diverse geographic, cultural, and agricultural contexts. Research on zero-tillage in Bangladesh, India, and Nepal revealed that zero tillage does not reinforce existing gender inequalities within households. In sub-Saharan Africa, evidence of gender-differentiated preferences for maize varieties remains inconclusive, and consequently changes in research approaches and priorities are called for. MAIZE's gender work also contributed to a collective bargaining agreement between workers and the Government of Morocco and led to a new conservation agriculture approach in a crop-livestock systems project in Tunisia. In southern Ethiopia, MAIZE researchers called for policies that not only ensure equal levels of productive resources, but also help households to build their capacity. These recommendations aim to improve both transitory and chronically food-insecure situations. – *See table 3, OICR4388*.

Are there differences in men's and women's access to and use of fertilizer in sub-Saharan Africa? Findings showed that a gender gap in the use of fertilizer indeed exists. More than a decade after the World Bank identified a gender gap in fertilizer use, there are no systematic national or global datasets comparing fertilizer use by gender. While farm input subsidies can improve women farmers' access to fertilizer and have a positive effect on agricultural productivity for both men and women farmers, this approach has little effect on reducing the gender gap in agricultural productivity. Solving the problem will require a holistic approach rather than "simple" sectoral interventions. Over time, suboptimal fertilizer use depletes the nutrient content of soils. The development of nutrient use efficient maize seed technologies could be an intermediate step.

1.3.2 Youth and other aspects of social inclusion / "Leaving no-one behind[1]"

A study of land use change in 63 rural communities in Mexico for the years 1987 and 2017 showed how a combination of socio-economic and biophysical factors can affect landscape change. It also highlighted the often-overlooked role of communities as a relevant bottom-up driver of change.

An assessment of the extent, diversity, and nutritional contribution of milpa systems through a quantitative analysis of data from a survey conducted in 989 small-scale farm households in the Western Highlands of Guatemala (WHG), found that the milpa systems present higher total productivity than monocropped maize, expressed as total energy yield of the harvested crops in the respective system. These were also better at providing the recommended daily allowances of 14 essential nutrients, based on a Potential Nutrient Adequacy (PNA) indicator.

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[1] Leaving no-one behind is a key facet of the SDGs: https://unstats.un.org/sdgs/report/2016/leaving-no-one-behind

Using satellite images, censuses, and field data, a study assessed changes in nutritional self-sufficiency over the last 30 years and the role of milpa systems in food security for two communities in the highlands of Oaxaca, Mexico. Three cropping systems (monoculture of maize, monoculture of common bean, and the milpa) were compared in terms of nutrients and vitamins produced, and a household typology was developed for each community to contrast nutritional self-sufficiency levels between the different household types. **Results showed that the milpa produced a higher volume of food per area unit compared to the other systems. The milpa also produced all the nutrients and vitamins** (except for B12) required to feed at least two persons ha^{-1}. However, while the farmers recognized the importance of the milpa, they preferred monocultures due to reduced labor demand.

A study assessed how on-farm trees impacted food security in addition to other household income sources in Rwanda. In each of this low income country's six agroecologies, a stratified sampling procedure was used to randomly select households for interviews. A positive association between tree density and food security was found in two out of six agroecologies. The proportion of income that came from tree products was high (>20%) for a small fraction of farmers (12%), with the more food insecure households relying more on income from tree products than households with better food security. Thus, **tree income can be perceived as a "safety net" for the poorest households**.

1.3.3 Capacity Development

Under the Accelerated Genetic Gains for Maize and Wheat Improvement (AGG), Regional Collaborative Maize Breeding and Testing Networks have been established in sub-Saharan Africa to improve NARS partners' breeding efficiencies. This includes strengthening partners' capacity to use modern breeding tools and approaches. Besides NARS partners, these networks also include public and private seed companies, farmers' organizations, non-governmental organizations, and community-based organizations. The networks serve as platforms for fostering greater efficiency and communication across sub-Saharan Africa and within the individual countries. They will improve sharing of best practices and protocols in maize breeding, increased collective ownership of products, and accelerated variety development and turnover.

In collaboration with the Excellence-in-Breeding Platform (EiB), MAIZE researchers launched a series of capacity development webinars on topics such as enhancing and measuring genetic gain in crop breeding and a three-webinar series on statistical analysis for plant breeders.

The full annex of MAIZE's 2021 Capacity Development Activities can be found here. For references, see table 7 below.

1.3.4 Climate Change

In collaboration with CCAFS, MAIZE researchers showed considerable N_2O emissions reduction potential globally, particularly in those countries and regions where existing N losses and emissions are very high. Although limited in spatial coverage, previous studies showed huge global total N losses from maize, wheat and rice fields (~ 44 Tg yr^{-1}), mostly concentrated in China and USA for maize, and China and India for wheat and rice production (Liu et al., 2016). This shows a tremendous potential for improving the efficiency of N use in cereal production in many countries without compromising yield (Liu et al., 2016, 2018) and even increasing it (Mueller et al., 2014; Xu et al., 2015). A meta-analysis found that in cases where nitrogen rate reduction is not possible, N_2O emissions can still be reduced by increasing yield through the implementation of improved fertilizer management practices, such as the 4Rs. Researchers also found that digital nutrient management tools like Nutrient Expert can be an effective aid in such a strategy. However, in the longer term, new strategies, such as a "more ammonium solution," may be required to meet the twin challenges of reducing N pollution and simultaneously increasing global crop yields.

Systematic evaluation of CIMMYT's work on climate change and food system interaction: By using digital methods and machine learning techniques, MAIZE scientists systematically analyzed the CIMMYT-led research portfolio within the climate change-food production nexus, including bilateral projects and MAIZE CRP (2012-2021). CIMMYT's research for development efforts generated many research outputs and contributed to scaling out several climate-smart technologies and practices in climatically challenged locations and production systems in Asia, Africa, and Latin America. The analysis showed that CIMMYT-led research and knowledge has been shared across thousands of websites. CIMMYT's outputs have been distributed to more than 150 countries across both the Global North and South – *See Table 10 (4491).*

Using primary data from 250 randomly sampled maize farmers in Kenya, scientists developed a resilience index and a structural equation model to assess climate smart agriculture (CSA)-based farmer resilience. With a 0.72 Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (above the recommended minimum), authors concluded that maize farmers affected by climate variability were more resilient when they used CSA practices, suggesting enhanced resilience to climate variability.

Conservation Agriculture for Sustainable Intensification (CASI) impacts in South Asia. Agricultural practices change in Bangladesh can contribute to climate change mitigation (CCAFS & CSISA). Adoption of climate-smart crop and livestock management options would offer GHG mitigation opportunities of 9.51 and 14.21 Mt CO_2e $year^{-1}$ by 2030 and 2050, respectively. Of this mitigation potential, 70–75% can be achieved through cost-saving options that could benefit smallholder farmers – *See Table 10 (4487).*

2. Effectiveness and Efficiency and OneCGIAR

2.1 Management and governance

The ***MAIZE-Independent Steering Committee*** (MAIZE-ISC) held two meetings together with WHEAT-ISC to understand OneCGIAR consequences for the continued impacts of work undertaken by both the CRPs, as well as the future of independent scientific advice at the research program level under OneCGIAR. Together with CGIAR Research Program on Roots, Tubers and Bananas (RTB) and MAIZE-ISC, the WHEAT-ISC continued to lead advocacy efforts, which culminated in a meeting with two of the new Global Science Directors in November and ISDC advice to System Council taking on some of the joint-ISC's concerns and recommendations.

The MAIZE-Management Committee managed uncertainties with regard to CRP closure and associated staff continuity in the face of CGIAR-EMT/SO guidance coming late in the day. Most important for MAIZE-MC was to maintain research pace, capacity, and quality in the face of some scientists engaging in Initiative Design Teams while simultaneously coping with the COVID-19 crisis. This had also affected some of the MAIZE's long-time partners, and thus, certain running partner grants (e.g., African NARS partners on FAW management; maize DH facility establishment in India). MAIZE experienced some core staff turn-over during 2021 (e.g., FP1 and FP4 Leads; IITA DDG-R; MEL specialist).

MAIZE-MC and ISC spent significant amounts of time on keeping up-to-date on the OneCGIAR progress and the possible consequences for the CRP's research scope and continuity.

MAIZE and WHEAT researchers developed 22 Golden Egg ideas, of which 4 made it to the Transfer Marketplace. Over several months, MAIZE and WHEAT scientists engaged in or (co-)led Initiative Design Teams, for example the Plant Health Initiative, which brought together experts from 10 CGIAR centers and non-CGIAR scientists. The Plant Health Initiative will incorporate MAIZE's MLN and FAW research.

2.2 Partnerships

2.2.1. Highlights of External Partnerships

An independent review of two decades of public-private breeding research partnerships with multinational companies, with a focus on new science (e.g. genetically modified maize) finds no significant impacts for smallholders so far – *see MELIA Table 10, 4625*.

In a mechanization and livestock research collaboration through CSISA-MEA and the Livestock Production for Improved Nutrition (LPIN) project, researchers targeted new solutions for chopping fodder while creating networks between farmers, agriculture service providers and the businesses that make and distribute the machines. Results of this collaboration not only resulted in increased knowledge on how to operate the machines among the farmers but also created an opportunity of supply and demand along the value chain. These efforts also helped support around 900,000 Rohingya refugees in Cox's Bazar district in eastern Bangladesh. For more External partnerships examples – *see table 8.*

2.2.2. Cross-CGIAR Partnerships

Collaborations with Big Data, CCAFS, WHEAT, PIM, A4NH, EiB, and RICE were maintained.

MAIZE's lead center (CIMMYT) and participant CGIAR center (IITA) in conjunction with six other CGIAR centers, joined a collaborative effort and launched Excellence in Agronomy 2030 initiative, in which a combination of 10 years of CRP research knowledge and results have been integrated. These include new sensing technologies, geospatial decision tools and farming systems, combined with the principles of sustainable intensification, climate change considerations, behavioral economics, and scaling pathways at the national and regional levels. This initiative, co-created with various scaling partners, represents the collective resolve of CGIAR's programs to transform the world's food systems through demand- and data-driven agronomy research for development.

FTA, GLDC, MAIZE and WHEAT scientists made the case for a reforestation pathway: A return to a more diverse agricultural landscape mosaic provided more secure and diversified income sources along with better provisioning of construction materials, fuelwood, and higher livestock numbers. In a related study, scientists show that that tree species diversity matters as much as the amount of tree cover for the production of food, and it can contribute to improve food security (parklands in Central Senegal) – *see Table 10 (4426). And see table 9 for more cross- CGIAR Partnership examples.*

2.3 Intellectual Assets

MAIZE co-funded the International MAIZE Improvement Consortia in Latin America, Africa and Asia (IMIC-LAC, IMIC-Africa, IMIC-Asia), which offers access to elite germplasm (plant genetic resources under development) to both public and private sector partners for strengthening maize breeding and seed systems in targeted market segments.

CIMMYT and IITA maintained their relevant policies to support greater transparency, including in partnerships and results dissemination, in line with CGIAR Principles on Intellectual Assets.

MAIZE is not a legal entity. The management of legal assets relevant to the CRP is managed by MAIZE Lead and participant centers, both of which annually submit a detailed and confidential intellectual asset report to the System Board and the information contained therein is not repeated here. Flagship projects, MAIZE and CIMMYT-PMU do not, on their own, manage intellectual assets without consulting with the Lead Center's legal department; the same applies to IITA.

CIMMYT and IITA have 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 MAIZE.

Critical issues and challenges that remain relevant:

- Ensure sufficient funding and adequate human resources to implement on a timely basis all actions needed for proper Intellectual Asset (IA) management. During 2021, Covid-19 delayed replacing specialist legal staff.
- 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; in certain CGIAR donor country NARS, reluctance to apply ITPGRFA standards (e.g., use of SMTA).
- Collecting, exporting, and licensing seed in view of the ITPGRFA and the Nagoya Protocol.
- Harmonization of licensing practices to disseminate digital sequence data with the Open Access obligation, in light of concerns raised among some ITPGRFA stakeholders in relation to the use of such datasets.
- The rising bar for centers' privacy protection and accountability in the context of dealing with datasets, wherein such data include personal information that carry with them accompanying dissemination obligations under Open Access.

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

During 2021 MAIZE was part of the Monitoring, Evaluation and Learning Community of Practice (MEL Cop) Steering Committee. MAIZE participated in the indicator collection exercise seeking to contribute to a stronger impact delivery through a better management portfolio in the OneCGIAR transition context, including the implementation of the International Aid Transparency Initiative (IATI) standard among other guidelines for decision-making and accountability.

Through the MEL CoP MAIZE also contributed to the CGIAR evaluation policy (CAS) and co-hosted the annual MEL CoP meeting, co-leading Day 1 on CRPs Theory of Change lessons learnt and scaling readiness in the OneCGIAR context.

MAIZE also actively participated and led a series of discussions on CRP wrapping and closing by sharing the close-out plan and the follow-up steps for the CRP Phase II Synthesis.

2.5 Efficiency

Nothing to report for 2021.

2.6 Management of Risks to CRP

Two major risks remained unchanged during Phase II: 1) W1&W2 budget insecurity and delayed transfer of W1&2 funds, which could directly affect CRP research and development operations; 2) Unfulfilled obligations by partners for commissioned and competitive (sub-)grants. Budget insecurity was lower than in 2020 however (see section 3, below). Because partners as well as CIMMYT and IITA scientists could not complete all deliverables on time due to COVID-19 consequences, several partners asked for no-cost extensions and some of the W1&2-funded milestones were partially achieved.

