MAIZE Full Proposal Draft 1.5
(Status 19th, February, 2016)
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Section 1: CRP MAIZE-AFS Phase II

1.1 Rationale and scope

With its multiple uses, maize is the world’s most multi-purpose crop; it is a staple food for hundreds of millions of people in the developing world, and provides feed to billions of livestock (especially poultry), in addition to the increasing industrial and biofuel uses. Maize is cultivated in 184 million hectares (M ha) globally, with a production of 1016 million metric tonnes (MMT) (FAOSTAT, 2013). By 2023, maize will account for the greatest share (34%) of the total area harvested, followed by wheat (23%) and oilseeds (17%) (OECD-FAO, 2014). Maize plays a key role in the food security and livelihoods of millions of poor farmers; 64% of the total maize production comes from low- and middle-income countries. Maize alone contributes over 20% of total calories in human diets in 21 low-income countries, and over 30% in 12 countries that are home to a total of more than 310 million people.

Maize’s central role as a staple food in Africa and Central America (Figure 1) is comparable to that of rice or wheat in Asia, with consumption rates being the highest in eastern and southern Africa (ESA). Of the 22 countries in the world where maize forms the highest percentage of calorie intake in the national diet, 16 are in Africa (Nuss and Tanumihardjo, 2011). Maize accounts for almost half of the calories and protein consumed in ESA, and one-fifth of the calories and protein consumed in West Africa. In Mesoamerica, annual maize consumption exceeds 80 kg per capita in El Salvador, Guatemala, Honduras and Mexico (Shiferaw et al., 2011). Although direct maize consumption is lower in South and South-east Asia, there are several areas in the highlands and tribal regions (e.g., Nepal, Bhutan, India, south China, south-western Bangladesh, Indonesia, Philippines) where maize is a main staple (Prasanna, 2014).

Population growth, changing diets and a rapidly growing poultry sector contribute to the sharp increase in maize demand. During 1991-2011, total utilization of maize almost doubled in Asia (Ramesh Chand and Saxena, 2014). Part of the response to the rising demand for maize has been bringing new land into cultivation. However, further expansion of the maize area will come at the cost of crop diversity and forests, and will be on erodible hill slopes, unless efforts to increase productivity are implemented more widely with involvement of poor farmers. Also, there are other areas of concern: ongoing soil erosion and degradation, loss of soil fertility, global warming associated with reduced and erratic rainfall and yield reductions in the tropics, and competition for/lack of rural labor (OECD-FAO 2014).

MAIZE focuses on the needs of the poor and disadvantaged in the maize agri-food systems. Initiated in 2011, it is a collaborative effort between the CGIAR Centers engaged in maize research-for-development (R4D) (CIMMYT, IITA, ILRI, CIAT and ICRAF), together with over 350 public and private sector partners worldwide. **MAIZE has a tremendous area of influence.** It develops and delivers germplasm to public
and private sector institutions in 108 mostly (sub-) tropical countries. These recipient countries include 98% of all the poor (<US$ 1.25) that live in maize growing areas. Also, MAIZE is more than a commodity program. Through the evolution of its own research into farm livelihood focused approaches and the integration of several sites from the Humid Tropics Program, it works and links with other CRPs (see Table 5 and Annex 3.7) on sustainable intensification and poverty reduction approaches in 24 focus countries (Figure 2) encompassing 76% of all poor in maize-based agri-food systems in low- and lower-middle-income countries.\(^1\)

**Figure 2.** Countries where MAIZE focuses on sustainable intensification, mapped by poverty.

MAIZE contributes to several Intermediate Development Outcomes (IDOs) of the CGIAR Strategy and Results Framework (SRF), most prominently the increased resilience of the poor to climate change and other shocks, increased incomes and employment, increased productivity, improved diets for poor and vulnerable people, and enhanced benefits from ecosystem goods and services. Among the cross-cutting IDOs, it contributes to adaptation and mitigation of climate change, greater equity and inclusion of women, and improves the enabling environment and capacities of national partners and beneficiaries (see Table 1 and Table 2).

MAIZE offers significant opportunities for enhancing productivity, resilience, natural and human resources in view of climate change, through its unique global germplasm exchange network and the sustainable intensification of distinct maize agri-food systems. In partnership with other CRPs (Table 5) as well as an array of public and private sector partners (Annex 3.2.1 and Annex 3.2.2), MAIZE ensures that the technologies and approaches for sustainable, resilient and profitable intensification are targeted towards the smallholders, and developed and adopted by them, while drawing on the best innovations worldwide and effectively combining genetic, biotechnological, agronomic, agro-ecological and socio-economic data and approaches. Technologies and approaches includes stress and climate resilient and nutritious maize varieties, new farm management and agronomic technologies, decision-making tools for crop production and marketing, scale-appropriate mechanization, and opportunities for value-addition, the reduction of losses and gender-responsive interventions. MAIZE also develops and provides policy advice to promote a more enabling environment for maize agri-food system development.

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1 Maize based agri-food systems are defined as agricultural lands with more than 25% of maize in the crop rotation, and inhabited by 219 million poor (<US$ 1.25). Maize growing areas includes all areas where maize is grown; these are inhabited by 977 million poor.
1.2 Goals, objectives, targets

MAIZE will contribute to the achievement of ten Sustainable Development Goals (SDGs) outlined by the United Nations, in particular to: End poverty in all its forms everywhere (SDG 1); End hunger, achieve food security and improved nutrition, and promote sustainable agriculture (SDG 2); Ensure healthy lives and promote well-being for all at all ages (SDG 3); Achieve gender equality and empower all women and girls (SDG 5); Ensure availability and sustainable management of water and sanitation for all (SDG 6); Promote sustainable, inclusive and sustainable economic growth, full and productive employment and decent work for all (SDG8); Ensure sustainable consumption and production patterns (SDG12); Take urgent action to combat climate change and its impacts (SDG 13); Protect, restore and promote sustainable use of terrestrial ecosystems, halt and reverse land degradation and biodiversity loss to improve natural resources systems and ecosystems services (SDG 15); and Strengthen the means of implementation and revitalize the global partnership for sustainable development (SDG 17). These SDGs are closely aligned with the System Level Outcomes and associated (sub-) IDOs of the CGIAR Strategy and Results Framework.

MAIZE contributes to the CGIAR Strategy and Results Framework (SRF) and Grand Challenges through a mutually reinforcing framework of five Flagship Projects (FPs): 1) Enhancing MAIZE’s R4D strategy for impact, including gender and social inclusiveness; 2) Novel diversity and tools to increase genetic gains; 3) Stress tolerant and nutritious maize; 4) Sustainable intensification of maize-based cropping systems for better smallholder livelihoods, and; 5) adding value for maize producers, processors and consumers (see Table 1).

Table 1: SRF Grand Challenges addressed by MAIZE Outcomes

<table>
<thead>
<tr>
<th>Grand Challenges / Flagship Projects</th>
<th>GC1: Competition for land from multiple sources: food and feed crops, livestock, bio-fuels and biomaterials, forest products, conservation, urban expansion, and a host of other ecosystem services.</th>
<th>GC2: Soil degradation on land already farmed in circumstances where new lands brought into production are often poorly suited for intensive agriculture.</th>
<th>GC3: Climate change threatening agriculture, while at the same time agriculture is a substantial producer of greenhouse gases.</th>
<th>GC4: Overdrawn and polluted water supplies threatening social breakdown and rising levels of conflict.</th>
<th>GC6: Diminishing genetic resources. Between 7 and 25% of vascular plant species are under threat of extinction by 2050.</th>
<th>GC7: Nutritious and diverse agri-food systems and diets are becoming more important. Increased consumption of animal products, fruits and vegetables alongside traditional cereal staples offers scope to improve nutritional and health outcomes among the undernourished.</th>
<th>GC8: Post-harvest losses of crop, livestock, fish, and tree-products to pests, spoilage and spillage are estimated at 30% to 50% globally. Reducing these losses offers considerable opportunities to improve the availability and affordability of food.</th>
<th>GC9: Employment and income opportunities created for men, women and youth as a result of the development of value chains for staple products and the provision of improved seeds, husbandry practices and small-scale mechanization.</th>
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<tbody>
<tr>
<td>FP1 Enhancing MAIZE’s R4D Strategy For Impact</td>
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<td>FP2 Novel Diversity and Tools for Increasing</td>
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**Value for Money**

**MAIZE is effective.** The CGIAR IEA team report on MAIZE ([FINAL REPORT: Evaluation of CRP on MAIZE](#)) stated: "MAIZE is largely a coherent program, which because of the unique genetic resources at its disposal, its excellent research facilities, its considerable breeding capacity and its partnerships and global mandate, has a strong comparative advantage that is consistent with its goals, SLOs and the SRF of the CGIAR." The IEA Report also stated that investments in maize research have had high returns, and MAIZE is well on target in its efforts to increase maize productivity in its target groups by 7% in 2020 and 33% in 2030. This would provide sufficient maize grain to meet the annual food demand of an additional 135 million poor consumers in 2020 and of 600 million consumers in 2030. The IEA team expressed confidence that MAIZE is ready to meet the future challenges and will contribute substantially to the CGIAR targets for poverty alleviation, food security and sustainable management of natural resources ([FINAL REPORT: Evaluation of CRP on MAIZE](#)).

Based on the importance of maize for poor producers and consumers in the developing world, one can estimate MAIZE’s potential contributions to SRF (2030) targets (Table 3). Additional benefits will arise through feed uses of maize and its impact on the price of animal produce. It is important that methodologies for calculating such impacts are aligned between CRPs.

**Table 2:** MAIZE contributions to SRF-SLO commitments, estimated relative to the importance of maize for poor producers and consumers (see details in Table 3 and Annex 3.6.3).