The risk of effectively double-booking resources grew during 2021: Approximately 20-25% of MAIZE scientists were pulled into the OneCGIAR Initiative Design Teams (IDTs) during much of 2021. They did this on top of their 'regular' job. Also, COVID-19 restrictions affected some of the regular field work.

Planning ahead for a semi-structured hand-over of the CRP's outputs, learnings, and program management practices to the new OneCGIAR Initiatives did not effectively take place, except for the Golden Egg activity and some SO-led CRP/FP/Initiatives matching efforts.

'Lack of a systematic and integrated approach for monitoring and evaluation at the outcome level' no longer presented a major risk, as the CRPs Phase 2 annual reporting standards, methods and tools proved to be effective and functional, with very few exceptions.

2.7 Use of W1-2 Funding

No change compared to 2020 deployment of W1&2 funds.

MAIZE is guided by the high-level framework for W1&2 deployment shown below. Table 12 shows in more detail where W1&2 has been invested during 2021, based on the 80+ work packages in the W1&2-per-FP annual workplan delivered by CIMMYT and IITA scientists and their implementation partners in the target geographies.

See Table 12 below.

3. Financial Summary

W1&2 funding level and disbursement was more stable in 2021 than in 2020. The risk of a lower W2 contribution from FCDO did become a reality in late August/September but was fully buffered by CGIAR Stabilization Fund. Notwithstanding intentions documented in the original 2017-21 CGIAR Financial Plan, 2021 disbursements did not take place earlier. A final disbursement (ca. 8% of 2021 W1&2 budget) remains to be issued in 2022.

In view of the CGIAR-EMT decision to allow only for $60,000 residual expenditure in 2022 for closing CRPs, both MAIZE and WHEAT-MCs noted that 2021 annual reporting would very likely be of a lower quality than previous years during Phase II, because required resourcing and scientists' commitment might not be secured, and their priorities and reporting lines may have changed. To mitigate this risk, both the MCs are committed to starting and finishing the 2021 annual reporting process earlier.

In 2021, MAIZE received US$2.08M W2 support from Australia (ACIAR) and UK (FCDO) and $7M W1 from Australia, Belgium, Canada, France, India, Japan, Korea, Netherlands, New Zealand, Norway, Sweden, Switzerland, UK and the World Bank. Total new W1&2 income was $9.08M, up from $8.543M (2020). As in 2020, USAID shifted earlier W2 contributions to W3, linked to the AGG and Crops to end Hunger bilateral projects. Bilateral funder support is documented in the MAIZE Annual Financial Report and in the CGIAR Financial Dashboards.

Part B. TABLES

Table 1: Evidence on Progress towards SRF targets

(Sphere of interest)

SLO Target (2022)	Brief summary of new evidence of CGIAR contribution	Geographic Scope
1.1 ADOPTION: 100 million more farm households have adopted improved varieties, breeds, trees, and/or improved management practices.	A review of 137 studies of adoption of sustainable intensification technologies in Global South maize systems (published between 2007 and 2018) examined how the framework of socioeconomic analysis could be altered, to facilitate overcoming major hurdles to adoption. By 2018, average sample size increased to more than 1,000 observations (e.g., greater analytical rigor and generalizability of observed patterns). For different types and combinations of sustainable intensification of agriculture (SIA) technologies, **both CGIAR-led (e.g., DTMA, SIMLESA) and not, average adoption of technologies in Sub-Saharan Africa varied from 23% (soil and water management practices) to 48% (organic fertilizers and manures; see Table 3 in the study)**. Figures should be interpreted with caution (e.g., not always random selection). Environmental benefits of sustainable intensification were found to be substantial. The studies fail to question the suitability of a given technology to the underlying sociocultural and agroecological realities.	• Geographic Scope: Regional. • Regions: Sub-Saharan Africa.

	Four decades of sustained CGIAR investment in research on stress tolerance provided the basis for significant yield gains and genetic sources of stress tolerance and disease resistance used by national maize breeding programs (Byerlee and Edmeades, 2021, p.18): **By 2020, 230+ varieties with drought tolerance & other key adaptive traits had been released** (Byerlee and Edmeades, p.17). Their rapid adoption showed that smallholders valued drought- and low-N-tolerant improved OPVs and hybrids, for their yield stability (Byerlee, p. 17). Increased emphasis on combining tolerance to abiotic stresses, Striga and the major diseases resulted in further improved varieties' adoption. An analysis of CGIAR maize germplasm adoption and impacts during 1995 to 2015 (incl. CRPs Phase I) **revealed significant economic benefits from CGIAR maize breeding of US$ 0.66-1.05 billion p.a. in 2015 and a benefit cost ratio (BCR) ranging from 22–35:1 for 18 African countries**, after accounting for the CGIAR parentage share (i.e. 80.5% parentage; Krishna et al., 2021, p.vi). Whilst the total number of maize farmer households associated with the BCR period cannot be credibly estimated, an estimated 5 million hectares were covered by CGIAR-related stress-tolerant varieties, benefiting nearly 8.7 million households (over 52 million people), in 2020 (Prasanna et al., 2021).	• Geographic Scope: Global.
1.2 EXIT POVERTY: 30 million people, of which 50% are women, assisted to exit poverty	Adoption of climate-smart agriculture (CSA) practices (e.g., sustainably increase productivity, resilience; reduce or remove greenhouse gases) in Malawi, Zambia and Zimbabwe resulted in a positive impact on the farmers' welfare (e.g. food security & HH income). To date**, farmers adopted CA systems in the three countries on >627,000 ha (Kassam et al., 2019); more than 3 million farmers benefited from large Governmental investment** . The average treatment effects on the treated (difference between the welfare of the adopters and what they would have, had they not adopted) versus on the untreated (difference between welfare of non-adopters and their counterfactuals) was positive and significant.	• Geographic Scope: Regional, Multi-national. • Region: Southern Africa. • Countries: Malawi, Zambia, Zimbabwe.
	Over a period of 17 years (2004-2021) in southern Africa, CIMMYT and partners focused on conservation agriculture-based climate-smart agriculture innovations in a systematic, or comprehensive, rather than a single commodity, or cropping system technology approach. They generated science-based evidence and enhanced local stakeholders' capacity, which informed policy change by several Governments towards smallholders' sustainable intensification (see feasibility study confirming business case). MAIZE/CIMMYT was a key knowledge provider to the **Government of Zimbabwe for its "Pfumvudza" concept, a scaling initiative originally developed by the Foundation for Farming, targeting 1.8 M farmers in 2020/2021 cropping season**. By July 2021, the Ministry of Agriculture announced it had reached 2.2 million farmers, which made the country food secure for the first time in several decades. This success prompted the government to engage	• Geographic Scope: National. • Regions: Southern Africa. • Countries: Zimbabwe.

	MAIZE/CIMMYT on smallholder mechanization, announcing an Alliance on Smallholder Mechanization: 1 million smallholders should access mechanization services by 2025.	
	MasAgro operated 12 hubs in Mexico, incorporating 68 distributed research platforms. Technologies improving sustainability of field practices were adopted on 159,944 ha, monitored through a robust data collection system. In 2018, farmers filled 66,384 field logbooks, resulting in a cumulative 221,961 records since 2012. In side-by-side multi-year comparisons of technologies, **maize yields were 21% higher than control yields, and profitability was 41% higher.** A 2019 MAIZE outcomes report (OICR 3322) had evidenced **Mexico-wide farmer (ca. 500,000) adoption on 1.3 million ha.** Considering future adoption pathways, a 2021 case study (Guanajuato, Mexico) argued for disaggregating conservation agriculture (CA) into smaller component packages that could increase farmer adoption in risky contexts. The ex-ante economic impact model showed that the two-component scenarios with a legume crop outperformed all other CA adoption scenarios (higher average farm net profit). These scenarios/practices offer greater potential that more farmers transition to more sustainable farming practices.	• Geographic Scope: National. • Regions: LAC. • Countries: Mexico.
2.1 YIELD INCREASE: Improve the rate of yield increase for major food staples from current < 1% to 1.2-1.5% per year	Using the economic (producer & consumer) surplus approach, **NARS scientists estimated the return on maize research in Nepal over the last 20 years: An internal rate of return (IRR) of 87%. Farmers planted modern varieties on 92% of Nepal's maize area; nearly 24% with varieties released after 2004.** Average varietal age is 20.5 years. **The majority of hybrids grown are CGIAR-derived**. Significant challenges to closing the yield gap and reducing maize grain-for-poultry imports (US$130 million p.a.) remain. Significant efforts are needed to improve maize productivity, hybrid maize area, and seed replacement as these remain below Government targets (e.g. Nepal's' National Seed Vision).	• Geographic Scope: National. • Regions: South Asia. • Countries: Nepal.
2.2 MINIMUM DIETARY REQUIREMENTS: 30 million more people, of which 50% are women, meeting minimum dietary energy requirements	N/A	
2.3 MICRONUTRIENT DEFICIENCIES: 150		

million more people, of which 50% are women, without deficiencies of one or more of the following essential micronutrients: iron, zinc, iodine, vitamin A, folate, and vitamin B12	N/A	
2.4 WOMEN'S NUTRITION: 10% reduction in women of reproductive age who are consuming less than the adequate number of food groups	N/A	
3.1 WATER AND NUTRIENT EFFICIENCY: 5% increase in water and nutrient (inorganic, biological) use efficiency in agro-ecosystems, including through recycling and reuse	N/A	
3.2 REDUCED GREENHOUSE GAS EMISSION: Reduce	N/A	

agriculturally-related greenhouse gas emissions by 0.2 Gt CO2-e yr–1 (5%) compared with business-as-usual scenario in 2022		
3.3 ECOSYSTEM RESTORED: 55 million hectares (ha) degraded land area restored	N/A	
3.4 PREVENTION OF DEFORESTATION: 2.5 million ha of forest saved from deforestation	N/A	

Table 2: Condensed list of policy contributions in this reporting year

(Sphere of Influence)

Title of policy, legal instrument, investment, or curriculum to which CGIAR contributed (max 30 words)	Description of policy, legal instrument, investment, or curriculum to which CGIAR contributed (30 words). See guidance for what to cover.	Level of Maturity	Link to sub-IDOs (max. 2)	CGIAR cross-cutting marker score				Link to OICR (obligatory if Level of Maturity is 2 or 3) or link to evidence (e.g., PDF generated from MIS)
				Gender	Youth	Cap dev	Climate Change	
852 - Southern African governments implement policy change towards climate-smart, sustainable smallholder farming systems	Climate-smart agriculture mainstreamed in Zimbabwe's National Agriculture Policy Framework, Climate Change Response Strategy; similarly for Zambia, including its Disaster Management Policy and Malawi. Adopted on 627,000 ha by 3M+ farmers.	Stage 2	• Reduced smallholders production risk • Closed yield gaps through improved agronomic and animal husbandry practices	1 - Significant	0 - Not Targeted	1 - Significant	1 - Significant	OICR4479

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
OICR4388 - Strategic gender research contributes to policy change in Sub-Saharan Africa and South Asia.	Link	Stage 1
OICR4465 - Agro-dealers and end-user demand ('pull')-driven seed system innovation in Eastern Kenya: Realities today; opportunities tomorrow	Link	Stage 1
OICR4479 - Sustainable Intensification of Smallholder Farming Systems, adapted to Climate Change, makes inroads with 3 million farmers in southern Africa	Link	Stage 2
OICR4564 - 65,000 South Asian farmers' resilience and income sustained through drought-tolerant maize	Link	Stage 2
OICR4599 – Comparative research points to sub-Saharan African farmers' willingness to pay for climate smart maize technologies and adoption dynamics and pathways	Link	Stage 1
OICR4600 - Collective efforts to fight fall armyworm (FAW) led to FAW-tolerant varieties in only 2 years and dedicated IPM extension efforts reaching 187,000 farmers	Link	Stage 1
OICR 4602 - Better breeding research and partnerships enable 43 million farmers to access and grow stress-tolerant maize in sub-Saharan Africa	Link	Stage 2
OICR4603 - On-farm impacts of breeding research improvements (focus cycle time, Genomic Selection)	Link	Stage 2

Table 4: Condensed list of innovations by stage for this reporting year

Title of innovation with link	Innovation Type	Stage of innovation	Geographic scope (with location)
2371 - 74 OPVs, 70 elite inbred lines, and 200 hybrids shared in 2021 with national partners in West Africa for testing, adaptation, and release	Genetic (varieties and breeds)	Stage 1: discovery/proof of concept (PC - end of research phase)	Regional: Western Africa
2566 - Monitoring land degradation with remote sensing in the United Republic of Tanzania	Research and Communication Methodologies and Tools	Stage 1: discovery/proof of concept (PC - end of research phase)	Sub-national: Tanzania, United Republic
2581 - Sustainable Intensification Farmer Manual (Zambia & Southern Africa)	Production systems and Management practices	Stage 4: uptake by next user (USE)	Regional: Southern Africa
2592 - Stepwise integrated soil assessment framework, to better understand the role of soil health in farmer decision-making in Malawi	Production systems and Management practices	Stage 2: successful piloting (PIL - end of piloting phase)	Regional: Multi-national: Malawi, Southern Africa
2598 - Efficient Genotyping Workflow for Accelerating Maize Improvement in Developing Countries	Research and Communication Methodologies and Tools	Stage 3: available/ ready for uptake (AV)	Regional: Global, Sub-Saharan Africa
2603 - Practical methods for exploring gender relations in maize seed systems for Sub-Saharan Africa	Social Science	Stage 1: discovery/proof of concept (PC - end of research phase)	Regional: Sub-Saharan Africa
2607 - Agronomic experimentation on-station for research platforms: Management Guide (in Spanish)	Production systems and Management practices	Stage 4: uptake by next user (USE)	Regional: National: Mexico, Latin America and the Caribbean