<table>
<thead>
<tr>
<th>SRF Targets (2030)</th>
<th>MAIZE Targets (2030)</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SLO 1: Reduced poverty</strong></td>
<td></td>
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<tr>
<td>1.1 350 million more farm households have adopted improved varieties, breeds or trees, and/or improved management practices.</td>
<td>41 M</td>
<td>137 M farm households producing maize in low- and middle-income countries; 20-40% impacted by MAIZE (depending on country income level)</td>
</tr>
<tr>
<td>1.2 100 million people, of which 50% are women, assisted to exit poverty</td>
<td>17 M</td>
<td>Based on the relative importance of maize for poor producers and consumers</td>
</tr>
</tbody>
</table>
### SLO 2: Improved food and nutrition security for health

<table>
<thead>
<tr>
<th>Objective</th>
<th>2.1 Improve the rate of yield increase for major food staples from current &lt;2% to 2.5% per annum (pa)</th>
<th>2.5% pa</th>
<th>SRF target assumes 50% improved germplasm: 50% crop management</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.2 150 million more people, of which 50% are women, meet minimum dietary energy requirements</td>
<td>25 M</td>
<td>Estimates relate to calculations available for rice</td>
</tr>
<tr>
<td></td>
<td>2.4 33% reduction in women of reproductive age who are consuming less than the adequate number of food groups.</td>
<td>5 M</td>
<td>Reaching 15% of the female poor in maize based systems in 24 MAIZE focal countries; potentially many more through impact of low maize prices</td>
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### SLO 3: Improved natural resources systems and ecosystems services

<table>
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<tr>
<th>Objective</th>
<th>3.1 20% increase in water and nutrients (inorganic, biological) use efficiency in agro-ecosystems, including through recycling and reuse.</th>
<th>10 M ha</th>
<th>25% maize area in focal countries</th>
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<td></td>
<td>3.2 Reduce agriculturally-related greenhouse gas emissions by 0.8 Gt CO$_2$ yr$^{-1}$ (15%) compared with a business-as-usual scenario in 2030.</td>
<td>TBD</td>
<td>To be defined, mostly based on N savings</td>
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<td>3.4 7.5 million ha of forest saved from deforestation</td>
<td>2 M ha</td>
<td>Stevenson et al. (2013) PNAS 110: 8363-8368.</td>
</tr>
</tbody>
</table>
Table 3: MAIZE Targets Matched to CGIAR SRF-SLO Targets

**Assumptions:**
- One target matched to at least one sub-IDO, even if other sub-IDOs relevant, to keep progress-towards-outcome monitoring manageable.
- Several sub-IDOs may have to be achieved to reach the SLO-level target.
- Several progress indicators may need to be monitored to assess progress toward one target and sub-IDO.

<table>
<thead>
<tr>
<th>SRF Targets (2030)</th>
<th>Relates to SDG</th>
<th>MAIZE Strategic Goals &amp; Targets by 2030 via MAIZE FP</th>
<th>Relates to CGIAR sub-IDO</th>
<th>Proposed Indicators</th>
</tr>
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<tr>
<td><strong>SLO1: Reduced Poverty</strong>&lt;br&gt;1. 350 M more farm households have adopted improved varieties, breeds or trees, and/or improved management practices&lt;br&gt;2. 100 M people, of which 50% are women, are assisted to exit poverty</td>
<td>2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture</td>
<td>A. 41 M (out of 137 M farm households producing maize in low- and middle-income countries) adopt improved maize varieties and/or improved agronomic management practices.&lt;br&gt;B. Annual genetic yield gains of 0.7&gt;&gt; 1% (under stress-prone tropical/subtropical environments) achieved via international partnerships and a steady flow of improved MAIZE germplasm to NARES and private sector for testing and adaptation, resulting in enhanced adoption of genetically diverse stress tolerant varieties in sub-Saharan Africa (SSA), Asia and Latin America (LA).&lt;br&gt;C. At least 17 M poor people, of which 50% are women, assisted to exit out of poverty through adoption of combination of improved management/agronomy technologies in maize-based agri-food systems&lt;br&gt;D. At least 100 new stress-resilient (with tolerance to drought, heat,</td>
<td>FP3 (aided by FP2), FP4, FP5 and FP6 (aided by FP1)</td>
<td>Enhanced genetic gain on-farm (1.4.3)&lt;br&gt;Increased value capture by smallholders (1.3.3)&lt;br&gt;Reduced production risk and greater input use efficiency (land, labor, purchased inputs, water) (1.1.2) OR&lt;br&gt;Reduced pre-, post- production losses (1.4.1)</td>
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waterlogging, acidity; resistant to major
diseases, insect-pests, and parasitic
weeds), nutrient use efficient and
nutritious maize hybrids/varieties
commercialized by seed company
partners in target geographies, replacing
the existing less-productive and 15+
year-old varieties.

E. More than US$100 M per year value
added, as women and men farmers
across SSA, Asia and LA change to new,
improved maize varieties every year
(10% variety replacement rate of 15+
year-old varieties), during 2015-2030

F. By 2030, total harvest losses (yield,
quality) avoided in the target regions in
SSA, Asia and LA, by farmers’ adoption
of improved stress tolerant maize
varieties (e.g., at least 20 MLN resistant
varieties in SSA); benefits estimated at
c. $ 500 M (conservative estimate).

| SLO 2: Improved food and nutrition security for health | 2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture. | G. via A4NH  
H. 10 M people consume nutritious maize-based food products by 2030 across SSA, LA and Asia (target to be finalized) | Linking FP3 (CoA 3.2) with A4NH, besides FP5 and FP6 | Increased availability of diverse nutrient-rich foods (2.1.1) | See A4NH  
• Number of households consuming nutritious maize-based food products in SSA, LA and Asia.  
• Number of maize germplasm characterized and improved for quality and processing traits  
• Number of seed companies producing and delivering nutritious maize varieties in SSA, LA and Asia  
Number of value chains analysed and nutritionally enhanced |
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<td>1. 500 M more people (50% female) without deficiencies of one or more essential micronutrients</td>
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<tr>
<td>SLO 3: Improved natural resources systems and ecosystems services</td>
<td>1. End poverty in all its forms 2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture 6. Ensure availability and sustainable management of water and sanitation for all.</td>
<td>FP4 and FP6 Agri systems diversified, intensified in ways that protect soils and water (3.2.2) Reduced GHG emissions from agriculture, forests ... (A.1.1)</td>
<td>• % change in nitrate leaching, P losses • % change in herbicide/pesticide use per unit of production • % change from baseline for soil C indices, erosion indices, soil biological properties • SDSN 12: [Nitrogen use efficiency in food systems] – to be developed • Crop water productivity (tons of harvested product per unit irrigation water) – to be developed</td>
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<tr>
<td></td>
<td>1. 20% increase in water and nutrient use efficiency in targeted maize-based farming systems by 2030 (target to be finalized)</td>
<td></td>
<td>CCAFS: Gt CO2-e yr-1</td>
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<td></td>
<td>J. Reduced agriculturally-related GHG emissions in wheat-based farming systems by 15%, compared to business-as-usual scenario, in 2030 (target to be finalized)</td>
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1.3 Impact pathway and theory of change

The MAIZE impact pathway, as presented below and associated Flagship Program theories of change were developed during workshops with Flagship Program teams. A participatory approach was used to capture all views, experiences and known evidence. The impact pathway will serve as the CRP’s hypotheses of the way by which change is expected to occur from output to outcome and impact.

On the basis of the Flagship Programs’ theories of change, the CRP will be focusing on eleven sub-IDOs and six cross-cutting sub-IDOs:

- 1.1.2 Reduced production risk;
- 1.3.1 Diversified enterprise opportunities;
- 1.3.2 Increased livelihood opportunities;
- 1.3.3 Increased value capture by producers;
- 1.3.4 More efficient use of inputs;
- 1.4.1 Reduced pre- and post-harvest losses, including those caused by climate change;
- 1.4.2 Closed yield gaps;
- 1.4.3 Enhanced genetic gain;
- 1.4.4 Increase conservation and use of genetic resources;
- 2.1.1 Increased availability of diverse nutrient-rich foods;
- 3.2.2 Agricultural systems diversified and intensified in ways that protect soils and water;
- A.1.4 Enhanced capacity to deal with climatic risks and extremes;
- B.1.2 Technologies that reduce women’s labor and energy expenditure developed and disseminated;
- B.1.3 Improved capacity of women and young people in decision-making;
- C.1.1 increased capacity of beneficiaries to adopt research outputs;
- D.1.1. Enhanced institutional capacity of partner research organizations; and
- D.1.3 Increased capacity for innovation in partner research organizations.

From these areas of focus and in line with the CGIAR Strategy and Results Framework, the CRP will contribute to reducing poverty (SLO 1), improving food and nutrition security for health (SLO 2), and improving natural resource systems and ecosystem services (SLO 3) by the mean of increasing resilience of the poor to climate change and other shocks (IDO 1.1), increasing income and employment (IDO 1.3), increasing productivity (IDO 1.4), improving diets for poor and vulnerable people (IDO 2.1), enhancing benefits from ecosystem goods and services (IDO 3.2), and enhancing the cross-cutting issues of climate change (A), gender and youth (B), policies and institutions (C) and capacity development (D).

The CRP impact pathway and associated Flagship Program theories of change respond and will contribute to the achievement of ten Sustainable Development Goals outlined by the United Nations (SDGs 1, 2, 3, 5, 6, 8, 12, 13, 15 and 17 – as detailed in section 1.2).
Figure 3: MAIZE CRP Impact Pathway

UN’s SDGs
1. No poverty
2. No hunger
3. Good health
4. Gender equality
5. Clean water and sanitation
6. Decent work and economic growth
7. Responsible consumption and production
8. Climate action
9. Life on land
10. Peace and partnership for the goals

SLOs
1. Reduced Poverty
2. Improved food and nutrition security for health
3. Improved natural resource systems and ecosystem services

1.1 Increased resilience of the poor to climate change and other shocks
1.1.2 Reduced production risk

1.3 Increased income and employment
1.3.1 Diversified enterprise opportunities
1.3.2 Increased livelihood opportunities
1.3.3 Increased value capture by producers
1.3.4 More efficient use of inputs

1.4 Increased productivity
1.4.1 Reduced pre- and post-harvest losses
1.4.2 Closed yield gaps
1.4.3 Enhanced genetic gain
1.4.4 Increased conservation and use of genetic resources

2.1 Improved diets for poor and vulnerable people

2.2 Enhanced benefits from ecosystem goods and services
3.2.2 Agricultural systems diversified and intensified in ways that protect soils and water

Cross-cutting IDOs and Sub-IDOs
Climate Change
A.1 Mitigation and adaptation achieved
A.1.4 Enhanced capacity to deal with climatic risks and extremes

Gender & Youth
B.1 Equity & inclusion achieved
B.1.2 Technology that reduce women’s labor and energy expenditure developed and disseminated
B.1.3 Improved capacity of women and young people to participate in decision-making

Policies and Institutions
C.1 Enabling environment improved
C.1.1 Increased capacity of beneficiaries to adapt research outputs

Capacity Development
D.1 National partners & beneficiaries enabled
D.1.1 Enhanced institutional capacity of partner research organizations
D.1.3 Increased capacity for innovation in partner research organizations

CRP Research and Development Outcomes
Theory of Change FP1 — Enhancing R4D Strategy for Impact

- Theory of Change FP2
  - Novel Diversity and Tools

- Theory of Change FP3
  - Stress Tolerant and Nutritious Maize

- Theory of Change FP4
  - Sustainable Intensification

- Theory of Change FP5
  - Adding Value
Results-Based Management and Monitoring, Evaluation, Learning and Impact Assessment

MAIZE will develop and implement a comprehensive results-based management (RBM) framework which will be based on six globally recognized RBM principles:

- A culture focused on outcomes;
- Strong leadership in RBM to model results orientation across the system;
- Participatory approaches at all levels including partners and stakeholders;
- Learning and adaptation through the use of performance information;
- Accountability and transparency where program staff are held accountable for appropriate levels of results that are acquired and reported in a transparent manner; and
- Utilization-focused and flexible operational system where RBM tools, procedures and practices can be adapted based on contexts and needs.

In order to effectively implement the RBM framework, strengthening monitoring, evaluation, learning and impact assessment (MELIA) will be necessary at both project and program levels. A robust and strategic plan is proposed and will support CRP cycle of planning, budget allocation, reporting steps. Operationalization of the plan will take place following submission of the proposal under the guidance of the CGIAR Monitoring, Evaluation and Learning Community of Practice.

For further details on the RBM framework and MELIA strategic plan, please refer to section 3.6.

1.4 Gender

The integration of gender and social inclusion in CRP MAIZE is guided by the MAIZE Gender Strategy (link). The point of departure for the way CRP addresses gender and social inclusion is to look at agriculture as a social practice (Fairhead & Leach 2005). This means paying attention to and analyzing the social context within which farming occurs, and which often enables or constrains opportunities and outcomes differently, for different social groups. Gender is a key part of that social context, often intersecting with other social identities such as age, caste, ethnicity etc.

New technologies are often targeted to poor farmers and consumers, or even to women specifically. However, women and men adopters live and work in the midst of complex social relationships, e.g. at household level, group and community level, market system level, and the wider society.

Power relations at each of these levels affect the extent to which women, and men, use and benefit from technologies. However, gender relations and the wider social institutional context (including
norms, mindsets) are not fixed (Risman 2004, Martin 2004, Kabeer 1994). MAIZE recognizes that in order to design and undertake agricultural R4D that is both technically and socially robust, it is necessary to understand and take into account, how agri-food systems operate across different social enabling environments.

The relevance of gender for maize R4D

Gender relations are a key aspect of the real-life contexts that agricultural technologies are deployed within. They affect what results can be achieved, how, and for whom. Key constraint to maize production include labor shortage, low soil fertility, land degradation, drought, insufficient institutional support, lack of knowledge, access to fertilizer and other inputs, micro-finance etc. Depending on the context, these constraints can all have significant gender dimensions (Doss & Morris 2001; Fisher and Kandiwa 2014; Hampton et al 2009; IFAD 1999; Kassie et al. 2014; Morris et al 1999; Ndiritu et al. 2014; World Bank, FAO and IFAD 2008).

Gender stereotypes and social restrictions often exclude certain groups, e.g. women, from research and extension programs, and from participation in farmer participatory experiments, demonstrations and field days. When men migrate, and women are left in charge of the farm, labor production relations are affected. Women sometimes face several constraints in addressing these challenges, for instance, because of lack of access to technical knowledge and technologies, which can reduce their drudgery and provide additional income (Bellon et al. 2002, Beuchelt and Badstue 2013; Mehr and Hill Rojas 2008; Quisumbing and Pandolfelli 2009). Moreover, women’s “triple roles” are well acknowledged in the literature (Momsen 2010, Moser 1993). To the extent that domestic and caring responsibilities may limit their mobility, women often lose out on crucial opportunities for learning and interactions that could stimulate agency and innovation.

Traits and technology preferences

Both men and women maize farmers value grain yield and stress resilience, and varieties of different crop cycle duration (Banziger and de Meyer 2002). However, several studies show, that women and men often rate maize characteristics differently and prefer different combinations of traits, because of the intended maize consumption objectives, e.g. for market, for own consumption, food security, special dishes, feed etc. (Bellon 1996; Bellon et al. 2000; Bellon 2002; Bellon et al. 2003; Deere 2005; Badstue 2006; De Groote and Kimenju 2008; De Groote et al 2013; Hellin et al. 2010, Lunduka et al 2012; Galie 2013). Men often prefer high-yielding varieties in view of the associated potential for selling of surplus production. In many cultures, women are traditionally regarded as the custodians of family diets. Women’s reproductive roles can influence their priorities towards a focus on food security and/or varieties that are both palatable and nutritious and further meet processing and storing requirements (Smale et al 1992; Smale and Heisey 1994, 1997; Smale 1995; Doss 2001; Bellon et al. 2003; Badstue 2006; Hellin et al. 2010). In addition to this, both in Mexico and Southern Africa, women farmers’ varietal preferences are also linked to their productive role and represent an important source of female income generation, e.g. from the artisanal processing and sale of maize products (Doss 2001; Bellon et al. 2003; Badstue 2006). However, as has been pointed out e.g. by Bourdillon et al. (2007) the bottom line is that gender differentiated preferences cannot be assumed. Rather, they are influence by crop use, local context and the gender division of labor.

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Other gender differences in preferences, needs and constraints, may apply to other types of technologies (e.g. related to post-harvest storage, labor saving, crop or natural resource management practices) or manifest themselves differently under different circumstances. As documented for instance by Paris and Pingali (1996), the same technology may have a positive impact in one context or for one social group, but not in another context or for another social group (see also Farnworth et al 2015; Nyanga et al. 2012; Beuchelt and Badstue 2013). The examples present trade-offs related to agricultural technologies, which in general are associated with positive development impacts. However, it is not necessarily possible to predict, how the introduction of new technologies may affect the patterns of labor, resource and land allocation between men and women, or how this, in turn, may influence whether the new technology will be adopted or not, and who will benefit/lose. Both intended and unintended impacts can occur at individual, household and / or community level. The challenge of estimating potential consequences therefore relates both to gender considerations (Doss 2001), as well as to broader aspects of human and sustainable development.

**Information and value chains**

One of the greatest constraints that poor women farmers face is access to new knowledge and reliable information on new technologies and practices (Aryal et al 2015; Meinzend-Dick et al 2011; Manfre et al, 2013). Information is important to women whether or not they are the final decision makers on what seed, fertilizer or other input to buy. When deferring to their spouses, it helps for the women to discuss and debate from the standpoint of knowledge. On the same note, it is best when both spouses have adequate information.

Maize is also an important cash crop in many contexts, however, with a few exceptions (e.g. Doss and Morris 2001) the literature on maize production and —markets has paid limited attention to gender perspectives, and has often failed to identify the differences in constraints faced by women and men as producers, processors, traders etc. and as knowledge seekers and buyers of inputs and services.

**Vulnerability and risk**

It has been argued that due to their socially constructed roles and responsibilities and the various constraints that tend to weigh heavier on women, women are often particularly vulnerable as well as responsive to shocks, e.g. climate variability and change, and depletion of the natural resource base (Alston and Whittenbury 2014). For example, as custodians of household food security in many contexts, women have a lot more at stake when a season fails, because they bear the brunt of managing hungry, malnourished, and sick children.

**Female farmers as agents of change**

Men and women both make significant contributions in maize-based farming systems and livelihoods, although gender roles in maize cultivation vary greatly across and within regions. On average women comprise 43 % of the agricultural labor force in developing countries, ranging from 20 % in Latin America to 50 % in Sub-Saharan Africa and East Asia (Quisumbing et al 2014; FAO 2011). Their contribution to agricultural work varies even more widely, depending on the specific crop and activity. By their sheer numbers, these women farmers represent an important potential market that needs to be understood, taken seriously, and be served. Given recent trends of rural out-migration primarily by men, the proportion of women in farming has either remained stable or increased. Regardless of the variations across regions, women make up a large part of the world’s small-scale maize farmers. As such they are important agents for agricultural development and change.
Women maize farmers participate actively in the maize economy through their involvement in the production, post-harvest and processing activities. They are also active participants in decision making about technology adoption: On one hand some women manage whole farms as female household heads or in the absence of their husbands. On the other hand, women also manage individual plots within male headed households, and most importantly, women provide significant input into the negotiations regarding technology adoption, where farming is managed jointly.

**Integrating gender in MAIZE:**

The integration of gender in MAIZE is guided by the MAIZE Gender Strategy (link), whose objective is to promote equality of opportunity and outcomes for resource-poor farmers in maize-based systems, including women and men, youth and other social groupings.

The MAIZE Gender Strategy follows a two-pronged approach: 1) Integrative gender research via the application of gender analysis as part of other technical research, e.g. socio-economic research, maize breeding or crop management; and 2) strategic gender research to further expand the knowledge base concerning gender specifically in relation to maize-based farming and livelihoods. Both of these avenues contribute to inform and deepen the relevance of other MAIZE research themes, as well as the overall CRP priority setting and targeting, in order to enhance the impact of maize agri-food systems R4D.

Drawing on the recommendations from the MAIZE Gender Audit undertaken in 2013, and to stimulate and catalyze the process of integrating gender considerations in MAIZE across the various flagships and throughout the project cycle, the gender research activities are complemented by additional investments to mainstream gender into program frameworks and procedures, as well as to strengthen the capacity of scientists and research teams to integrate gender into research. As results and lessons learnt are generated in gender analysis and -research implementation, these will provide feed-back to the FP- and CRP- based learning processes and contribute to further development and adjustment of the programmatic frameworks, which, in turn, will inform the next generation of research projects and adjustments in the diverse FP implementations. As these dynamics progress and gain traction, the integration of gender in MAIZE continues to expand and improve.