2609 - Video-based Product Ranking Tool (elite MAIZE lines with multiple traits)	Production systems and Management practices	Stage 1: discovery/proof of concept (PC - end of research phase)	Global
2615 – Genome editing of the eukaryotic translation initiation factors in maize	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	Regional: Africa
2621 - High throughput assay to measure phytic acid for improved biofortification of cereal grains	Genetic (varieties and breeds)	Stage 3: available/ ready for uptake (AV)	Global
2733 - Digital Soil Map for Nepal	Research and Communication Methodologies and Tools	Stage 4: uptake by next user (USE)	National: Nepal
2734 - Early Career Maize Breeders Online Course	Research and Communication Methodologies and Tools	Stage 4: uptake by next user (USE)	Global
2735 - Genetic dissection of maternal influence on in vivo haploid induction in maize	Genetic (varieties and breeds)	Stage 4: uptake by next user (USE)	Global
2736 - CIMMYT maize product catalog	Genetic (varieties and breeds)	Stage 2: successful piloting (PIL - end of piloting phase)	Regional: Sub-Saharan Africa
2737 - Determining appropriate harvesting time for orange (high vitamin A) maize based on consumer preferences in Western Africa	Production systems and Management practices	Stage 1: discovery/proof of concept (PC - end of research phase)	Regional: Western Africa
2738 - Protocol for inoculum production and inoculation of maize with E. turcicum for resistance screening of pathogen	Genetic (varieties and breeds)	Stage 1: discovery/proof of concept (PC - end of research phase)	Global
2739 - Radiative transfer model inversion for measuring maize leaf area index (directly related to crop productivity)	Biophysical Research	Stage 2: successful piloting (PIL - end of piloting phase)	Global

2741 - Manual on Road mapping (participatory planning) for scaling Agricultural Mechanization (Nepal)	Research and Communication Methodologies and Tools	Stage 4: uptake by next user (USE)	National: Nepal
2742 - Five e-learning courses (FAO e-learning academy) on mechanization business models	Research and Communication Methodologies and Tools	Stage 4: uptake by next user (USE)	Global
2747 - 65 MAIZE derived varietal releases-2021	Genetic (varieties and breeds)	Stage 4: uptake by next user (USE)	Global
2773 - Plant breeding strategies to improve bioactive food components	Biophysical Research	Stage 1: discovery/proof of concept (PC - end of research phase)	Global
2776 - Introduce disease resistance directly in elite lines by gene editing	Biophysical Research	Stage 2: successful piloting (PIL - end of piloting phase)	Global
2829 - Development of eight maize hybrids with high yield potential and competitive agronomic characteristics for the mid-altitudes of Mexico and lowland tropical of Latin-America.	Genetic (varieties and breeds)	Stage 2: successful piloting (PIL - end of piloting phase)	Regional: Latin America and the Caribbean
2830 - Development of 43 maize hybrids with high yield potential and competitive agronomic characteristics for the mid-altitudes of Mexico and lowland tropical of Latin-America	Genetic (varieties and breeds)	Stage 2: successful piloting (PIL - end of piloting phase)	Regional: Latin America and the Caribbean

Table 5: Summary of status of Planned Outcomes and Milestones

(Sphere of Influence-Control)

FP	FP Outcomes 2022	Sub-IDOs	Summary narrative on progress against each FP outcome this year.	Milestone	2021 milestones status	Brief Explanation Provide evidence for completed milestones (refer back to means of verification, and link to evidence wherever possible) or explanation for extended, cancelled or changed	Link to evidence
FP1	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	FP1 scientists reported on Sustainable Intensification impacts in sub-Saharan Africa and long-term breeding impacts in Ethiopia and Nepal. They also generated learning about farmers' adaptation practices to climate change in eastern and southern Africa. Looking forward, researchers investigated the future role of staples in providing food and nutritional security and recommended making changes to current bio-fortification approaches in the short-term.	2021 - Ex-ante studies assess future preferences of maize producers and consumers and implications for maize innovation	Completed	MAIZE team developed a data-rich spatial framework to guide agricultural research and development (AR&D) prioritization and to perform ex-ante impact assessment spatial framework that: (i) provides strategic insight to guide decisions about the number and location of testing sites, (ii) define the target domain for scaling-out a given technology or technology package, and (iii) estimate potential impact from widespread adoption of the technology(ies) being evaluated.	•doi.org/10.1017/S1742170521000016 •https://journals.sagepub.com/doi/10.1177/0973005221998244 •https://www.researchgate.net/publication/350060482_Impacts_of_CGIAR_Maize_Improvement_in_Sub-Saharan_Africa_1995-2015 •https://www.sciencedirect.com/science/article/pii/S2667010021000147?via%3Dihub •https://doi.org/10.1016/j.worlddev.2021.105789 •https://doi.org/10.1002/agj2.20536

							•https://doi.org/10.1371/journal.pone.0252832 •https://www.cimmyt.org/news/new-integrated-methodology-supports-inclusive-and-resilient-global-food-systems-transformation/ •https://globalagriculturalproductivity.org/partnership-pursues-new-approaches-to-productive-sustainable-food-systems/ •https://doi.org/10.1016/j.gfs.2021.100558
	FP1 Outcome: 1.10 Farmers have greater awareness and access to, and increased adoption and adaptation of improved technologies		The main objective of the adoption-impact CoA in MAIZE was to institutionalize a structured approach to meet the increasing demand for evidence on R4D outcomes, following a relevant, credible, and rigorous methodology that is both financially efficient and socially inclusive. MAIZZE scientists developed a generic framework of adoption-impact assessment.	2021 - Robust and systematic evidence base of MAIZE technology adoption and impacts	Completed	Conceptual framework stablished to help the MAIZE team to better prioritize the research activities based on evidence and feedback from the field.	•https://doi.org/10.1007/s12571-021-01209-0
				2021 - Gender / social inclusion lenses applied to	Completed	Researchers synthesized the main studies under thematic sections, including gendered preferences & use of improved maize germplasm; gender &	•https://doi.org/10.1057/s41287-020-00289-6

				major MAIZE innovation pipelines		innovations; GENNOVATE; gendered market participation & value chain development; gender & farm performance/-typologies; social inclusion & youth; and gendered guidelines/tools.	•https://doi.org/10.1016/j.jspr.2020.101734 •https://www.cimmyt.org/blogs/improve-rural-womens-financial-access-to-help-solve-hunger/ •https://doi.org/10.1080/00220388.2020.1808195 •https://doi.org/10.17170/kobra-202104133655
	FP1 Outcome: 1.9 Last mile provider (extension partners, farmer organization, community-based organizations, private sector) increased access and promotion of technologies to farmers	• Increase capacity of beneficiaries to adopt research outputs	In sub-Saharan Africa, FP1 scientists continued to support FP3 and FP4 colleagues in better understanding and improving seed sector and extension/scaling partnerships (mainly funded by bilateral projects; STMA, now AGG, TELA MAIZE). On the agronomy/farming systems side, researchers investigated how farmer decision support when using new or improved technologies could be improved. In Latin America (Mexico), last-mile partnerships with private sector partners (responsible sourcing, mechanization providers/business models)	2021 - Value chain analyses for selected maize producers and R&D implications assessed	Completed	FP1 provided MAIZE development partners with evidence-based information that could be used to develop interventions along the value chain for the improvement of livelihoods in maize agri-food systems. Also, knowledge generated by this work helped target breeding programs better (by incorporating preferred traits by men and women farmers, processors, feed millers, agro-processors, and consumers). Similarly, this CoA identified and assessed input value chain constraints (e.g. slow variety testing and release procedures) and opportunities, which then dovetailed into work related to developing seed markets and seed market segmentation (under MAIZE FP3), as well as non-seed input.	•https://guardian.ng/news/fg-authorizes-deregulation-of-tela-maize-in-nigeria/ •https://www.cimmyt.org/news/understanding-decision-support/ •studySummary.do (cgiar.org) •https://doi.org/10.3390/agronomy11061214 •https://www.cimmyt.org/news/cimmyt-becomes-partner-of-choice-in-pepsicos-sustainability-strategy/ •https://www.cimmyt.org/blogs/improve-rural-womens-financial-access-to-help-solve-hunger/

			continued. In South Asia, 'last mile' research focused on farmer access to heat-tolerant maize varieties and precision nutrient management.				•https://www.cimmyt.org/news/mechanization-takes-off/ •https://iyouth.iita.org/international-youth-day-2021/ •https://www.iita.org/news-item/tackling-the-fall-armyworm-in-northern-nigeria/
FP2	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	FP2 and partner scientists contributed to forward-looking advisory about the future direction of pre-breeding research, methodologies and processes, which was linked to OneCGIAR research portfolio design. As in past years, FP2 researchers made progress on novel genetic discovery, also by making use of genetic diversity conserved in genebanks. Pre-breeding for specific pests and diseases, such as Fall Armyworm, Maize Lethal Necrosis, Striga and Tar Spot Complex, remained a priority.	2021 - Genomic prediction replaces up to 50% of the stage 1 testing efforts in the MAIZE breeding programs of SSA, Asia and LA	Completed	MAIZE scientists worked on the application of environmental Genome-wide Association Studies and environmental Genomic Selection, as well as generating genotyping and bioinformatics pipelines to support Genomic Selection applications. They also worked on integration of validated breeder-ready markers/haplotypes for priority traits.	•https://pubmed.ncbi.nlm.nih.gov/34276721/ •https://www.nature.com/articles/s41437-021-00412-1 •https://www.sciencedirect.com/science/article/pii/S2214514120301410?via%3Dihub
				2021 - Novel germplasm donors, alleles and/or haplotypes for at least 2 priority traits	Completed	MAIZE team continued improving genetic gain through the strategic introduction of novel genetic diversity for target traits into the breeding pipeline. This introduction was facilitated through deployment of cost-effective markers for major	•https://doi.org/10.1038/s41598-021-03566-4 •https://link.springer.com/article/10.1007%2Fs00122-020-

				selected from biotic and abiotic stresses and nutritional and end user quality traits, identified and moved into pre-breeding and/or breeding pipeline		diseases & through application of genomic selection for more complex traits	03744-4 •https://doi.org/10.3389/fpls.2021.726767 •https://doi.org/10.1111/pbr.12951
				2021 - Useful haplotypes or alleles from genetic resources validated and information disseminated publicly for at least two priority traits	Completed	MAIZE FP2 team continued to develop and implement strategies to identify and deliver allelic diversity of value from genetic resources to core breeding through the use of marker-based selection for simply inherited traits and the use of GP for complex traits in tropical maize.	•https://twk.pm/vpsokmd1bx •https://www.frontiersin.org/articles/10.3389/fpls.2021.658267/full •https://acsess.onlinelibrary.wiley.com/doi/10.1002/csc2.20394 •studySummary.do (cgiar.org)
				2020 extended to 2021 - Bridging germplasm carrying favorable novel alleles for Tar Spot Complex (TSC) disease, drought tolerance and maize lethal necrosis (MLN) tolerance released to public.	Completed	Bridging germplasm carrying favorable variation for TSC and drought tolerance has been released as newly defined pre-breeding lines called CIMMYT Maize Genetic Resource Lines (CMGRL), MLN tolerant donors were evaluated in the field for release in 2022.	•https://www.frontiersin.org/articles/10.3389/fpls.2021.672525/full •https://data.cimmyt.org/dataset.xhtml?persistentId=hdl:11529/10246

	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	a new network of specialists, the Breeding Informatics Network (BrIN) was established to standardize and modernize breeding data storage, access, curation, analysis, visualization, and decision support. The network groups also coordinate the best practices and processes implemented in the Enterprise Breeding System (EBS) Breeding Analytics and Services platforms. They partner with the EBS development team in validating the implementation in EBS and also share the same standards with Breedbase and BMS	2020 extended to 2021 - Centralized breeding data management system and associated tools deployed to provide breeders with better access to germplasm, genealogical, and phenotypic data	Completed	MAIZE team, in collaboration with EiB, finalized implementation of a centralized breeding data management system, used by MAIZE and national agricultural research systems (NARS) breeders and researchers.	•https://excellenceinbreeding.org/toolbox •https://ebs.excellenceinbreeding.org/ •https://excellenceinbreeding.org/BrIN
				2021 - High value historic phenotypic, genotypic and genealogical data curated and stored in centralized publicly accessible data repositories	Completed	Data was transferred between Maize Field book and KSU Field Book, as a stepping stone for using KSU Field Book across CGIAR maize breeding (the EBS chosen data capture application). Additionally, work has been ongoing to ensure all traits required for data capture are included in EBS. . R scripts and protocols for checking and curating genotypic data for upload to standalone GOBii have been enhanced. These base scripts can be repurposed into pre-loading validation processes in the EBS. Efforts have ensued to update pedigree curation processes to incorporate new nomenclature rules,	•https://data.cimmyt.org/dataset.xhtml?persistentId=hdl:11529/10548370 •https://excellenceinbreeding.org/toolbox/tools/field-book

						e.g. new backcross nomenclature and to enhance the efficiency of the curation process to help load more current and historic germplasm faster in preparation for EBS rollout.	
FP3	FP3 Outcome: 3.1 Improved exchange and utilization of germplasm and data by MAIZE partner breeding teams	• Increased capacity for innovations in partner research organizations	Whilst two independent scholars published an overview of 50 years of CIMMYT and CGIAR maize improvement impacts, MAIZE scientists continued their breeding research on drought tolerance in sub-Saharan Africa and South Asia, quality protein maize, zinc-nutritious maize and developing new sources of resistance to major pests and diseases. They also invested more time on root traits. Considering first and second user outcomes, 65 CGIAR-derived, improved maize varieties were released through MAIZE partners in 2021, which included some with special traits stacked (e.g., drought tolerance, nitrogen use efficiency, increased provitamin A content (in partnership with A4NH).	2021 - New MAIZE hybrids advanced through stage-gate advancement after Regional Trials announced through CIMMYT website (along with the data), and allocated to public/private sector partners in Africa, Asia and LatAm for varietal release and commercialization	Completed	Developed and deployed elite climate-resilient maize varieties in sub-Saharan Africa, Asia and Latin America, including key traits relevant for smallholders, such as tolerance to drought and heat, and resistance to diseases (e.g., MLN, Fusarium stalk rot), insect-pests (especially Fall Armyworm; FAW), parasitic weeds (e.g., Striga), and other relevant agronomic and adaptive "must-have" and "emerging" traits identified in different product profiles. Breeding for native genetic resistance to FAW was intensified in Africa, besides South Asia.	•https://www.cimmyt.org/tag/allocations/ •https://doi.org/10.3390/plants10122596 •https://www.cimmyt.org/news/cimmyt-releases-12-new-maize-lines/ •https://www.cimmyt.org/service/imic-asia/ •https://www.cimmyt.org/news/aaa-drought-tolerant-maize-now-available-in-myanmar/ •https://www.cimmyt.org/news/mexicos-seed-producers-honor-cimmyt-work-to-breed-and-spread-high-yield-maize/ •https://doi.org/10.1007/s00122-021-03773-7 •https://www.harvestplus.org/knowledge-market/in-the-news/release-new-vitamin-maize-varieties-sparks-optimism-maize-farmers
			Distribution of elite maize germplasm with high yield			Several open pollinated maize varieties and hybrids with high yield potential and desirable	MAIZE map: https://twk.pm/7vb63m7zoo

			potential, resistance to Striga, stem borers, nutrient use efficiency and high lysine and tryptophan to partners			agronomic and adaptive traits were tested in participatory on-farm trials. Also, few superior open-pollinated maize varieties and hybrids were released in various counties at the end of 2021.	https://ajae.ng/abstracts/18/Participatory-Evaluation-Of-Provitamin-A-rich-Maize-zea-Mays-L-Hybrids-In-Savanna-Zones-Of-Northeast-Nigeria
	FP3 Outcome: 3.2 Effective pest/disease surveillance, monitoring and diagnostics protocols/procedures for controlling the spread and impact of existing/emerging threats	• Reduce pre- and post-harvest losses, including those caused by climate change	Breeding for native genetic resistance to FAW was intensified in Africa, besides South Asia. To rapidly increase genetic gains in maize breeding pipelines, the FP3 team used maker-assisted forward breeding and genomic selection/prediction, in combination with doubled haploidy, besides high throughput and precise phenotyping for key traits, such as Gray leaf spot, Turcicum leaf blight, and Fusarium ear rot. Three-season nurseries were adopted across the breeding hubs to reduce the breeding cycle time. A functional maize doubled haploid facility was established in India to serve the maize breeding programs of CIMMYT and partners in South Asia.	2020 extended to 2021 - Technical manuals on MLN disease management and IPM for Fall Armyworm (FAW) management published and disseminated, and awareness created among relevant stakeholders on tools / technologies for effective and sustainable management of the transboundary diseases/insect-pests on maize, especially in Africa and Asia	Completed	MAIZE team brought out a comprehensive Integrated Pest Management manual for fall armyworm (FAW) management in Asia and played a key role in implementation of FAW Global Action Plan coordinated by FAO. The team continued with the successful initiative of curbing the spread and impact of MLN in Africa.	•https://mln.cimmyt.org/maize-partners-announce-a-new-manual-for-effectively-managing-maize-lethal-necrosis-mln-disease/ •https://csisa.org/wp-content/uploads/sites/2/2021/04/210426-FIGHTING-FAW-2020-21-SEMI-ANNUAL-REPORT.pdf

				2021 - First-generation Fall Armyworm (FAW) tolerant elite MAIZE hybrids announced and nominated by partners for varietal release and commercialization ; An IPM manual for FAW control released for the benefit of stakeholders (scientists, extension agents, farmers, policy makers) in Asia.	Completed	Based on the results of on-station screenhouse trials for fall armyworm tolerance (under artificial infestation) conducted at Kiboko during 2017-2019, CIMMYT researchers evaluated in 2020 a set of eight test hybrids (four early-maturing and four intermediate-maturing)) against four widely used commercial hybrids (two early- and two intermediate-maturing) as checks. The eight test entries with fall armyworm tolerance were also included in the regional on-station trials (comprising a total of 58 entries) evaluated at 28 locations in Kenya and Tanzania. The purpose of these regional trials was to collect data on agronomic performance.	•https://www.cimmyt.org/news/new-cimmyt-maize-hybrids-available-from-southern-africa-breeding-program/ •https://www.herald.co.zw/centre-develops-new-hybrid-maize-resistant-to-armyworm/ •https://doi.org/10.1002/csc2.20649
			IITA under Africa Rising bilateral project produced a manual knowledge on the management of harvested grain, to reduce postharvest losses, and improve quality and safety. It is expected that through use of this manual, farmers will be better able to take important decisions on choice and application of improved technologies to reduce postharvest food losses, and therefore improve food security at household and national level,			The content of this manual is intended for extensionists and farmer advisors who link directly with smallholder farmers, and the target is to address knowledge and technology-use gaps. The first part presents a general description of the maize post-harvest system. It identifies the various unit operations involved and gives an overview of the losses in the system. The second part describes the main loss causing biological agents (insects, rodents, and fungi) and points out the general measures that may be applied to mitigate losses caused by them. The third part is a presentation of some improved postharvest technologies validated by the Africa-RISING (Research in Sustainable Intensification for the next Generation) program,	https://cgspace.cgiar.org/bitstream/handle/10568/109804/Improved%20post%20harvest%20practices.pdf?sequence=1&isAllowed=y

			earn employment and incomes, protect the environment, and increase productivity without the need to employ extra production resources.			and their potential benefits when applied by farmers.	
				2021 - Learning, knowledge, and products created and used by MAIZE to implement strategies, activities, and technologies to tackle Fall Armyworm in Africa and Asia	Completed	1. FAW-endemic African and Asian countries technically supported for implementing IPM-based FAW management 2. FAW IPM Manual for Asia published and disseminated 3. FAW R4D International Consortium coordinated 4. FAW IPM promoted and disseminated through various national/regional/continent-wide events	•https://repository.cimmyt.org/bitstream/handle/10883/21658/64245.pdf?sequence=4&isAllowed=y •https://mln.cimmyt.org/ •https://www.cimmyt.org/tag/fall-armyworm/
						IITA Scientists, under the TAAT Fall Armyworm Compact has developed technologies for very low infestations of FAW and others for heavy and medium infestations of FAW. Intercropping maize with other legume crops has also been encouraged among farmers to smother weeds and fix nitrogen. Besides IITA researchers have piloted an ambitious training program on FAW management in Kano and Kaduna States (Northern Nigeria). A total of 300 EAs were trained in Kano and Kaduna	https://www.cgiar.org/news-events/news/delivering-scalable-sustainable-fall-armyworm-technology-to-taat-beneficiaries/ https://www.iita.org/news-item/tackling-the-fall-armyworm-in-northern-nigeria/
				2021 - MAIZE Atlas/web portal populated with available information (resistant germplasm,	Completed	The team validated and deployed high-throughput phenotyping tools for relevant abiotic and biotic stresses in SSA, Asia and Latin America. In addition, protocol was standardized for screening germplasm for post-flowering stalk rots (PFSR), a	•https://link.springer.com/article/10.1007/s00122-021-03773-7 •https://seedsofdiscovery.org/maize/maize-molecular-atlas/

				pathogen / pest /parasitic weed survey data, management recommendations , etc.)		complex biotic challenge for maize farmers in South Asia.	
	FP3 Outcome: 3.3 Partner breeding teams' access and adopt improved breeding processes, including new technologies, methodologies, approaches and genetic resources	• Increased capacity for innovations in partner research organizations	MAIZE team has made strong progress towards all milestones and outcomes: * Optimization of breeding tools and methods to increase rate of genetic gain. * Climate-resilient, input-responsive maize varieties developed and accessed by partners in SSA. * Accelerated varietal turnover and adoption of superior maize varieties in SSA.* Capacity of targeted African NARS and SME seed companies strengthened	2021 - NARS and seed company partners trained for enhanced use of validated protocols for high-throughput field-based phenotyping and molecular breeding for increasing genetic gains in stress-prone tropical maize environments	Completed	Capacity of targeted African NARS and SME seed companies strengthened. • Following breeding program assessments conducted jointly with the CGIAR Excellence in Breeding Platform (EiB), customized improvement plans were developed with and for KALRO (Kenya), NARO (Uganda), and DR&SS (Zimbabwe) and endorsed by respective management teams. • Regional Collaborative Maize Breeding and Seed Systems Networks implemented in EA, SA and WA. • KALRO and NARO are receiving support to adopt the Breeding Management System (BMS) data management system in preparation for the transition to the Enterprise Breeding System (EBS). • Despite the severe challenges from the COVID-19 pandemic, virtual capacity building activities benefiting 753 participants (565 male and 188 female) were conducted.	•https://doi.org/10.1177%2F00307270211059551 •https://www.cimmyt.org/content/uploads/2020/07/AGG-Year-1-Executive-Summary-and-Impact-Report.pdf
			IITA MAIZE team helped to further improve productivity and food safety in the value chains, contributing to build capacities of smallholder farmers on productivity and farm safety technologies. And create job opportunities for women and youths through the establishment of				https://reliefweb.int/report/nigeria/giz-giae-and-iita-target-job-creation-and-increase-productivity-maize-and-cassava

			commercial seed enterprises for retailing of disease-free improved stems, marketing of aflasafe and Purdue improved crop storage (PICS) bags an improved agricultural storage bag.				
	FP3 Outcome: 3.4 Increased deployment of improved MAIZE varieties by seed companies in target agroecologies	• Closed yield gaps through improved agronomic and animal husbandry practices	A value chain analysis conducted in Kenya, Tanzania and Uganda on 32 seed companies, 612 agro-dealers, and 466 farmers found challenges to increasing varietal turnover: 1) only 20% of farmers actively seek new varieties; 2) agro-dealers hesitate to invest in the promotion of new varieties and prefer selling varieties they know are demanded by farmers; 3) seed companies focus investments on triggering farmer demand, but invest little in strengthening their retail network; and 4) companies take a big risk when updating their seed portfolio as demand for the new varieties.	2020 extended to 2021 - Women and youth participation across the maize seed value chain promoted; Information generated and documented on technology adoption patterns and key drivers to design marketing strategies (linkage with FP1).	Completed	MAIZE identified several research priorities to support gender-intentional maize breeding, including a more nuanced understanding of gender relations in maize production and maize seed decision-making, new and more gender-responsive approaches to measuring farmer preferences and seed demand more broadly, and research to address operational challenges in gender-intentional breeding.	•https://www.cimmyt.org/news/buying-into-new-seed/ •doi.org/10.1016/j.jcs.2021.103274 •doi.org/10.1177/00307270211058208 •https://practicalactionpublishing.com/book/2527/value-chain-development-and-the-poor
			To avoid yield losses due to maize streak virus MAIZE scientists at IITA developed a study in wish diagnostic				https://doi.org/10.3390/agriculture11020130 https://doi.org/10.1079/pavsnnr202116030

			markers linked to MVS have been identified for use in forward breeding. MAIZE IITA scientists also investigated how to resolve the problem of Striga hermonothicca by developing high yielding Striga resistant maize in Sub Sahara Africa				
				2021 - International Maize Improvement Consortium (IMIC) in Africa, with at least 25 local/regional seed companies as members.	Completed	The effective use of improved, climate-resilient and multiple-stress-tolerant maize varieties has achieved tangible results in this region. Elite drought-tolerant (DT) maize hybrids developed by CIMMYT have demonstrated at least 25-30 percent grain yield advantage over non-DT maize varieties in sub-Saharan Africa under drought stress. CIMMYT has also derived elite heat-tolerant maize hybrids for sub-Saharan Africa, and during the recent outbreak of maize lethal necrosis (MLN), the rapid development and deployment of elite MLN-resistant hybrids was instrumental in the containment of this threat to eastern Africa.	•https://mln.cimmyt.org/how-do-we-sustainably-manage-transboundary-diseases-and-crop-pests/ •https://mln.cimmyt.org/visit-of-partners-and-farmers-and-key-stakeholders-to-mln-screening-facility-naivasha-kenya/
	FP3 Outcome: 3.10 Farmers adopted improved varieties in farming systems	• Reduced smallholders production risk	Recent analysis of the weighted average age of CIMMYT-related improved maize varieties in 8 countries across eastern and southern Africa reveals that the overall weighted average age has decreased from 14.6 years in 2013 to 10.2 years in 2020. The remarkable progress in accelerating the rate of variety turnover and	2021 - New germplasm, traits and technologies incorporated in MAIZE breeding products to effectively tackle abiotic stresses (drought, heat, waterlogging), emerging diseases (e.g., MLN in	Completed	breeding efforts for developing and deploying improved maize germplasm with climate resilience and other client-preferred traits are more than four decades old. CIMMYT follows a decentralized maize breeding strategy in SSA, Asia, and Latin America to reduce the effects of large GEI. An extensive maize germplasm phenotyping/testing network in the tropics of SSA, Latin America, and Asia is at the heart of CIMMYT's breeding strategy for developing multiple stress-tolerant maize	•https://link.springer.com/article/10.1007%2Fs00122-021-03773-7#Sec17 •https://doi.org/10.1016/j.cj.2021.03.012 •https://doi.org/10.3390/agronomy11050831