The MAIZE Gender Strategy (link) lays out the MAIZE gender impact pathway and includes an overview of key gender issues and research questions related to each of the five FPS; and of the details of the operational aspects related to integrating gender as part and parcel of MAIZE R4D.

**Gender issues informing MAIZE Phase-II**

Ensuring gender-responsive outcomes is an integral component of MAIZE’s strategy for maximizing impact. The Phase-II MAIZE proposal is informed by gender research achievements from Phase-I, which includes strategic and integrative gender research on small-scale mechanization (Eerdedwijk & Danielsen 2015), improved post-harvest storage technologies (Kandiwa et al, forthcoming), conservation agriculture (Farnworth et al 2015), participatory varietal selection (PVS), and seed sector development (Kandiwa et al, forthcoming). Similarly progress has been achieved in relation to documenting gender aspects of technology adoption and impact assessments, e.g. Teklewold et al 2013a; Gitonga et al 2013; Teklewold et al 2013b; Rodney et al 2013; Fisher and Kandiwa 2014; Ndiritu et al 2014; Farnworth et al

3 For brief overview of the MAIZE Gender Strategy, see also Annex 4
Selected ongoing projects (e.g. SIMLESA, DTMA, IMAS, FACASI, WEMA, CSISA) include integrative gender research, e.g. gender responsive technology development and testing in SSA; for instance integration of gender considerations in value-chain R4D and capacity building; gender responsive service provision and information diffusion in S Asia; assessing the life histories of women’s and men’s cultivated plots and how they have evolved over time in SSA; and action-oriented pilot projects in SSA to motivate and engage young adults in a range of improved crops, post-harvest processing and agri-business opportunities, and to take agriculture as a viable business.

MAIZE is also a leading actor in GENNOVATE (link), a cross-CRP comparative research initiative focusing on how gender norms and agency influence the ability of men, women and youth to learn about, try out, adopt and adapt new agricultural technologies. MAIZE findings from GENNOVATE will strengthen the key role of contextually grounded systems approaches and actions - needed for the design and roll-out of equitable and efficient maize agri-food systems innovations. The reports and publications based on this work, as well as the study methodology, will fill an important gap in the existing gender and maize-based systems literature and contribute to CRP MAIZE’s strategic planning of phase-II by: (1) enhancing the gender responsiveness of MAIZE’s targeting, priority setting and theories of change; (2) advancing gender transformative outcomes of maize research and development interventions at scale; (3) building the evidence base and actions to address the role of gender norms in relation to adoption of improved maize technologies and related development processes.

1.5 Youth
Gender is a relational concept, intersecting with other social identities, including youth. As such, gender and youth are not mutually exclusive, but often intersect, depending on the specific context/situation. In CRP MAIZE, the approach to gender is informed by the concept of social heterogeneity, i.e. men and women, boys and girls representing and experiencing diverse combinations of social identities and positionalities, for instance belonging to different social or ethnic groups, different ages, etc. As such, in CRP MAIZE, gender research in principle also includes consideration of young men and women. Youth-focused research, on the other hand, centers on young men and young women.

With increased focus on the role of youth in relation to agri-food systems development, in phase II CRP MAIZE will seek to increasingly address youth-centered research questions. In 2016 and the first stage of phase II, CRP MAIZE will develop a strategic framework for its engagement with young people and youth-related issues, as well as implement key standards for age-disaggregation in data collection and analysis. The rationale and overall approach for how CRP MAIZE will address youth in its research in phase II is outlined in Annex 5.

1.6 Program structure and flagship projects
MAIZE contributes to the CGIAR Strategy and Results Framework (SRF) and Grand Challenges through a mutually reinforcing framework of five Flagship Projects (FPs): 1) enhancing MAIZE’s R4D strategy for impact, including gender and social inclusiveness; 2) novel diversity and tools to increase genetic gains; 3) stress tolerant and nutritious maize; 4) sustainable intensification of maize-based cropping systems for better smallholder livelihoods, and; 5) adding value for maize producers, processors and consumers.
Figure 4: Inter-relationships among MAIZE Flagship Projects.

**FP1** enhances MAIZE’s R4D across all the Flagships, informing strategies for impact through foresight and targeting, learning from adoption and impacts, strategic and transformative gender research, and identifying value chain opportunities. FP1 integrates socio-economic research with germplasm improvement, agronomy and value addition. FP2 draws on the genetic diversity held in trust in the CIMMYT/IITA maize germplasm bank and focuses on characterizing and exploiting genetic diversity for germplasm enhancement. It develops enabling tools and identifies traits and novel germplasm resources which are mainstreamed through FP3 for increasing genetic gains. **FP3**, guided by FP1, uses outputs from FP2 and develops high-yielding, stress tolerant and nutritious maize varieties that are targeted at region-specific needs of the poor, and deployed in partnership with over 300 partners. It supports maize seed sector development of over 200 indigenous, small- and medium-sized enterprises to develop increasing access by the 40-50% smallholders that are not reached by established seed companies. It leverages germplasm globally and among projects, and contributes to climate change adaptation and increased rates of genetic gain in farmers’ fields. It targets stress-prone and other areas not served by the private breeding sector, and affected by maize diseases and pests with devastating impact on smallholder food production. **FP4** generates and tests farming systems intensification technologies and institutional innovations to improve farm livelihoods in maize agri-food systems with high poverty concentration. Comprehensive, climate-smart genotype-by-environment-by-management solutions are co-developed with local partners, farmers and value chain participants including young entrepreneurs,
and through site integration with other CRPs. It scales up and out sustainable intensification practices through innovation platforms, and other multi-stakeholder mechanisms. FP5 strengthens maize value chains from harvest-to-fork, based on analysis of pro-poor options for value-addition by producers and local processing groups. It provides an entry point for incorporating the needs of processors, retailers and consumers in the developing world and offers linkages with aggregators and processors to tap into local surplus production of maize and reduce losses.

1.7 Cross CRP collaboration and site integration
Significant cross-center and cross-CRP site integration took place during Phase-I. MAIZE Agri-Food Systems (AFS) CRP will therefore start from a strong base in Phase-II. Most of the achievements in terms of site integration and existing cross-center collaborations are a direct consequence of multi-center large W3/bilateral projects, particularly in Africa and Asia (see Table below).

One of the key challenges AFS CRPs, such as MAIZE (and WHEAT) face, is defining appropriate ‘entry points’ at the site/system level that define research questions (what are we trying to solve and at what scale?), and hence the necessary local, country and regional partnerships and frameworks that will drive integration and scaling on the ground at multiple levels. One key ‘entry-point’ is livelihoods, primarily of farming households, but also including consumers, small-scale processors and other maize value chain actors; people ultimately make the decision on where to invest their human and capital resources within the context of their livelihood system.

MAIZE-AFS is involved in 14 of the 20 CGIAR Site Integration Country Collaborations, which include all the six ++ countries (see Table below). MAIZE-AFS co-leads in three countries (Nepal, Tanzania and Zambia), of which Tanzania is a ++ country. This process has just started but initial discussions suggest the priorities are: (i) national level integration to align CGIAR with national (and donor) agricultural development strategies in line with CGIAR/GCARD3 processes, and in line with country investment plans, (ii) identifying key AR4D issues – including capacity development – where CGIAR and national programs can integrate their activities more closely, and (iii) improved integration on the ground of CGIAR CRP and partner activates in well-defined and representative research sites. Site integration was also identified as a mechanism to ensure joint research funding and outputs, effective use of resources, capacity strengthening, and policy engagement, which should strengthen the enabling environment and offer significant opportunities to respond to acute development challenges (e.g. the recent emergence of MLN in eastern Africa and the current 2015/2016 drought in southern Africa).

To improve integration at ground-level between MAIZE, other CRPs and partners, MAIZE-AFS will: (i) define areas of Interest and identify benchmark sites (learning from Humid-Systems); (II) agree on governance structure and model(s) or plans for integration. In Bangladesh, a ++ country, CGIAR centers have already implemented an initial site integration model in partnership with the Bangladesh Agricultural Research Council, in order to align research objectives across centers and with NARES; (iii) map (geo-reference) and keep updated research sites, partners and activities so that all are aware of current activities, (iv) build a database of previous activities and results (this would be useful); and (iv) map innovation platforms (or networks) and other mechanisms for feedback and joint policy initiatives.

Discussions are underway towards incorporation of the ex-Humid Tropics Action Area in Western Kenya and Action Site in Nan, Thailand, into MAIZE-AFS in Phase-II. Good progress has also been made with CIAT in Central America towards stronger collaboration and coordination of R4D efforts in the region. A strong community of practice in the area of trade-off, synergies, characterization, and targeting and
livelihoods analysis is evolving. This should subsequently assist the overall research design and the conduct of participatory research with stakeholders, as well as harmonizing data collection and improving curation, processing and exchange.

Proper attention to the design of CRP Phase-II, based on clear definition of the key ‘entry-points’ and R4D challenges, should further strengthen the existing collaborations, leading to more coherent, integrative and holistic approaches, and ultimately greater synergies and impact of CGIAR research.

Table 5: MAIZE Collaboration with other CRPs in Phase-II

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<thead>
<tr>
<th>FP4</th>
<th>FP2, FP3 &amp; FP6</th>
<th>FP1 &amp; FP5</th>
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| **Other Agri-food System CRPs (e.g., DCGLAS, GRiSP, WHEAT, RTB, Livestock)** | • Precision agriculture and approaches to increase input use efficiency  
• Systems approaches, technologies, methodologies; Helping ensure positive or neutral ecosystem impacts  
• Technologies tested and integrated at common innovation platforms | • Integrated Breeding Platform / Breeding Management System  
• The GOBII project is a showcase example of cooperation among the CRPs (e.g., MAIZE, WHEAT, GRiSP, DCLAS), involving five major crops. It is already generating interest from alternate crops, and the pioneering work done within GOBII is expected to benefit other non-focus crops within a ten year timeframe.  
• Enabling tools for increasing genetic gains (e.g., precision phenotyping using remote-sensing based approaches)  
• Developing a shared high-throughput genotyping facility that could support mainstreaming of genomic assisted breeding strategies across crops and institutions, complementing current collaborations with private sector marker service providers.  
• Pre-/Breeding technologies and methods  
• Improved maize germplasm for sustainable intensification of farming systems, including full-purpose crops  
• Leveraging phenotyping competencies and best practices from extensive research done on major crops (maize, wheat and rice) to rapidly translate insights to smaller crops with lower research intensities.  
• Feedback loops and learning about stakeholders’ needs  
• Joint capacity building interventions in the target geographies | • Docking of activities with Livestock/ILRI and RTB for using maize and its by-products as animal feed.  
• Shared approaches to processing and storage options (e.g. with DCLAS and RTB). |
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<tr>
<th>A4NH</th>
<th>CCAFS</th>
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<tbody>
<tr>
<td>• Market driven approaches to diet diversification in maize-based systems</td>
<td>• Participatory evaluation of MAIZE technologies and practices in climate smart villages</td>
<td>• Co-investment in development of drought and heat tolerant maize as a main approach to climate change adaptation</td>
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<tr>
<td>• Coordinated work on food basket approach work, especially in Africa and LA</td>
<td>• Improving resource use efficiency, particularly nitrogen and water</td>
<td>• Participatory evaluation of abiotic and biotic stress-resilient maize hybrids within climate smart villages (CSVs) under heterogeneous production and socio-economic conditions</td>
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<tr>
<td>• Agronomic biofortification, especially through Zn fertilizers</td>
<td>• Evaluation of the C sequestration potential of SI interventions</td>
<td>• Linking the environment characterization and crop modeling work under CCAFS, with the work on maize physiology and breeding under MAIZE FP3</td>
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<td>• Creation of minimum datasets for climate-smart technologies</td>
<td>• Strengthening local maize seed systems, and linking these with CSVs and CCAFS business cases for capacity development</td>
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<td>• Big data analysis</td>
<td>• Joint capacity building interventions in the target geographies</td>
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<td></td>
<td>• Effective use of MAIZE and CCAFS climate projections, farm typologies and farming system models to support evaluation of technologies in terms of enhanced resilience to climate variability and extremes (drought, floods, and high temperatures), mitigation of GHG emissions and associated costs.</td>
<td>• Weather index insurance</td>
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<td>• Integrating MAIZE FP4 data with CCAFS for: (a) generating multi-criteria minimum datasets for maize-based systems to develop standardized methods and metrics to quantify climate smart agricultural technologies and practices over a range of scales and (b) building a community of practice around the use of Big Data to identify climate resilient</td>
<td>• Joint policy briefs/dialogues/workshops on climate-resilient agriculture</td>
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<tr>
<td>• Exploration of a wider range of nutritious diet-relevant traits in maize</td>
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<tr>
<td>• New diversity and traits from mining of genetic resources for nutritional quality</td>
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<tr>
<td>• Collaborate on technology adoption by national partners</td>
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<tr>
<td>• Products coming from planned food-to-food fortification (fortifying maize with legumes) research in MAIZE CoA 5.1 can be linked with A4NH for deployment, to create greater nutritional outcome.</td>
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<td>• MAIZE CoA 5.2 can potentially catalyze greater availability of maize-based processed products to both urban and rural consumers.</td>
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<tr>
<td>• Joint capacity building interventions in the target geographies</td>
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<tr>
<td>• Approaches and lessons to be learned on diet shifts, advocacy for better data capture and integration of value chain research into agri-food systems research.</td>
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<tr>
<td>• New entrepreneurial and job opportunities and options to address post-harvest losses and enhance food safety.</td>
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GxExM technologies and improved cropping system models that better characterize the effects of climate extremes on maize-based systems in terms of yield performance, resource use, GHG emissions and their trade-offs (including costs)

- Using GYGA spatial framework as a means to explicitly evaluate climate smart options in both current and future climates.
- Layering precision nutrient and water management with stress-resilient and nutrient use efficient maize hybrids, and quantifying the adapted-mitigation co-benefits under diverse farming systems and production ecologies

**Policies, Institutions and Markets (PIM)**

- Overcoming value chain bottlenecks
- Precision agriculture mechanization

- Joint studies on impact assessment to enable scaling-out decisions
- Gender tools, collaboration
- Value chain analysis tools
- Foresight models
- Seed sector policies

**Note:** While some activities are already ongoing, for specific additional interventions of mutual interest among the CRPs, and the opportunities for co-investment through W1/W2/bilateral projects, will be decided through consultations with the CRP teams at the time of full proposal development.

### 1.8 Partnerships and comparative advantage

MAIZE draws on a strong partnership network with diverse contributions of partners for discovery/innovation, validation/proof-of-concept, and deployment/scale-out, besides providing feedback loops at various levels for defining R4D priorities (**Table 6 below; Annex 3.2 and Annex 3.2.2**). The range of MAIZE partnerships cover:

1. CGIAR Centers, including CIAT, IFPRI, ILRI, ICRAF, IRRI, ICRISAT and IWMI, that implement various CRPs (WHEAT, GRiSP, PIM, CCAFS, A4NH, DCLAS, RTB) and collaborate in cropping systems and value chains in MAIZE target geographies;
2. advanced research institutes (ARIs) and universities for discovery research;
3. NARES partners and Governments in the target countries in SSA, Asia and LA, that play a key role in implementation, and ensure sustainability of the work and impact;
4. an array of development partners, especially private sector, regional and sub-regional organizations, extension agencies, NGOs, CBOs, farmers, farmer organizations etc., who validate, adopt, scale-up and scale-out the improved tools/technologies/practices. Therefore, each of these stakeholders contributes strongly, and uniquely, to the implementation and impact of MAIZE.
Table 6: Some of the strategic and inclusive partnerships of MAIZE under various Flagship Projects.

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<th>FP1</th>
<th>FP2</th>
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<tr>
<td>• PIM and the University of Minnesota for foresight work</td>
<td>• Cornell University on high-density genotyping-by-sequencing (GBS), and genomic selection</td>
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<tr>
<td>• Wageningen UR and the former Humid Tropics CRP for systems characterization and systems trajectories, synergies and trade-off analysis</td>
<td>• US and UK-based universities (e.g., Minnesota, Purdue, Alabama, Wisconsin) on genomic selection</td>
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<tr>
<td>• KIT for gender and development work.</td>
<td>• University of Hohenheim on R4D on haploid inducers and DH technology</td>
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<tr>
<td>• Oak Ridge National Laboratory (ORNL) and the University of Minnesota on Big Data</td>
<td>• IBP, DArT and JHI on database management, medium-density GBS, and breeding informatics</td>
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<tr>
<td><strong>Note:</strong> While these partnerships may not directly lead to delivery and impact, collaboration with the best and most innovative foresight, systems and gender specialists available ensures that interventions are designed and targeted in such a way as to maximize maize-based systems outcomes and impacts.</td>
<td>• The University of Barcelona and the private sector on field-based phenotyping;</td>
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<td>• Multinational companies (Monsanto, Pioneer) and partners in SSA (e.g., KALRO, ARC and NARO) on maize transgenic testing under CFTs and stewardship implementation,</td>
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<td>• KALRO and the private sector on the MLN trait pipeline.</td>
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<td><strong>Note:</strong> These partnerships effectively help develop novel tools, explore new diversity to enrich the breeding pipeline, and derive decision support tools that together with other tools increase genetic gains and breeding efficiency.</td>
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<th>FP3</th>
<th>FP4</th>
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<tr>
<td>• A wide array of NARES, seed companies and NGOs are partners in germplasm development and multi-location testing in SSA, LA and Asia Introggression of other institutional germplasm and technologies (e.g., Monsanto under WEMA; Pioneer under IMAS).</td>
<td>• Public sector – NARES in Mexico; Guatemala, Haiti, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Nigeria, Rwanda, Zambia, Zimbabwe; Bangladesh, India and Nepal for adaptive research</td>
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<tr>
<td>• Some NARES partners (e.g., KALRO and ARC) contribute elite germplasm for product development.</td>
<td>• Private sector (machinery manufacturers, Input suppliers etc.) for co-invention of technologies</td>
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<tr>
<td>• USDA-ARS provide maize germplasm for developing MLN resistant and aflatoxin resistant germplasm.</td>
<td>• ARIs (KIT, WOCAN, Univ. Illinois, Univ. Sheffield) for household and farm systems analyses</td>
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<tr>
<td>• Purdue University provides diverse yellow/orange maize germplasm for provitamin A enrichment</td>
<td>• Wageningen UR, Oak Ridge National Laboratory, CIAT, CIRAD, SAIL Earth Institute-Colombia University and ITC for systems frameworks and quantitative analysis at landscape scale, and institutions</td>
</tr>
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<td><strong>Note:</strong> These collaborations help MAIZE leverage the best germplasm from both public and private sector sources, and through extensive regional testing networks ensure that the right germplasm is selected for use by smallholders in target countries.</td>
<td>• Humid Tropics for cropping systems research and systems modelling</td>
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<td></td>
<td>• Water, land &amp; ecosystems CRP for efficient water, nutrient and soils management and reducing the environmental footprint of MAIZE</td>
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<th>FP5</th>
<th>FP6</th>
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<tr>
<td>• Wageningen UR</td>
<td>• Close to 200 seed company partners and community-based seed suppliers across SSA, Asia and LA, for scaling-up and delivering improved maize seed generated through MAIZE</td>
</tr>
<tr>
<td>• Purdue University</td>
<td>• CTA and KIT for value chain facilitation and gender transformative interventions.</td>
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<tr>
<td>• EMBRAPA</td>
<td>• Scaling-out of sustainable intensification innovations through public sector (NARES), private sector (machine</td>
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<tr>
<td>• PIM, A4NH, DCLAS andLivestock CRPs</td>
<td>)</td>
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<tr>
<td>• NARES</td>
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<tr>
<td>• Private sector partners</td>
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<tr>
<td>• Technical Centre for Agricultural and Rural Cooperation (CTA)</td>
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MAIZE Comparative Advantage

The CGIAR Independent Evaluation Arrangement (IEA) team stated in its report on MAIZE (April 2015; [FINAL REPORT: Evaluation of CRP on MAIZE]): “MAIZE has a clear comparative advantage in supplying improved germplasm at different stages of advancement for the needs of smallholder farmers both in stress-prone and in market-oriented environments. MAIZE also leads in long-term field experimentation, evaluating conservation agriculture, and in organizing regional breeding networks, and it has unique experience in agro-ecological zones that are of high priority for the CGIAR. Furthermore, MAIZE benefits from and contributes to the global reputation and strong credibility of the CGIAR among policy makers and the scientific community. The ability of MAIZE to mobilize efforts for strategic research, technology design and mechanisms for delivery of outputs further adds to the strength and comparative advantage of MAIZE.”