			deploying the improved genetics, with climate resilience, nutritional-enhancement, and grain yield, has benefited more than eight million smallholders in Africa.	eastern Africa), and expanding threats (e.g., invasive and parasitic weeds).		varieties. Increasing genetic gain, including a reduction in breeding cycle time, is key for providing farmers with a steady stream of improved varieties.	•https://doi.org/10.3389/fgene.2021.767883
			As a response of increasing average global temperature IITA scientists developed QPM< hybrids with tolerance to combined drought and heat stress (CDHS) as well as low soil nitrogen with the potential to mitigate adverse effects of climate change . IITA germplasm is tested and ready to be used by NARS breeding programs.			With the objective to determine the gene action conditioning grain yield, assess the performance of the early QPM inbred lines and identify high yielding and stable QPM hybrids under CDHS, low-nitrogen and optimal environment conditions. Ninety-six early QPM hybrids and four checks were evaluated in Nigeria for two years under CDHS, low-nitrogen, and in optimal environments. Scientists found that c Hybrid TZEQI 210 × TZEQI 188 was the most stable across environments and should be tested on-farm and commercialized in SSA. ITA germplasm with resistance to S. hermonthica resistant/tolerant genotypes displayed desirable resistance/tolerance to S. asiatica relative to local commercial checks	file:///D:/OneDrive/OneDrive%20-%20CIMMYT/Documents/CIMMYT/2021%20AR/plants-10-02596-v2.pdf https://doi.org/10.1155/2021/9915370
FP4	FP4 Outcome: 4.4 NARS increased use of participatory approach in system research	• Enhanced institutional capacity of partner research organizations	FP4 and partner scientists evidenced relevant outcomes in OICR 4479 for Southern Africa and several MELIA studies for Southern Asia (S4412, 4495), as well as for Latin America (S4496 4568). MAIZE, WHEAT, and partner researchers reinforced the ex-ante business case (S4487) for climate-smart practices	2020 extended to 2021 - multi-criteria assessments taking into account environmental and social acceptability aspects, based on	Completed	Significant progress over CRPs Phase 1 and/or Phase 2 documented. Some constraints to actual project implementation during 2021 due to Covid-19-driven restrictions.	•https://doi.org/10.1007/s10668-020-01106-0 •https://hdl.handle.net/10883/21865 •https://doi.org/10.1371/journal.pone.0252832

			(CSA, CASI) in South Asia. The Covid-19 pandemic constrained participatory research practice during 2021. Scientists also summarized and published research produced jointly with CCAFS colleagues (S4459), whilst assembling about 10 MELIA studies linked to climate change adaptation and mitigation.	standardized protocols for multi-criteria assessments of advanced crop management packages (not individual technologies)			•https://doi.org/10.1002/ldr.3816 •https://repository.cimmyt.org/handle/10883/21624
				2021 - more teamwork and interdisciplinary research practice in 10-15 partner organizations in specific scaling-out projects	Partially Complete	Limited progress in 2021, also due to Covid-19 restrictions reducing the scope for experiential learning, workshops, and trainings. Researchers linked variety adoption analysis with socio-economic household data (Ethiopia, EIAR; S3708; Bangladeshi national partners, S4462).	•https://marlo.cgiar.org/projects/Maize/study.do?expectedID=4462&edit=true&phaseID=329 •https://marlo.cgiar.org/projects/Maize/study.do?expectedID=3708&edit=true&phaseID=329
	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	Significant progress, in particular synthesizing findings and learning across bilateral projects under MAIZE: CSISA Phase III, Milpa systems in Central America.	2021 - Improved integrated weed management practices that decreases farmers' drudgery, particularly for women	Completed	Progressed as planned.	•https://marlo.cgiar.org/projects/Maize/study.do?expectedID=4583&edit=true&phaseID=329 •https://doi.org/10.1371/journal.pone.0246281
				2020 extended to 2021 - Adaptive research improves understanding of	Completed	Policy change-relevant research in South Asia and sub-Saharan Africa summarized in OICR4388;	•https://doi.org/10.1016/j.jspr.2020.101734

				gender, youth and adoption, adaptation, and scaling-up processes, with focus on market demand as trigger of innovation		results from multi-year studies documented (fertilizer use in SSA; smallholder food insecurity in Guatemala); some detailed case studies documented (e.g., joint decision-making in Ethiopian households re: maize price/selling; post-harvest storage).	•https://marlo.cgiar.org/projects/Maize/study.do?expectedID=4388&edit=true&phaseID=329 •https://doi.org/10.17170/kobra-202104133655 •https://www.frontiersin.org/articles/10.3389/fsufs.2020.00051/full •https://doi.org/10.1007/s10745-021-00252-x
	FP4 Outcome: 4.9 Smallholder farmers increased their capacity to adopt and adapt SI practices and products (associated with cross-cutting sub-IDO)	• Increased access to productive assets, including natural resources	FP4, in collaboration with FP1 published 10 adoption dynamics/pathways- and impact assessment-relevant papers. Several SLO evidence and OICRs document multi-year achievements in Sustainable Intensification scaling.	2021 - Decision support tools for farmers, service providers and development actors	Completed	Progress on validation, adaptation, and extension of farmer decision support tools: See Precision Nutrient Management in South Asia; and via TAMASA project in select Sub-Saharan countries. Two randomized trial (RCT) studies ongoing in Ethiopia and Nigeria, with regard to farmer adoption of targeted fertilizer recommendations (which increase productivity and profits).	•https://tamasa.cimmyt.org/tools-data/nutrient-management/ •https://doi.org/10.1016/j.agsy.2021.103181 •https://marlo.cgiar.org/projects/Maize/study.do?expectedID=4059&edit=true&phaseID=153
				2021 - Capacity change case studies in Ethiopia and Zimbabwe (survey work needed if Covid permits). Link to SI impact study	Completed	Multi-year work on better understanding Zimbabwe farmer adoption dynamics (Climate-smart Agriculture practices) published; ex-ante work on inorganic fertilizer use in maize systems in Ethiopia: Drivers for change (e.g. increased use) and project to better understand Ethiopian farmers' capacity to adapt to climate change (e.g. verify major adaptation practices, such as adjusting planting dates, intercropping, recommended mineral fertilizers, etc.).	•https://doi.org/10.1080/23311932.2021.1911046 •https://doi.org/10.3390/su13179622 •https://doi.org/10.1186/s40066-020-00277-3

	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	An OICR and several publications document progress on service provider business models and their implementation at (sub)-national levels.	2021 - Public private partnership related to scaling of small-scale mechanization assessed and documented	Completed	See OICR4042 under WHEAT, which is also relevant to rice- and maize-based systems in South Asia; better understanding adoption drivers and dynamics (South Asia, Nepal); detailed studies on maize shelling in sub-Saharan Africa, including gendered access;	• https://marlo.cgiar.org/projects/Wheat/studySummary.do?studyID=4042&cycle=Reporting&year=2021 •https://doi.org/10.1016/j.agsy.2021.103200 •https://doi.org/10.1016/j.techsoc.2021.101591
	FP4 Outcome: 4.10 Smallholder farmers adopted and adapted SI practices and products	• Closed yield gaps through improved agronomic and animal husbandry practices	See relevant sections SLO Table, OICRs and MELIA Table 10; Conservation Agriculture-based (CA) Climate-smart Agriculture innovations in southern Africa informed policy change - see Table 3, OICR4479. MAIZE/CIMMYT key knowledge providers to Government of Zimbabwe for its "Pfumvudza" scaling concept. By July 2021, the Ministry of Agriculture announced it had reached 2.2 million farmers, Farmers adopted CA systems in 3 sub-Saharan countries on 627,000 ha; and more than 3 million farmers have benefited from large governmental investment. -	2020 extended to 2021 - Strengthened ability to synthesize and apply available knowledge related to SI oriented research methodologies (multi-criteria assessments), management practices, technologies, machinery, in 10-15 partner orgs	Completed	Validation and promotion of The Integrated Agri-food System Initiative (IASI) methodology; mainly thanks to bilateral projects, MAIZE-NARS partner knowledge-sharing and -development, including on research methodologies continued at more or less 2020 levels.	•https://marlo.cgiar.org/projects/Maize/study.do?expectedID=4406&edit=true&phaseID=329 • https://doi.org/10.1371/journal.pone.0252832 • https://www.cimmyt.org/news/new-integrated-methodology-supports-inclusive-and-resilient-global-food-systems-transformation/ • https://globalagriculturalproductivity.org/partnership-pursues-new-approaches-to-productive-sustainable-food-systems/

			see SLO 1.1, Table 1.				
				2021 - more teamwork and interdisciplinary research practice in 10-15 partner organizations in specific scaling-out projects increased adoption of combinations of SI strategies, technologies with poverty reduction impact in specific target geographies compared to 2019	Completed	Several scaling-related papers published; Scaling Community of Practice meeting held; 10 MELIA studies by FP4/FP1 scientists on adoption pathways/drivers/dynamics documented in this Annual Report.	•https://doi.org/10.1016/j.cliser.2021.100248 •https://doi.org/10.1016/j.landusepol.2021.105482 •https://www.cimmyt.org/events/scaling-up-community-of-practice-cop/ •https://doi.org/10.1371/journal.pone.0251958
				2021 - SI impact assessment study conducted in 2 countries (Zimbabwe and Ethiopia). If Covid permits, farm surveys	Completed	See OICRs 4602 and 4479, as well as SLO Table 1: Documentation of Sustainable Intensification outcomes and impacts based on multi-year interventions, including gender & adoption dynamics/constraints aspects.	•https://doi.org/10.1016/j.foodpol.2021.102122 •https://doi.org/10.3390/agriculture11100938 •https://doi.org/10.1186/s40066-020-00277-3

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

(Sphere of control)

	Number	Percent
Peer-Reviewed publications	237	100.0%
Open Access	180	76%
ISI	208	88%

Publications will be accessible via the CGIAR Results Dashboard.

Table 7: Participants in Capacity Development Activities

Number of trainees	Female	Male
In short-term programs facilitated by CRP/PTF	1450	10444
In long-term programs facilitated by CRP/PTF	30	32
PhDs	22	23

Evidence Link

Table 8: Key external partnerships

Lead FP	Brief description of partnership aims (30 words)	List of key partners in partnership. Do not use acronyms.	Main area of partnership (may choose multiple)
FP1	Contribute to the development of classification criteria and feedback on the new maize mega environments developed.	• ICAR-IIMR - ICAR-Indian Institute of Maize Research • NARC - Nepal Agricultural Research Council • BARI - Bangladesh Agricultural Research Institute • NARS - National Agricultural Research System, Pakistan	• Research • Policy
FP2	Gene Editing project will help to bred high-quality seed of new hybrids that perform under stressful low-input, drought-prone conditions, including farming regions impacted by maize lethal necrosis (MLN).	• Corteva	• Research
FP3	Establishment of a state-of-the-art maize doubled haploid (DH) facility at Kunigal, India, and manage the DH operations.	• UAS - University of Agricultural Sciences, Bangalore	• Other
FP3	Multilocation trials, product deployment scale out / extensive strategic on-station trials. evaluation under different biotic and abiotic stress and optimal conditions.	• ICAR-IIMR - ICAR-Indian Institute of Maize Research • KALRO - Kenya Agricultural and Livestock Research Organization • ARC - Agricultural Research Council, South Africa • EIAR - Ethiopian Institute of Agricultural Research • INTA - Instituto Nicaragüense de Tecnología Agropecuaria • IDIAP - Instituto de Investigación Agropecuaria de Panamá • ICTA - Instituto de Ciencia y Tecnología Agrícolas (Guatemala) • AGROSAVIA - Corporación Colombiana de Investigación Agropecuaria • INIFAP - Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (Mexico) • BMWRI - Bangladesh Maize and Wheat Research Institute	• Research • Delivery
FP4	Research project that aims to improve the approaches of (RD) for assessing and achieving sustainable intensification of maize-based farming systems in Africa.	• WUR - Wageningen University and Research Centre	• Research
FP4	A cross-country working group on agricultural mechanization striving to improve knowledge on mechanization, exchange best practices among country projects and programs, and foster links between members and other mechanization experts.	• GIZ - Deutsche Gesellschaft für Internationale Zusammenarbeit / German Society for International Cooperation • FAO - Food and Agriculture Organization of the United Nations	• Capacity development