Hence, MAIZE partners have a proven track record, strength of partnerships, and demonstrated outcomes and impacts through development and deployment of improved maize varieties and sustainable intensification options in the maize agri-food systems in SSA, Asia and LA.

1. Institutions in more than 100 countries, mostly in the tropical and subtropical regions, annually request and receive stress tolerant and nutritionally-enriched elite MAIZE germplasm, developed by CIMMYT and IITA, as international public goods. This germplasm with diverse trait combinations, coupled with adaptation to various agro-ecologies, is the key driver behind commercial products developed by NARES and small- and medium-size seed companies in SSA, LA and Asia. MAIZE is also the largest provider worldwide of improved germplasm with abiotic stress tolerance (drought, heat, water-logging, NUE), resistance to Striga and Maize Lethal Necrosis (MLN), as well as Quality Protein Maize (QPM) and provitamin A-enriched maize. The strong pipeline of improved maize germplasm is the result of more than five decades of breeding history, intensive efforts of a dedicated team, and establishment of the largest managed stress phenotypic network for maize in the public system for a range of traits relevant to smallholders in the tropics.

2. MAIZE has an extensive sustainable intensification work, co-designing and implementing sustainable intensification solutions in real conditions with farmers, NARES and other partners in an array of agro-ecologies and under diverse socio-economic environments. MAIZE undertakes multidisciplinary R4D approaches in partnership with world’s leading research institutions, leading to the increased adoption of sustainable intensification practices, and ultimately impact.

3. MAIZE is at the forefront in tackling emerging threats to smallholders’ food security. MAIZE’s rapid response to the MLN epidemic in the last four years was a clear demonstration of the capacity of the CGIAR and its public and private partners in eastern Africa to act quickly and effectively, and to galvanize
and organize an effective multi-institutional response. This was recognized as a major achievement of MAIZE in Phase-I by the IEA Report [FINAL REPORT: Evaluation of CRP on MAIZE].

4. MAIZE uses its germplasm bank to characterize and exploit genetic resources to improve crop resistance and adaptability and in doing so widens the genetic diversity utilized and breeding gains achieved for traits or genetic variation that are missing in improved germplasm. Access to, and use of, this diversity and ensuing germplasm is unique to MAIZE, and is a core comparative advantage that is made available to the international community.

5. CGIAR partners co-leading MAIZE have scientific and technical staff based in SSA, LA and Asia. These teams have strong linkages with public and private sector partners in the target countries/regions, besides intensive engagement with farming communities, including women, youth and the socially disadvantaged in the maize agri-food systems. MAIZE scientists and managers are widely acknowledged as “honest brokers” of knowledge and innovative technologies. A strong legal team has negotiated access to a substantial number of IPR protected technologies for use by NARES and SMEs.

6. MAIZE provides one of the biggest platforms for training and capacity building of students, scientists, technicians and professionals from NARES and SME seed companies on maize R&D with over 50,000 training days annually, and close to 100 Graduate Students finishing their degree training every year.

7. MAIZE shares its knowledge and data with the world to enable spillover benefits and to maximize the return on research investment. MAIZE researchers published over 250 articles in academic journals from 2011 till July 2015, with an increasing focus on publishing open access articles (~30%). Large data sets are also shared with the public, including results from over 17,600 multi-location maize trials (in SSA, Asia and LA) that can be downloaded for use with the MaizeFinder software.

1.9 Evidence of demand and stakeholder commitment
Maize agri-food systems are inherently complex, yet offer tremendous opportunities. Indeed, maize feeds the poorest of the poor, be it as a subsistence crop in marginal areas or as the cheapest energy source in urban slums, and offers a genuine opportunity to lift smallholders out of poverty where value chains are established. Maize supply is equally diverse, from the large scale mechanized farms that supply global markets to the hillside farmer that barely produces enough to feed the family; from the hybrid seed that can yield over 10 tons per hectare (t/ha) with adequate management to an average yield of 1.4 t/ha in sub-Saharan Africa (SSA); from biotech high-end science to the lack of even the most basic crop management practices; and a cultivation footprint that spans the globe from the tropics to temperate environments. This diversity is a reflection of many realities. Particularly relevant here is that it reflects a demand for context-specific solutions. Multinational seed companies have no commercial interest to address such diverse market niches, and more than seed based solutions are needed to increase productivity and reduce poverty. There are, thereby, significant needs for public-sector agricultural R4D investment in addressing the areas neglected or less reached by the multinationals as well as areas where complementary public-private partnerships can bring greater impact on the livelihoods of the poor producers and consumers dependent on maize agri-food systems.

The MAIZE R4D portfolio was shaped by the demands and priorities expressed by the clients and stakeholders in Africa, Asia and Latin America (LA⁵). MAIZE organizes at least 30 project workshops/review meetings every year across the target geographies through various special projects,

⁵ Latin America (LA) is a region of the Americas that comprises countries where Romance languages are predominant; primarily Spanish and Portuguese, but also French. It consists of 20 sovereign states which cover an area that stretches from the southern border of the United States to the southern tip of South America, including the Caribbean. (Source: Wikipedia)
bringing in at least 800-900 participants, and documenting their feedback. In addition, MAIZE organized e-consultations, and phone interviews with highly informed partners and donors, as well as some major international/regional conferences over the last four years, with participation of policy makers, representatives of governments, regional and sub-regional organizations, farmers’ organizations, farmers, and donors. All these efforts helped receive valuable insights and feedback that shaped the present portfolio. A few examples are highlighted here:

1. The recent 12th Asian Maize Conference and Expert Consultation on “Maize for Food, Feed, Nutrition and Environmental Security”, jointly organized by the Asia-Pacific Association of Agricultural Research Institutions (APAARI), CIMMYT, FAO and the Department of Agriculture-Thailand, held in Bangkok (October 30-November 1, 2014), brought together nearly 300 participants from 19 Asian, and 11 non-Asian countries. All of its 15 major recommendations (Paroda et al., 2015) have been addressed in the MAIZE Phase-II preproposal.

2. NARES and SME seed companies have no access to the breeding tools utilized by large multinationals. Publications provide proof-of-concept type applications for molecular markers, yet more than theoretical knowledge is needed to mainstream such tools in breeding programs. NARES and SMEs hence shaped the demand for MAIZE tools in FP2 that can be applied in their breeding programs.

3. FP3 components were derived with inputs from donors [Bill & Melinda Gates Foundation (BMGF), USAID and Syngenta Foundation for Sustainable Agriculture (SFSA)] and public/private sector partners. These include target product profiles (CoA 3.1); areas of emphasis under CoA 3.2, particularly MLN; end-use traits (CoA 3.3); seed production research and recommendation domains (CoA 3.5).

4. CIMMYT together with APAARI, ICAR, NAAS and BISA, organized a stakeholder consultation at New Delhi, India, in May 2015 (attended by nearly 100 participants from public and private sector institutions) on alleviating malnutrition through nutritious maize. This helped in designing strategic interventions reflected under FP3 CoA 3.3 and FP5.

5. Sustainable intensification of areas with high poverty concentration (FP4) and the scaling-up and scaling-out work projected under FP6, is shaped by the demands and priorities expressed by clients (especially NARES and private sector partners in the target geographies), and strongly supported by the donors (e.g., BMGF, USAID, SAGARPA, ACIAR, etc.).

1.10 Capacity development
The Maize Agri-food systems CRP seeks to ensure that technologies and approaches for sustainable and profitable intensification of maize-base framing systems are targeted towards smallholders and developed and adopted by them. On the basis of the framework laid down by the CGIAR Capacity Development Community of Practice, this strategic framework is developed to ensure that a range of relevant considerations on Capacity Development is factored into the Maize CRP.

An analysis of how the MAIZE CRP can best help strengthening the capacity of partners in development and sustain their activities led to the formulation of the four strategic objectives for CRP Capacity Development: (i) Enhancing MAIZE science capacity through the development of highly competent
Maize research workforce to enhance global maize science capacity. This will be implemented mainly through a graduate and short-term skills and competencies development program. This will involve training courses in key areas such as genetics, in collaboration with leading universities, the NARES, the private sector, and advanced research institutes, and internships, etc. Capacity will be strengthened in developing a more comprehensive understanding of impacts of maize innovations through foresight, targeting and modeling approaches, impact assessment, adoption pathways and include factors such as markets, assets, institutions, agro-ecologies and farmers’ risk and preferences; (ii) Enhancing gender in research design and impact pathways to improve the capacity in gender sensitive approaches. In particular, the capacity of young women and men to participate in decision-making and to facilitating their access to markets and value chain opportunities and job opportunities; (iii) Improving research-based management, governance, learning and knowledge sharing to increase organizational and institutional capacity through the establishment of a sustainable culture of learning and collaboration by primarily focusing on people, partners and processes. Capacity will be enhanced to use action learning to solve organizational problems and spread innovation through improving the harvesting of research findings, best practices and insightful lessons from seminars, learning events and research projects into knowledge and learning resources and to make these accessible via the MAIZE platform and other delivery modes. Capability should also be enhanced in data and information management, learning and knowledge sharing in all research areas in order to accelerate research feedback, and to comply with CGIAR policies on open-data access, as well as in the development of tools, protocols and support materials to support the development of competency based approaches and collaboration. It is also proposed to support the improvement of the research infrastructure of the NARS to enable them to carry out research successfully; and (iv) Strengthening capacity in technology dissemination and upscaling through the establishment and strengthening of innovation platforms, enhancing extension services, private sector, farer organizations and NGOs capacity to scale-out appropriate technologies to support sustainable intensification.

The Maize Capacity Development Strategy lays emphasis on engaging with other CRP and platforms such as the BIG DATA and the GENE BANK Platforms, and partners in development (NARES, seed companies, NGOs, CBOs, and farmers associations). The Capacity Development Strategy is a strategic enabler to strengthening the capacity of partners to develop sustainable, productive, profitable and socially acceptable varieties, seed production, cropping systems and value chains for resource-poor farmers in lower- and middle-income countries. This engagement will be based on local ownership; demand driven processes and respond to expressed needs of partners. Secondly, it will be coordinated to foster mutual understanding and yield prioritized needs that justify investment while strengthening the science and delivery capacity and emphasizing the socioeconomic contributions of the CRP to the CGIAR research outcomes in terms of human welfare benefits (poverty and nutrition). Several approaches and delivery methods will be used, including the use of ICT to strengthen the capacities of intermediary and ultimate beneficiaries, through: a) training of trainers and training courses on areas identified by the stakeholders; b) farmer field days and demonstrations of improved technologies; c) mentoring, coaching, visiting and post-docs schemes; d) advanced degree training (via co-supervision of postgraduate students); e) learning by doing and on-the-job training of visiting scientists, and; f) learning and sharing of tools, procedures and best practices.
1.11 Program management and governance

Oversight and management of MAIZE is based on the management principles defined in the CGIAR SRF and the standard performance contract of the CGIAR Consortium. It uses institutional capacities and networks, as they are deployed across the globe, and largely focuses on the pragmatic implementation of a R4D agenda, driven by stakeholders’ priorities. MAIZE is overseen by an Independent Steering Committee (ISC) with nine members that combine disciplinary expertise (germplasm, agronomy, socioeconomics, gender, value chains) with regional (Africa, Asia, LA) and CGIAR/public/private sector/farmer organization representation. The Committee is chaired by a non-CGIAR Chair and has been fully operational since 2013. It oversees the MAIZE Director and Management Committee as per CGIAR guidelines. The lead center is CIMMYT. Under the CRP, CIMMYT and IITA created one maize improvement program, which is coordinated by the newly appointed MAIZE Director (effective June 1, 2015), in line with the recent IEA recommendations on MAIZE. The professional experience and expertise of MAIZE Director, Flagship and CoA leads, and key external partners, are reflected in Annex 3.8.

The MAIZE Management Committee (MMC) is chaired by the CRP Director, and comprises representatives of CIMMYT, IITA, and four non-CGIAR partners as Tier-1 partners: Kenya Agriculture and Livestock Research Organization (KALRO); SAGARPA (Mexico); Wageningen UR (Netherlands); and Syngenta Foundation for Sustainable Agriculture (SFSA). SAGARPA (Mexico) and KALRO (Kenya) are the largest current research partners in MAIZE, while the SFSA, a non-profit organization, links MAIZE with research capacities in the multinational private sector. Wageningen UR brings in significant expertise relevant for various Flagships, while leading CoA 5.2. While responsibilities for various Flagship Projects are allocated to distinct MMC members, the MMC discusses and endorses strategies, work plans, partner grants and budgets as an entity. All MMC decisions require the endorsement of at least some non-CGIAR members, i.e., CGIAR centers on their own cannot dominate a decision. The MAIZE Management Committee also oversees and promotes adoption of best practices in data management, and data sharing policies across the Flagships.

Much of MAIZE is implemented in a decentralized manner to ensure participatory decision making, and effective engagement of regional and local partners for targeted outcomes. Due to the strong regional nature of operations, thematic MAIZE Flagship and Cluster of Activity (CoA) leadership is shared.
between organizations to cover the global portfolio. Performance of such shared leadership is managed through the accountability matrix for distinct work-packages included, discussed and agreed by the M-MC for the annual work plan. In Phase-II, regional leadership by CGIAR centers is being expanded through the integration of Humid Tropics research hubs that were led by IITA in SSA, ICRAF in South-east Asia, and CIAT in Latin America. MAIZE implementation is based on partnership approaches with NARES and the local private sector that emphasize: a) regional priority-setting among and within various Flagships; b) collaborative planning, execution and assessment towards impact; and c) needs-driven capacity building. Currently, over 75% of partner funds are managed through participatory approaches at the regional level, and only 25% at the global level.

1.12 Intellectual asset management
CRP Maize is committed to the effective and efficient management of intellectual assets at every stage of the CRP life cycle. CRP research outputs will be managed in line with the CGIAR Principles on the Management of Intellectual Assets (IA Principles) and their Implementation Guidelines, as International Public Goods. The research outputs will be disseminated to reduce poverty, enhance food security, improve nutrition and health, and sustainably manage natural resources.

Critical issues to address during CRP implementation and anticipated challenges from an IA management perspective include: (i) incorporation of IA management into the project lifecycle; (ii) alignment of CGIAR IA Principles’ requirements with private sector partner interests, as well as with local legislation and local markets/practices; (iii) available human resources for proper implementation and funding; and (iv) due diligence to allow for dissemination of CRP outputs.

CRP Project planning and implementation will be addressed through three main activities: (i) participation in the project management lifecycle; (i) implementation of IA Principles for the Lead Center, participating Centers and other partners; and (iii) capacity building.

Key dissemination pathways for maximizing global impact are further described in the annex and include open access repositories, adapted information channels to specific target groups, partnership approaches and capacity development, management of International Public Goods, partnerships (with NARs, PPPs, etc.), scaling up and out, networks, on-farm management & participatory research.

Operations envisioned refer to incorporation of IA management into project cycles; IA tracking; negotiation and drafting of agreements with partners; compliance with Convention on Biological Diversity; compliance with International Treaty on Plant Genetic resources for Food and Agriculture; compliance with country by country laws and regulations on genetic resources; ethics in research and privacy protection; and policy developments/updates. Any coordination and decision making will be handled through the CRP Wheat Management Committee (MC) with the IP & Legal office of the Lead Center and/or in accordance with the CGIAR and Lead Center relevant policies.

Other resources for developing the activities described in this document or that will be developed in the future are included in that attached annex or will be included in any future annex.
1.13 Open access management
MAIZE seeks to ensure that all Research Data and other Information Products produced or supported by the CRP are managed to enable further research, development and innovation, leading to the best possible impact on target beneficiaries in accordance with the CFCSIAR SRF goals. MAIZE fully supports the rollout of the CGIAR Open Access and Data Management Policy, which is a critical component to providing International Public Goods, Safeguarding and utilizing genetic resources, and strengthening research capacity (see MAIZE comparative advantages, section 1.8). CIMMYT and IITA both have Open Access and Data Management Policies that adhere to these principles (hyperlinks to these if available and endorsed) and are in the process of finalizing data management plans guided by the CGIAR implementation plan guidelines. MAIZE will encourage all non-CG collaborators, however they are funded, to abide by CGIAR OA/OD principles and to coordinate their open access efforts with the Lead or Participating Center.

Lead and Participating Center Management will support the early inclusion of open access planning in the project management lifecycle for new projects. It plans to initiate activities that induce behavioral change in scientists to embrace Open Access practices; both within and outside the CGIAR. An overview of CIMMYT and IITA repositories can be found (hyperlink).

MAIZE will continue to (co)-fund and, through its researchers, participate in further development of Open Access and Open Data-related standards, methods and tools (e.g. CGIAR Open Access & Open Data Support Pack), both within the CGIAR (including in collaboration with the two Platforms) and, more importantly, without: Namely international efforts focused on interoperability, dissemination pathways and other topics related to increased uptake of CRP data and information products. For an overview of MAIZE participation in non-CGIAR OA/OD-related initiatives and projects, go to (insert hyperlink).

1.14 Communication strategy
The MAIZE Communications team will lead communications, providing expertise and strategic guidance to CRP researchers and partners to enhance effectiveness, impact, public image, and donor support through these and related activities:

- Communicating about the program, the science, results and progress towards achievement of the SRF 2022 targets throughout the CRP life cycle. EXAMPLEs
  - Document the successes of projects, partnerships (MasAgro, CSISA, SIMLES, AIP-Pakistan, SARD-SC, etc.), and competitive grantees, and share with relevant audiences through diverse outputs and media.
  - Assist partners and donor agencies to document successes.
  - Ensure that the CRPs capitalize on the communications capacities and expertise of the lead Center and collaborating CRPs.
  - Ensuring that all CRP communications reflect political sensitivity, promote the engagement of partners and stakeholders, support research and delivery (MLN, Scaling up, nutrition, etc), and provide full attribution for intellectual and material contributions.
- Promoting learning and sharing of information to improve communications and collaboration with CRP oversight, CGIAR, partners, and within and across CRPs, among other ways, through: 
- Support and communicate about the multi-CRP gender-related initiative GENNOVATE.
- Platforms (web sites, social media) with pertinent CRP documentation and tools.
- Promoting the development and effective use of apps (Slate, infographics, interactive maps, etc.).
- Sharing information about progress and impacts (reporting, studies, and newsletter).

- Engaging with actors on the ground to scale out technologies and practices. The following approaches and practices have been put in place to support adoption and mainstreaming of innovations.
  - Media and marketing campaigns to generate technology awareness, local engagement.
  - Development of outreach material (print, video, other).
  - Catalyzing and other support for extension, including strategic guidance and building local capacity.
  - Working with agro-communications experts and organizations (Digital Green, AgroInsight), to achieve the above.
  - Work with NGOs (TotalLandCare, Malawi; OneAcre Fund) and other CRPs (CCAFS, Climate Smart Villages in India; A4NH, pro-Vitamin A maize in sub-Saharan Africa) to document farm-level success and learning.

- Engaging in and providing support for policy dialogue and events (FARA-2013, CGIAR Development Dialogues, Mexico Forum with State Ministers of Agriculture) attended by policy makers, opinion leaders, and other key stakeholders.
  - Providing diverse communications support (event management, media outreach, messaging development, impact and policy briefs, proceedings, presentations, follow up, etc.).
  - Supporting gender studies and analysis in developing countries where wheat and maize work.