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
Gennovate 2- integration of gender transformative research and methodologies to advance change towards SDG 5 & 10 on gender and other forms of inequality.	ILRI, IITA, IWMI, WorldFish, BIOVERSITY, Gender, Wheat, RTB, IFPRI, CIAT, IRRI	Making sure efforts started during GENNOVATE are cultivated and moved forward important lessons and practices in the new CGIAR portfolio, HER+
Genotyping / sequencing tools and services: Mid-density genotyping applying a DArTAg genotyping method primarily suited to genomic selection applications, t can also be used for diversity studies, material fingerprinting or background recovery in marker assisted selection (MAS) to complement low-density genotyping.	EiB	Cost-effective flexible panel genotyping for between 200 up to 4,000 markers
Series of CGIAR webinars with a multidisciplinary approach to climate change and plant health.	RTB, RICE, IRRI, CIP, IITA, IFPRI, WHEAT, CIMMYT, A4NH, GLDC	Exploring the challenges posed by climate changes and transboundary pests to major crops
Multi-partnership, multi-year, farming systems research-in-development program -synergistic and coordinated efforts on sustainable intensification of smallholder farm households in different communities and countries.	AfricaRice, IITA	The main benefits of animal traction are more efficient planting and reduction in farm labor, which complement conservation agriculture advantages of on increased soil fertility, climate resilience, and crop productivity.
Documenting lessons learnt about scaling processes from Africa Rising projects. See MELIA Table 10 and here: https://doi.org/10.1371/journal.pone.0251958	ILRI, IWMI, Bioversity, ICARDA, ICRISAT, ICRAF	Contribute to improving scaling approaches

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
S3708 - Database linking DNA fingerprinting of adopted wheat varieties in Ethiopia with household survey information	On-going	Other MELIA activity	Ethiopia, DNA extraction; survey analysis & policy engagement: Grain samples of barley, maize and sorghum collected in six regions. Variety identification by matching samples to a reference library. Data became part of a study documenting the reach of CGIAR-related germplasms in Ethiopia. These objective measures of crop varietal adoption, unique in the public domain, can be analyzed along with a large set of variables related to agroecologies, household characteristics and plot management practices (from the Ethiopian Socioeconomic Survey 2018/19).	https://doi.org/10.3886/E124681V9 https://www.cimmyt.org/news/ethiopian-policymakers-consider-wider-use-of-dna-fingerprinting/ https://www.cimmyt.org/news/shining-a-brighter-light-on-adoption-and-diffusion/
S3709 - Global Sustainable Intensification assessment; Tool development and data collection for global assessment of Sustainable Intensification	Completed	Correlates of adoption/impact study	Farmer adoption of sustainable intensification technologies in the maize systems of the Global South published between 2007 and 2018 (137 adoption studies): Most empirical studies oversimplify the adoption process, thereby limiting the scope of learning on how the attributes of the technology and the dissemination system could have been altered to realize a more efficient and more inclusive technological change, by meeting the demand and needs of different farmer groups. MAIZE scientists argued for a realignment of empirical adoption analysis. The main findings were: (1) Limited information access and technologies not suitable for the small landholdings were the major constraints of farmer adoption of technologies. (2) Criticisms on the conventional adoption analysis were reaffirmed; (3) The empirical adoption research needs to incorporate the attributes of technologies and the socio-institutional context to develop better research strategies toward inclusive agrarian development.	https://hdl.handle.net/20.500.11766/66907

S3710 - Synthesis and learning products concerning maize germplasm adoption and impact assessment	Completed	Synthesis (secondary) study	Synthesis and learning products with regard to maize germplasm adoption and impact assessment, notably "Fifty years of maize research in the CGIAR: diversity, change, and ultimate success" (2021) and "Impacts of CGIAR maize improvement in sub-Saharan Africa, 1995-2015" (2021).	https://repository.cimmyt.org/handle/10883/21633 https://www.cimmyt.org/news/tracing-the-evolution-of-50-years-of-maize-research-in-cgiar/ https://repository.cimmyt.org/handle/10883/21292
S3711 - Develop and apply classification criteria for new maize mega environments (e.g. breeding profile development)	Completed	Ex-ante, baseline and/or foresight study	Develop classification criteria for new maize mega environments; related to breeding profile development	https://data.cimmyt.org/dataset.xhtml?persistentId=hdl:11529/10246
S3713 - Predicting adoption of sustainable intensification practices (Ghana)	Completed	Ex-ante, baseline and/or foresight study	Predicting adoption of sustainable intensification practices in northern Ghana: Findings suggest that farmers are truly interested in sustainable intensification (SI). Development actions are more likely to succeed if they consider preference heterogeneities among farmers and adapt to local conditions. Researchers proposed an evaluation criterion for designing and testing (a mix of) sustainable maize production technologies, to guide national and regional level efforts for R4D and scaling prioritization. One example of SI innovation is maize- legume strip cropping systems, which can mitigate production risk. Such cropping resulted in better grain yield productivity, income, and income risk reduction (on average 75%) than that of the sole cropping; and saved 90–100% (on average) of agricultural land for other agricultural activities. Another study offers different findings regarding grain yield but showed that maize leaf stripping had more positive than negative interactions with farm system performance (e.g., forage protein yield, sheep liveweight).	https://doi.org/10.1016/j.worlddev.2021.105789 https://doi.org/10.1002/agj2.20536 https://doi.org/10.1016/j.agsy.2021.103206

S3721 - Integrating the soybean-maize-chicken value chains to attain nutritious diets in Tanzania	On-going	Synthesis (secondary) study	Researchers employed fuzzy cognitive mapping to understand the current soybean, maize and chicken value chains, to highlight stakeholder relationships and to identify entry points for value chain integration to support nutritious diets in Tanzania. They found that the soybean, maize and chicken value chains were interconnected, particularly at the level of the smallholder farming systems and at processing facilities. Chicken feed is an important entry point for integrating the three value chains, as maize and soybean meal are the main sources of energy and protein for chicken. Enhancing local sourcing and adequate processing of soybean, coupled with strengthening the integration of smallholder farmers with other soybean, maize and chicken value chain actors offers an important opportunity to improve access to nutritious diets for local people. Their method revealed the importance of interlinkages that integrate the value chains into a network within domestic markets.	https://biblio1.iita.org/handle/20.500.12478/7248?show=full https://doi.org/10.1007/s12571-021-01213-4
S4405 - Status quo and opportunities for multinutrient biofortification of maize in Africa	Completed	Program/project evaluation/review	Many people's diets in sub-Saharan Africa (SSA) lack multiple, nutrients, since the majority of people heavily depend on cereals. Major limiting nutrients in maize-based diets are essential amino acids (lysine, tryptophan) and micronutrients (vitamin A, zinc and iron). Separate maize biofortification programs took on this challenge: Several cultivars were commercialized. This single-nutrient biofortified cultivars-strategy did not address the challenges in an integrated manner. Developing multi-nutritional attributes - maize with increased concentrations of both macro and micronutrients - is more promising, if factors contributing to low adoption are considered from the outset (e.g. affordable maize available; seed subsidies). Quality assurance at all breeding and seed production stages is critical, to ensure the nutritive value reaches consumers. Dietary diversification is practical and feasible as a long-term solution. Today, too many people in SSA cannot afford to consume diversified foods. Thus, focusing on preventing reduced nutrient bioavailability in some foods makes more sense.	https://doi.org/10.3390/nu13031039
S4406 - A new approach to tackle the shortcomings of food	Completed		The IASI methodology supports transformation of national food systems, by achieving consensus between multiple stakeholders and building on successful participatory agricultural research experiences. It has been piloted and validated via successful integrated development projects in Mexico and	https://doi.org/10.1371/journal.pone.0252832 https://www.cimmyt.org/new

production systems: The Integrated Agri-food System Initiative (IASI)		Ex-ante, baseline and/or foresight study	Colombia, the latter jointly by CIMMYT and Alliance Bioversity-CIAT. Virginia Tech's 2021 Global Agricultural Productivity Report endorsed the integrated agri-food systems methodology. Proponents call for a structured global network to advance adaptation and evolution of essential tools like the IASI methodology. IASI could serve as the backbone of new OneCGIAR Regional Integrated Initiatives (2022-2024).	s/new-integrated-methodology-supports-inclusive-and-resilient-global-food-systems-transformation/ https://globalagriculturalproductivity.org/partnership-pursues-new-approaches-to-productive-sustainable-food-systems/
S4412 - Why do Bangladeshi farmers adopt Zero Tillage? (ex-post, outcome level)	Completed	Program/project adoption or impact assessment	Based on a farm household survey with 606 rice-maize farmers, who had earlier either participated, or not, in Conservation Agriculture-based tillage (CA-T) trials, MAIZE scientists determined the factors influencing CA-T adoption and its intensity. After five years of trials (2009-13), participatory (236) and non-participatory farmers (370) had adopted CA-Ts in 12% and 3% respectively of annual cropped areas, with overall adoption of 6.6% of annual cropped land – and up to 30% for winter maize, a relatively new crop in the country. Factors explaining adoption of CA-T are age, cropping system, climate, soil, machinery, and project services. Cropped area and farm size are factors that affect only the intensity of adoption. The most recent assessment (published 2018) of CA-T adoption in Bangladesh in 2015/16 came to 15,000 ha (of ca. 7.7M ha arable land (2018), or of 790,000 ha maize & wheat area (USDA, 2019).	https://doi.org/10.1016/j.wdp.2021.100297 https://doi.org/10.1080/00207233.2018.1494927 https://taa.org.uk/wp-content/uploads/2019/02/2018_Kassam_Global_spread_of_CA.pdf
S4415 - Long-term trials show soil health benefits of Conservation Agriculture in Ethiopia	Completed	Program/project adoption or impact assessment	Long-term (2005–2013) influence of Conservation Agriculture-based systems on soil health and crop productivity in northern Ethiopia: Treatments used include two types of CA-based systems (permanent raised bed PRB and contour furrowing CF) and conventional tillage (CT) arranged in a randomized complete block design. Two pathways in which CA-based systems contributed to improved productivity: (a) via higher density of bacteria and improved hydraulic conductivity, and (b) via higher density of fungi and increase soil organic carbon content in the topsoil. The study	https://doi.org/10.1002/ldr.3816

			concludes that CA-based systems have the potential to improve crop productivity through improved soil health.	
S4455 - Staple cereals will provide 50% of daily calories in 2050; and higher nutritional value too	Completed	Other MELIA activity	FAO (2017: pp.83–84) projected that staple cereals to continue to play a critical role for food security till 2050, contributing nearly half of both daily calories and protein intake in low- and middle-income countries. Considerable benefits in terms of yields and sustainability have been also found in integrated systems, where maize and wheat, livestock production and agro-forestry in SSA are practiced together (e.g., Baudron et al., 2014). Echoing the Royal Society (2009), because of the scale of the food security challenge, no option should be ruled out. Staple cereals will remain critical for adequate and affordable intake of calories and proteins in diets in Africa and Asia. More diverse diets call for complementary investments in many food groups. The decline of natural resources will continue in Africa, if more nutrients are not provided to the soils. In contrast, in many parts of Asia, intensity of production has to be reduced.	https://doi.org/10.3389/fsufs.2020.617009 https://repository.cimmyt.org/handle/10883/21504
S4457 - How many maize & wheat farmers will there be in 2030? (CGIAR-level foresight & targeting)	Completed	Ex-ante, baseline and/or foresight study	Maize is cultivated on 197 million ha, of which 32% is produced in Low and Lower-Middle Income Countries (L/LM-IC's). Compared to the HICs in 2020, LICs have more than four-fold the number of farms, double the rural population on half the agricultural area, and a tenth of HICs average farm size. Based on projected crop areas, maize will overtake wheat as the most widely grown crop in the world in the coming decade. Researchers estimate that a third and a fifth of global farms cultivated maize and wheat respectively in 2020, increasing with 5% to 227 million maize farms globally and decreasing 4% to 130 million wheat farms globally by 2030. Farms will remain the foundation of rural development. The farm number estimates, and associated indicators merit more attention in global sustainable development efforts and the quest to understand and support economic and rural transformation.	https://doi.org/10.1016/j.gfs.2021.100558 https://doi.org/10.1177%2F00307270211025539
S4458 - Climate-smart agriculture in Zimbabwe: Farmer	Completed	Ex-post adoption study	Climate-smart Agriculture (CSA) offers important opportunities for enhancing food security and incomes, via greater agricultural productivity. Researchers investigated CSA adoption using cross-sectional survey data collected from 386 households (e.g., sample of adopters and non-adopters) across 4 districts in Zimbabwe. The econometric results show that soil	https://doi.org/10.1186/s40066-020-00277-3

adoption dynamics & impacts			fertility status in fields, distance to input and output markets, ownership of communication assets, and Total Livestock Units (TLU) significantly impact on the farmers' decision to adopt CSA (or not). This also indicates that CSA adoption has had a significant, positive impact on the welfare of the farmers (e.g., income & food security).	
S4459 - The future of India's cropping mix / rotation from a water footprint perspective (CCAFS/WHEAT)	Completed	Other MELIA activity	Scientists gained insights into the influences of climate change on India's future water footprints (WF) of cereal crop production and put forth regional strategies for future water resource management. In view of future variability in the WFs, a water footprint-based optimization for relocation of crop cultivation areas, with the aim of minimizing blue water use (fresh, non-renewable), would be a possible management alternative.	https://www.nature.com/articles/s41598-021-88223-6
S4462 - Better understand farm-level productivity and household income generation in coastal Bangladesh	Completed	Other MELIA activity	Discussions with farmers in Coastal Bangladesh showed they prefer using off-farm income to purchase agricultural inputs, rather than credit. Public policy that creates off-farm income generation opportunities is particularly likely to be of use, where current level of fertilizer application is below optimum. This applies particularly to resource-poor farm families. Where farmers routinely over-apply fertilizers, or practice imbalanced application, more complex policy and development interventions may be needed: educational programs, direct training and behavioral nudging methods that may encourage more rational use. Increasing awareness about negative externalities of inappropriate use will be important. The overall declining tendency to apply manure underscores the importance of balanced fertilization, including organic sources of fertilizer - and the negative environmental externalities of inorganic fertilizers.	https://doi.org/10.1371/journal.pone.0256694
S4463 - How do eastern and southern African farmers adapt to climate change?	Completed	Other MELIA activity	78% of the sampled smallholder maize farmers perceived increasing temperatures while 83% perceived decreasing amounts of rainfall. About 75% of the farmers indicated that they became aware of climate change and variability from their own experience and perceived deforestation as the main cause; that drought, diseases, and pests, dwindling soil fertility, and declining crop yields were major impacts of climate change affecting maize production. Farmers' major adaptation practices include adjusting planting dates, using improved varieties, intercropping, recommended mineral	https://doi.org/10.3390/su13179622

			fertilizers, supplementary irrigation, and soil and water conservation measures. In future, both governmental and non-governmental organizations should support farmers by building their capacity and enhancing their access to irrigation water via climate-smart water harvesting technologies, climate-smart varieties, information on weather forecasts and inputs and agro-chemicals.	
S4471 - Continuous improvement in molecular breeding: Low cost arrays for genetic analyses and molecular breeding through genotyping by target sequencing and liquid chip	Completed	Other MELIA activity	Molecular breeding efforts have been constrained in developing countries' NARS and smaller companies by a lack of high-throughput and cost-effective genotyping platforms that can be shared across the community - and due to limited resources. Despite significant progress, the current genotyping by target sequencing (GBTS) system needs to be improved for cost reduction and wide application in molecular breeding. MAIZE and CAAS scientists investigated options for cost-effective, user-friendly, and less-demanding platforms. They developed a new SNP array in maize that can be captured in solution, increasing the marker loci from 20K to 40K. A new protocol enabled identification of more than six SNPs from each individual amplicon, further reducing the cost of genotyping. The system was validated in terms of its power for DNA variation detection and genome-wide association study (GWAS). The technologies & protocols developed for maize can serve as a model for similar systems in other plants.	https://doi.org/10.1016/j.xplc.2021.100230
S4472 - Delivering climate-smart breeding solutions cost-effectively and faster: The case for an enviromic assembly approach.	Completed	Other MELIA activity	Quantitative genetics states that phenotypic variation is a consequence of the interaction between genetic and environmental factors. Predictive breeding is based on this logic. MAIZE scientists present an “enviromic assembly approach,” which uses ecophysiology knowledge in shaping environmental relatedness into whole-genome predictions (GP) for plant breeding (referred to as enviromic-aided, E-GP). Researchers derived markers of environmental similarity cost-effectively and then designed optimized multi-environment trials coupling genetic algorithms, enviromic assembly, and genomic kinships capable of providing in-silico realization of the genotype-environment combinations that must be phenotyped in the field. As proof of concept, they highlighted two E-GP applications. They observed that E-GP outperforms benchmark GP in all scenarios, especially for smaller training sets. Representativeness of genotype-environment	https://doi.org/10.3389/fpls.2021.717552

			combinations is more critical than size of multi-environment trials. Enviromic assembly enabled prediction of the quality of a yet-to-be-seen environment, by increasing the accuracy of yield plasticity (variation observed across diverse growing conditions) predictions.	
S4474 - Is breeding possible for maize roots traits that impact soil organic matter mineralization?	Completed	Ex-ante, baseline and/or foresight study	Maize root traits associated with soil organic matter mineralization have a heritable genetic basis. Root length, root diameter and plant-derived C mineralization are strong predictors of soil organic matter mineralization. Two candidate maize genes are associated with enhanced soil organic matter mineralization rates. There is potential to target these genes, to enhance release of nutrients from soil organic matter, with potentially beneficial effect on nutrient/nitrogen use efficiency, fertilizer use and consequent lower negative environmental impact.	https://doi.org/10.1016/j.soilbio.2021.108402
S4483 - Conservation Agriculture effects on soil health in the diverse Mexican farming environments	Completed	EPIA: Ex-post Impact Assessment	Physicochemical soil health (soil quality) was studied in 20 trials in agroecologies (2018), ranging from handplanted traditional systems to intensive irrigated systems, initiated between 1991 and 2016. Soil under Conservation Agriculture practices (CA) was compared to local conventional practice (CP), which commonly involves tillage, residue removal, and continuous maize production. Across the sites, under CA, organic matter and nitrates were higher in the top (0–5 cm) layer of soil and soil aggregate stability was greater than under CP. For other soil health parameters, such as nutrient content, pH or penetration resistance, the effects of management varied widely across sites and soil types; most were determined more by local soil type than by management. CA increased maize yields at most sites, on average by 0.85 ± 1.80 t ha^{-1}.	https://doi.org/10.1002/ldr.3894
S4485 - N2O emission hotspot countries possess considerable mitigation potential linked to their maize and wheat production	Completed	Ex-ante, baseline and/or foresight study	Scientists estimated the potential for N2O emission reductions from maize and wheat fields based on reducing excess N applications while keeping current yield levels. Results show considerable N2O emission reduction globally, particularly in those countries and regions where existing N losses and emissions are very high (see Fig. 6). Although limited in spatial coverage, previous studies showed huge (~ 44 Tg yr^{-1}) global total N losses from maize, wheat and rice fields, mostly concentrated in China and USA for maize, and China & India for wheat and rice production. This points to a tremendous potential for improving N use efficiency (NUE) in cereal	https://doi.org/10.1016/j.scitotenv.2021.146696 https://doi.org/10.1111/gcb.15588

			production in many countries, without compromising yield - and even increasing it.	
S4486 - Is there a link between Climate-smart agriculture in Zambia and deforestation?	Completed	Other MELIA activity	In aggregate, smallholder cropland expansion into forests represents about 60% of the estimated 250,000 ha of forests lost per year in Zambia. Most households expanded cropland because they needed to meet subsistence food requirements; a few others in response to market opportunities. Scientists did not find statistically significant associations between adopting Climate-smart Agriculture practices (CSA) and cropland expansion in this nationally representative sample (2019). Given the low extent and intensity of CSA adoption, relying only on CSA as a means to spare forests may be risky.	https://doi.org/10.1016/j.landusepol.2021.105482
S4487 - Changing current agricultural practices in Bangladesh can contribute to Climate Change mitigation	Completed	Ex-ante, baseline and/or foresight study	Scientists identified mitigation options, their potentials and cost or benefit of adoption in the form of Marginal Abatement Cost Curves (MACC). Based on their analysis, total GHG emissions from agricultural sector in Bangladesh for the year 2014–15 is 76.79 million tonne (Mt) carbon-dioxide equivalent (CO_2e). Business-as-usual GHG emissions from the agricultural sector in Bangladesh are approximately 86.87 and 100.44 Mt CO_2e $year^{-1}$ by 2030 and 2050, respectively. Adoption of climate-smart crop and livestock management options would offer GHG mitigation opportunities of 9.51 and 14.21 Mt CO_2e $year^{-1}$ by 2030 and 2050, respectively. Of this mitigation potential, 70–75% can be achieved through cost-saving options that could benefit smallholder farmers. Examples of climate smart management practices and mitigation options: Alternate wetting and drying (AWD) for rice, improved nutrient-use-efficiency particularly for N, adoption of strip-tillage; for livestock: green fodder supplement, increased concentrate feeding and improved forage/diet management for small ruminants.	https://doi.org/10.1016/j.scitotenv.2021.147344
S4488 - Land-sharing or -sparing to minimize trade-offs between agriculture and biodiversity? We	Completed	Other MELIA activity	Scientists, particularly ecologists, have looked for strategies to minimize trade-offs between agriculture and biodiversity. Two major limitations of the land sparing/sharing framework are: Relying only on yield-density relationships that focus on trade-offs and overlook synergies between agriculture and biodiversity; and the overemphasis on crop yield, neglecting	https://doi.org/10.1016/j.biocon.2021.109167 https://www.cimmyt.org/blogs/sharing-or-sparing-land/ https://www.slideshare.net/CIMMYTAfricaagronomy/1st-

need more interdisciplinary R4D!			other metrics of agricultural performance which may be more important to local farmers, and more relevant to positive biodiversity outcomes.	lunch-meeting-18-august-2021-frdric-baudron
S4491 - Systematic evaluation of CIMMYT project portfolio that focused on climate change-food system interactions	Completed	Other MELIA activity	By bringing together a Digital Methods perspective and machine learning techniques, researchers systematically analyzed CIMMYT's climate research portfolio at various levels and assessed CIMMYT's engagement with the broader network of climate action. Key learnings: The geographical focus of climate research centered on three main countries: Mexico, India, and Ethiopia. Farming systems, Food security, Technology transfer, and Innovation were the most frequent cross-cutting topics across the four data sources. Profitability, Productivity, Production, Resource management, Adaptation and Mitigation were the most frequent climate-focused topics in all content assessed. Farming systems and Food security were the cross-cutting topics with the most significant and steady rise in prevalence over time. The climate-focused topics emerging in the last five years across the datasets are Carbon sequestration, Emission reduction, Energy conservation and Sustainable intensification. CIMMYT's outputs have been distributed to more than 150 countries across both the Global North and South.	https://hdl.handle.net/10883/21865
S4495 - Changing South Asian farmers' fertilizer practice requires combining the right incentives with the right information.	Completed	Other MELIA activity	Fertilizer policies review and extension efforts to promote the balanced application of nutrients in Bangladesh, India, Nepal, and Sri Lanka and draw 4 important lessons. If true, the dismantling of fertilizer subsidies may not be economically desirable or politically feasible. DCT requires the removal of price controls, integration of land records, farmer identity cards, a cash transfer system with universal coverage, and a competitive fertilizer retail sector. This leaves us with two options for rationalizing subsidies. Option one is to allow a gradual increase in the price of urea over the next few years and transfer the money saved on subsidy to farmers through other channels to garner their support for this change. The second option is to switch to non-distortionary direct cash transfer of fertilizer subsidies.	https://doi.org/10.1016/j.gfs.2020.100464
S4496 - Understanding Mexican smallholder farmers' intention to	Completed	Other MELIA activity	Very few studies have focused on drivers of the farmer's intention and initial decision to adopt. Based on a survey of 394 smallholder farmers in 2019, this study investigated willingness to adopt an agricultural advice app in Guanajuato, Mexico. Results showed that the intention to adopt the app is predicted by how farmers appraise the technical infrastructure and acquire	https://doi.org/10.3390/agronomy11020194

adopt agricultural apps			new knowledge by using an app. The multi-group analysis revealed that performance expectancy is a relevant predictor of the intention to adopt, whereas the mastery-approach goal is relevant only for younger farmers and farmers not connected to the innovation hub. This study provides valuable insights about the innovation hubs' role in the intention to adopt apps, offering precision agriculture advice in developing countries.	
S4498 - How to fight child zinc (Zn) deficiency in Ethiopia	Completed	Ex-ante, baseline and/or foresight study	Study confirms that zinc (Zn) deficiency is a serious public health problem in Ethiopia and related to low soil Zn. We expanded that analysis by calculating the potential impact in terms of the number of Zn-deficient children that could be reached. This strengthens the evidence on the potential of Zn agronomic biofortification. However, the potential impact of Zn fertilizer on Zn-deficient soils in maize- and wheat-based (or other cereal-based) systems, at least by soil application, is limited. If grain Zn could be increased through Zn fertilizer on less deficient soils, the potential could be much larger, depending on the maximum soil Zn level up to which Zn fertilizer is effective in increasing grain Zn. More experimental work is needed.	https://doi.org/10.1038/s41598-021-88304-6
S4499 - How much damage has Fall Armyworm (FAW) done in Ethiopia between 2017 and 2019?	Completed	Other MELIA activity	Using a combination of an agroecology-based community survey and nationally representative data from an agricultural household survey, authors found that over 3 years (2017-19), FAW caused an average annual loss of 36% in maize production, or 0.67 M tons (0.225 M tons p.a.), equivalent to 2.54% of the maize production. Total economic loss was US$ 200 million, or 0.08% of the gross domestic product. Lost production could have fed 4 million people with maize (based on 152 kg per capita p.a.). Governments and development partners need to invest more in sustainable FAW control strategies. Researchers also found that insecticides to control FAW have more and significant toxic effects on the environment than on humans. The efficacy of a synthetic insecticide-based management strategy is not guaranteed, as FAW has developed resistance to many active ingredients from different classes of insecticides, calling for innovations and scaling in/of integrated pest management.	https://doi.org/10.1371/journal.pone.0257736
S4500 - Climate-smart agricultural practices (CSA) make Kenyan			Using primary data from 250 randomly sampled maize farmers in Kenya, scientists developed a resilience index and a structural equation model to assess Climate Smart Agriculture (CSA)-based farmer resilience. With a 0.72	

maize farmers more resilient	Completed	Other MELIA activity	Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (above recommended minimum), authors concluded that maize farmers affected by climate variability were more resilient when they used CSA practices, suggesting enhanced resilience to climate variability. To analyze the maize household resilience index, the study used a structural equation model (SEM), which was significant. Results indicated that both maize-legume intercropping and use of manure as fertilizer reduce the variance in maize yields, suggesting that they enhanced the resilience of maize farmers. CSA practices improve farmers? food security and welfare, and their adoption should be promoted.	https://hdl.handle.net/10883/21866
S4533 - Where people live in Ethiopia and Malawi influences access to cereals-derived micronutrients and their composition	Completed	Program/project evaluation/review	Scientists showed that there is geospatial variation in the composition of micronutrients that is nutritionally important at subnational scales. in Ethiopia and Malawi. For rural households consuming locally sourced food—including many smallholder farming communities—the location of residence can be the largest influencing factor in determining the dietary intake of micronutrients from cereals. Positive relationships between the concentration of selenium in grain and biomarkers of selenium dietary status occurred in both countries. Surveillance of micronutrient deficiencies (on basis of biomarkers of status and dietary intakes surveys) could be improved by using subnational data on the composition of grain micronutrients. Beyond dietary diversification, interventions to alleviate deficiencies (e.g., food fortification, biofortification) to increase micronutrient concentrations in crops should account for geographical effects that can be larger in magnitude than intervention outcomes.	https://doi.org/10.1038/s41586-021-03559-3
S4536 - Farm size drives food security and income; land is often very constraining in 6 sub-Saharan countries;	Completed	Correlates of adoption/impact study	A detailed analysis of food self-sufficiency, food and nutrition security, and income among households from divergent farming systems in Ethiopia, Ghana, Mali, Malawi, Tanzania, and Uganda, revealed marked contrasts in food security and household incomes. The different case studies examples reveal a strong interplay between population density, farm size, market access, and agroecological potential on food security and household incomes. Within each location, farm size is a major determinant of food self-sufficiency and a household's ability to rise above the living income threshold. Closing yield gaps strongly increases the proportion of households	https://doi.org/10.1007/s12571-021-01209-0

Subsistence farming isn't farming!			that are food self-sufficient. Yet in four of the locations (Ethiopia, Tanzania, Ghana and Malawi), land is so constraining that only 42–53% of households achieve food self-sufficiency and a living income. Farming will remain very important for food security and income, as one enterprise among a diverse livelihood portfolio - that competes with off-farm options.	
S4547 - What farm size and -practices sustain a living in smallholder sub-Saharan Africa? 3 scenarios in the East African Highlands	Completed	Other MELIA activity	MAIZE and partner scientists explored what is a "viable farm size" in sub-Saharan Africa; the farm area required to attain a "living income," sustaining a nutritious diet, housing, education, and health care. Three modeling/survey-based scenarios focused on constraints that farmers face. They showed that with current yields, cultivated areas would have to increase considerably to attain a living income (up to 4 times the median cultivated area) - and also that feasible yield increases would lift 70% of the households to a living income on their current cultivated area, in some cases combined with livestock or other income. Households unable to earn a living income from farming would need social protection and/or alternative employment. Fundamental institutional and policy changes are needed to address both rural poverty and the greater agricultural productivity needed to meet growing national food demand.	https://doi.org/10.3389/fsufs.2021.759105 https://www.frontiersin.org/articles/10.3389/fsufs.2021.759105/full
S4562 - Farming trajectories, landscape change and the role of rural communities	Completed	Other MELIA activity	Results of these studies show how a combination of socio-economic and biophysical factors can affect landscape change, but it also shows the often-overlooked role of communities as a relevant bottom-up driver of change. A typology of farm household trajectories can be used to monitor policy impact and households' strategic responses, to arrive at better articulation of policy objectives and policy impact while considering household type diversity. Communities can conserve natural resources despite of adversities such as poverty.	https://doi.org/10.1016/j.landusepol.2020.104912 https://doi.org/10.1016/j.jrurstud.2020.10.022
S4567 - Mexican farmers may more readily adopt Conservation Agriculture via smaller	Completed	Other MELIA activity	This study suggests that disaggregating Conservation Agriculture (CA) into smaller component packages could increase farmer adoption in risky contexts. Our findings provided valuable insights on CA feasibility and could help establish policy and reporting metrics. The study highlighted the need for employing a range of research tools to understand the relative value of	https://doi.org/10.3390/agronomy11061214

component packages. Policy implications.			agricultural innovations and to identify and reduce trade-offs and uncertainty in farming systems.	
S4568 - Milpa systems drive improved nutrition (diverse diets) in Mesoamerica	Completed	Other MELIA activity	Based on analysis of 357 plots for which specific yields were available, milpa systems present higher total productivity than mono-cropped maize, expressed as total energy yield of the harvested crops in the respective system, and were also better at providing the recommended daily allowances of fourteen essential nutrients, based on a Potential Nutrient Adequacy (PNA) indicator. Maize-bean-potato, maize-potato, and maize-bean-faba intercrops had the highest PNAs, and mono-cropped maize, the lowest. These results support the implementation of milpa systems tailored to different agroecologies, to improve nutrition in Guatemala's western highlands and a variety of similar regions. Similar nutrition advantages were also highlighted in other studies in Mexico.	https://doi.org/10.1038/s41598-021-82784-2 https://doi.org/10.1371/journal.pone.0246281 https://www.frontiersin.org/articles/10.3389/fsufs.2020.00051/full
S4583 - In Bangladesh, India and Nepal, Zero Tillage use did not reinforce or deepen existing gender inequalities	Completed	Other MELIA activity	Findings indicate that the switch to Zero Tillage contributed to substantial time savings in India and Nepal and did not lead to any reallocation or increased burden of roles and responsibilities to women in any of the surveyed localities (24 households in 3 countries), while knowledge on weed management practices were balanced among spouses (e.g., no gendered knowledge divide created). In contrast to other study findings for other geographies (which warrants more in-depth analysis), Zero Tillage use did not reinforce or deepen existing inequalities within households. Zero Tillage may be an important component of an inclusive agricultural development pathway in the Eastern Gangetic Plains (EGP). Further research on the inclusivity of ZT in the context of labor burden in the EGP is needed. Extension efforts should target herbicide use as it becomes more normalized, enabling both male and female community members.	https://doi.org/10.1177%2F00307270211013823
S4584 - Near-Infrared Reflectance Spectroscopy for Protein, Tryptophan, and Lysine Evaluation in Quality Protein Maize (QPM) Breeding	Completed	Other MELIA activity	MAIZE scientists examined the potential of near-infrared reflectance spectroscopy (NIRS) to enhance the efficiency of quality protein maize (QPM) research efforts, by partially replacing more expensive and time-consuming wet chemistry analysis.	https://pubs.acs.org/doi/10.1021/jf201468x

S4586 - Nutritional properties of Ogi powder and sensory perception of Ogi porridge made from synthetic provitamin A: Novel Maize genotypes	Completed	Other MELIA activity	This study evaluated the chemical, carotenoid composition, and retention of PVA, the phytic acid content in ogi powder, and the sensory perception of ogi porridge produced traditionally from three novel PVA maize genotypes (PVA SYN HGAC0 Maize 1; PVA SYN HGBC0 Maize 2; and PVA SYN HGBC1 Maize 3) and one yellow maize variety (control).	https://www.frontiersin.org/articles/10.3389/fnut.2021.685004/full
S4595 - Comprehensive assessment of farmer-desired traits in Ghana to drive future breeding	Completed	Ex-ante, baseline and/or foresight study	Using participatory rural appraisal involving farmers, input dealers, traders, and processors (in Northern Ghana), researchers gathered trait preferences, which overlapped and revolved around grain quality including nutritional value, and stress tolerance and grain yield. Overall, farmers preferred high-yielding varieties with multiple cobs per plant, white grain endosperm color, and bigger and fully filled cobs. This first-time holistic assessment revealed a comprehensive list of traits, which breeders could build on. Most national/public maize breeding programs in West and Central Africa already consider drought tolerance, Striga resistance, early maturity, and grain yield as high priority traits. In responding to demand (e.g., comprehensive list above), breeders could incorporate other traits into new varieties. While new varieties are being developed, old varieties could be replaced by the more recently released, early maturing drought- and Striga-tolerant hybrids that are more suited to northern Ghana value chain actors' preferences.	https://doi.org/10.1007/s13593-021-00708-w
S4596 - Nutritional properties and consumer preferences of soy-fortified maize snacks at household level to combat hidden hunger.	Completed	Other MELIA activity	A study evaluated the nutritional, properties, and consumer preferences of five maize-based snacks at the household level to combat undernutrition/hidden hunger, most especially Fe and Zn deficiencies. The addition of soy flour and eggs caused an increase of about 50% ash content in the product this implies that Fe, Zn, and other minerals contents will be markedly higher in the soy-fortified maize products. Maize snacks have proven to contain high nutritional content whose quality can be further improved by fortification with soybean flour with a reasonable level of acceptability. This will help to create a diversity of nutrient-dense foods, thereby shrinking the pool of an under-nourished population. Maize chin-chin fortified with 20% soy flour has the highest acceptability in Monze, Katete, and Mkushi districts.	https://www.mdpi.com/2304-8158/10/4/750 https://www.tandfonline.com/doi/full/10.1080/23311932.2020.1868665

S4597 - How fertilizer application increased the number of marketable maize cobs and cassava storage root yields profitability in the cassava-maize intercropping system	Completed	Other MELIA activity	Fertilizer application had significant effects on the yield of crops and profitability in the cassava-maize intercropping system. The study shows how fertilizer application increased the number of marketable maize cobs and cassava storage root yields. As is well-known, most tropical soils lack important nutrients required to sustain or improve crop yield, Hence, N, P, and K fertilizer application can improve crop yields and many studies have indeed reported the beneficial effects of NPK fertilizers on the yields of cassava and maize, either as sole crops or when intercropped (Adeniyan et al., 2014; Ezui et al., 2017; Munyahali, 2017; Olasantan et al., 1994; Kreye et al., 2020).	https://doi.org/10.1016/j.fcr.2021.108283
S4609 - AFRICA RISING project portfolio-based lessons learnt on scaling	Completed	Program/project evaluation/review	Documenting lessons learnt about scaling processes from Africa Rising projects, based on qualitative assessment (e.g. focus group discussions, key informant interviews, document analysis): The Africa RISING experience shows that well beyond the technicalities of validated innovations, scalability is often contingent on the scalar politics that define the research project in the first place, and the complex partnerships required for scaling, e.g. local partners in local innovation systems were part of scalar politics involving government bureaucracies and coordination and linkage mechanisms of agricultural extension and development. Researchers identified four broad lessons for the current understating of agricultural innovation scaling. First, scaling requires a balance between the technical and the social dynamics surrounding scaling targets and actors; scaling is never 'just' linear and that scaling strategies need to be flexible, stepwise, and reflective, to manage the social, processual and emergent nature of the practice of scaling.	https://doi.org/10.1371/journal.pone.0251958
S4625 - Have public-private GMO breeding research partnerships brought benefits for smallholder farmers?	Completed	Program/project evaluation/review	Independent scientists concluded that with more than two decades of experience, CIMMYT partnerships with multinational companies to access new science (in this case GMO) have yet to yield significant impacts for smallholders. Insect resistant GMOs hold the most promise. The conventional breeding component of the WEMA project (Monsanto, now Bayer Crop Science) yielded several hybrids for drought-prone environments that have accounted for around 2% of annual seed sales of drought tolerant hybrid seed of CGIAR origin. GMO approaches may soon be supplanted by new gene editing technologies (e.g. new science) that are less controversial	https://repository.cimmyt.org/handle/10883/21633

			and more cost effective (Byerlee, see chapter: Partnerships with the Multinational Sector to Access New Science, 2021, p.32-36).	

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

Not applicable.

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

	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 & environmental data	FP3 new diseases & pests: FAW, MLN, Spittlebug	FP2-3: Germplasm improvement methodologies, methods, data management (e.g., genetic gain, cross-crops) FP4: Research on scaling out, innovation pathways	MAIZEISC, MAIZE -MC. SMB, Board Member (DG), CRPs Rep in SMB, MEL CoP co-leadership
Validation	FP3: New traits into elite lines: heat & drought. Precision phenotyping platforms with NARS partners; yield testing. FP1: draw lessons from the previous MAIZE years and across MAIZE W3/bilateral studies and geographies to identify implications and priorities for enhancing the impact of MAIZE in Phase-II		FP4: Country coordination, systems research approaches; strategic support to national research programs, private-sector led scaling FP2: develop decision support tools to enhance genetic gains in breeding programs, in partnership with EiB.	
Scaling out (downstream)	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., FP4: Country coordination, companion crops into maize- based systems, capacity development	
CGIAR-SRF Cross-cutting themes	Gender / social inclusion applied to MAIZE innovations and rapid value chain assessments with proper gender lens		FP1, 4: AFS-CRPs & CCAFS FP3: MAIZE & A4NH on improved nutrition How to improve gender mainstreaming into research	

Table 13: CRP Financial Report

CRP on MAIZE

2021 POWB SUMMARY BY CATEGORY

(000) USD

Classification	Forecast 2020 (Carryover)	Budget 2021	Total budget 2021	Comments on Major Changes
Personnel	320	2,743	3,063	
Consultancy	-	542	542	
Travel	55	107	162	
Operational Expenses	390	2,660	3,050	
Collaborators & Partnerships	1,405	1,727	3,132	
Capital & Equipment	7	1,301	1,308	
Closeout Cost		-	-	
CRP Total Budget	**2,177**	**9,080**	**11,257**	Lower carryover (final audited figures) Vs prior version at $29K

CIMMYT

Classification	Forecast 2020 (Carryover)	Budget 2021	TOTAL Budget	
Personnel	320	1,243	1,563	
Consultancy	-	542	542	
Travel	55	103	158	
Operational Expenses	390	2,381	2,771	
Collaborators & Partnerships	1,405	1,727	3,132	
Capital & Equipment	7	1,301	1,308	
Closeout Cost	-	-	-	
CRP Total Budget	**2,177**	**7,297**	**9,474**	Lower carryover (final audited figures) Vs prior version at $29K

RESEARCH PROGRAM ON
Maize

CGIAR

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