1.15 Risk management
In 2014, the MAIZE Management Committee developed and operationalized a risk management matrix. Its purpose is to regularly assess and manage CRP-specific risks, which are mainly driven by the rights and obligations of the Performance Implementation Agreement signed between the Consortium and the Lead Center CIMMYT, as well as CGIAR regulations referenced therein. The matrix identifies a number of risks related to asset management, compliance, general management, change management, finance and technology. Based on the risk assessment, MAIZE Management Committee agrees on specific mitigation measures. This complements (and does not duplicate) the risk management performed by CIMMYT and IITA Center Management. The top risk in the past and going forward is the in-financial year W1&2 budget changes and delayed transfer of W1&2 funds, which directly affects CRP research and development operations. Up to now, the MAIZE Management Committee has agreed to prioritize CGIAR-led research over partner and management budgets, to maintain the MAIZE partner budget as the most flexible component of the budget and commit a reserve. MAIZE continues to sign only one-year partner sub-grant contracts, to manage partner expectations and minimize any delays of payments to them. Given MAIZE experience in Phase I, ‘non-fulfilled obligations by the partners for commissioned and competitive grants’ is considered a low likelihood and low impact risk, but remains monitored on a
quarterly basis. To date, only a handful of competitive grants have been terminated due to under-performance.

1.16 Budget narrative summary (To be Completed)

Section 2: Flagship Programs

FP1: Enhancing MAIZE’s R4D Strategy for Impact

2.1 Rationale, scope

Maize is one of the three leading global cereals that feed the world (Shiferaw et al., 2011) and is a staple food for hundreds of millions of people in the developing world. However, it also has multiple other uses, providing feed to billions of livestock (especially poultry) and increasing industrial and biofuel uses. This makes maize the world’s most multi-purpose crop. It also makes maize agri-food-systems inherently complex, diverse and dynamic.

An agri-food system (AFS) considers both agricultural and agro-industrial sectors and how both “interact closely with other production and service sectors. This broadens the vision of agriculture and recognizes the importance of economic and production activities that take place outside the primary production process, as well as highlighting the impact of the political, environmental and social environment on these activities.” (Santacoloma et al., 2009). MAIZE Flagship Project 1 (FP1) provides a coherent horizontal guiding platform to help MAIZE embrace an integrated AFS approach in general, and grasp the implications for its international research-for-development (R4D) in particular.

Realizing the potential of agricultural development for poverty alleviation and food security is challenging (IBRD, 2007; Christiaensen et al., 2011). An AFS approach broadens the perspective beyond the traditional and narrow focus on the farm and the farmer, including the enabling environment and the forward and backward linkages along the value chain, all the way from input supply through processing and value addition to the final consumer. At the same time the maize AFS provides valuable focus and corresponding entry point for R4D.

AFS inherently put emphasis on the supply-demand nexus. Subsistence autarkic maize-based systems producing maize solely/primarily for household self-sufficiency in isolation are increasingly scarce. They also provide limited prospects for economic development and poverty alleviation. Instead, the burgeoning and diverse maize demand still offers huge developmental dividends for smallholder producers able to produce surplus maize across the developing world. Maize may be generically categorized as a staple food crop – but for millions of resource poor farmers it is seen as a cash crop, inherently scalable, accessible and viable. Indeed agricultural development of maize producers hinges on market access for both the innovation supply/access and providing economically viable outlets to surplus production (Frelat et al 2016). Economic viability hinges on producing maize that meets the demand for maize in terms of maize products (food, feed, fuel) at a competitive price and quality.

MAIZE has a large area of influence. Maize is the major cereal crop in SSA and LA, regions where many countries still have land availability for some degree of area expansion i.e. land extensification along with sustainable intensification (see FP 4). Maize continues to rapidly expand in importance in Asia. A relatively recent FAO study (Alexandratos and Bruinsma, 2012) foresees maize production global growth to 2050 of 1.43% p.a. (including 0.83% yield improvement and 0.59% land expansion), a yield growth driven mostly by the increasing need for animal products and evolving food and feed industries in Africa.
and Asia. Maize is also well placed to help feed Africa, the only continent that has seen an increase in the number of undernourished over the last decades and yet has an additional billion mouths to feed by 2050 – double the current population.

MAIZE has a diverse area of influence. The scope for further maize AFS development in the developing world remains great – but implications differ given maize AFS specifics, different uses, different dynamics, different stakeholders and different public-private complementarities. AFS actors operate in diverse contexts shaped by agro-ecological circumstances, market access and development, population pressure and institutional arrangement and governance structures. This calls for a better understanding of the supply-demand nexus of maize AFS and associated agricultural innovations within its temporal, spatial and social dimensions. In other words, further research and understanding of the R4D implications and nuances of maize AFS – and close integration and strategic alignment with national and regional priorities and complementarities with the private and public sector based on comparative advantage.

The context in which MAIZE operates is evolving. Both future needs of our beneficiaries as well as the context in which they will operate are shaped by a number of factors: megatrends (global drivers of change), pressures and events; and these are forcing women and men of different age groups, civil societies and countries to reassess priorities and interventions. Drivers of change include changes in agro-ecological production potential and comparative advantage of different crops in different locations; changes in diets; changes in the socio-economic and politico-institutional environment which influence innovation, research supply (private sector, ARIs, NARS) and social inclusiveness (women, youth); and changes in maize as an input into the bio-based economy (bio-fuels, bio-chemicals). The evolving context thereby calls for systematically re-assessing R4D priorities and implications, including market opportunities and comparative advantages within maize AFS.

Maize AFS and many of the grand challenges are directly interlinked. FP1 enhances MAIZE R4D strategy for impact by enhancing our understanding and thus directly assesses the implications of various Grand Challenges (Table FP5.1).

2.2 Objectives and targets
MAIZE aims to strengthen a strategic, international approach of public-private partnership for maize research-for-development (R4D) to sustainably strengthen resource-poor women and men farmers of different age groups and poor consumers in maize AFS. MAIZE’s strategy for impact should be based on a solid understanding of its potential impact and comparative advantage and consequent priorities in the target areas. Ex ante analysis should make future potential impacts explicit and help in thinking through implications and impact pathways. Ex post analysis should make actual achieved impacts explicit – including unintended consequences. Both ex ante and ex post analysis will help illustrate MAIZE’s value for money to the international community and to refine priorities. Its strategy for impact should be cognizant of social inclusiveness throughout – thinking through the implications to ensure intended resource-poor beneficiaries of different age groups are reached and documenting and learning from its achievements in the context of social inclusiveness. Its strategy for impact should assess changes in context to identify new opportunities and changes in comparative advantage and refine priorities accordingly. MAIZE’s strategy for impact should hinge on its comparative advantage with strategic consideration to the dynamics in demand and use of maize products (food, feed, fuel) and research supply (private sector, ARIs, NARS) to establish and refine priorities in its target areas.

MAIZE Flagship Project 1 (FP1) strategizes MAIZE’s R4D to enhance impact in maize AFS. FP1 aims to do this by better understanding the supply-demand nexus of agricultural innovations in maize AFS within its temporal, spatial and social dimensions. FP1 inherently recognizes and researches the complexity of
maize AFS, their interconnections with environmental and socio-economic factors and the consequences of globalization. FP1 will enhance MAIZE’s understanding of the big picture and household-level implications in maize AFS, while keeping an eye on strategic priorities to avoid mission drift.

FP1 enhances MAIZE’s R4D across all the Flagships, informing strategies for impact through foresight and targeting, learning from adoption and impacts, strategic and transformative gender research, and identifying value chain opportunities. This FP will utilize and expand on MAIZE’s rich understanding about livelihoods, AFS, markets, agro-ecology, nutrition, social inclusiveness and other socio-economic phenomena to help MAIZE prioritize and adjust based on the new evidence. FP1 revolves around multi-disciplinary research to prioritize, target, understand and enhance maize interventions for greatest impact within an AFS perspective. It thereby integrates socio-economic research with germplasm improvement, agronomy and value addition. This flagship links analysis of completed technology diffusion, with current technology pipelines in all stages of development and informs the technology development process of its key findings to enhance impact.

FP1 maximizes the value-for-money for MAIZE as a whole by providing horizontal guidance to MAIZE and supporting the internal coherence among all FPs through four specific objectives, each being the basis for a Cluster of Activities (CoAs):

1. To inform MAIZE’s R4D strategy through foresight and targeting.
2. To learn from MAIZE’s interventions through their adoption and impacts.
3. To enhance MAIZE’s gender and social inclusiveness.
4. To identify maize value chain opportunities to enhance livelihoods.

The investment made in FP1 will generate multiple outcomes and contributions to sub-IDO. By providing horizontal guidance to MAIZE and its outcomes-to-impact, FP1 also contributes to the full range of MAIZE outcomes generated by the other FPs. FP1 documents and enhances MAIZE’s contribution to CGIAR 2022 (and 2030) targets as specified in the CGIAR SRF, through ex-ante and ex-post impact assessment activities, with particular focus on: (i) Number of farm households adopting improved maize varieties and/or improved crop management practices; (ii) Number of people assisted to exit poverty (by gender); (iii) The rate of yield increase for maize; (iv) Number of seed companies distributing MAIZE cultivars (e.g. hybrids with 1 or more inbred parents from MAIZE or containing a significant proportion of MAIZE germplasm); (v) Number of people that meet minimum dietary energy requirement (by gender); (vi) The increase in water and nutrient (inorganic, biological) use efficiency in agro-ecosystems, including through recycling and reuse; and (vii) The area of forest saved from deforestation.

FP1 plays a critical cross-cutting role in reinforcing many of the SRF guiding principles in MAIZE, including, inter alia, representing and demonstrating its value for money, increasing operational efficiency, generating public goods with multiple benefits, providing attractive investment opportunities and accelerating impact at scale with a particular focus on women and youth. Its support will improve the use of scarce research resources, accelerate the uptake of innovations and enhance benefits and social inclusiveness for resource-poor producers and consumers in maize AFS in Africa, Asia and Latin America. The geographic focus of FP1 follows MAIZE’s target geographies with a prevalence of maize AFS and international development potential (with focal countries including Ethiopia, Kenya, Malawi, Nigeria, Tanzania, Uganda, Zambia, Zimbabwe, India, Bangladesh, Pakistan, Nepal and Mexico).
2.3 Impact pathway and theory of change

The FP Enhancing R4D Strategy for Impact’s theory of change was developed during a workshop with the Flagship Program teams from both MAIZE and WHEAT CRPs. A participatory approach was used to capture all views, experiences and known evidence into the theory of change. The workshop participants were able to increase their understanding of the CGIAR Strategy and Results Framework and awareness of results-based management concepts. The workshop was also structured to encourage sharing and learning on a variety of topics and across both CRPs.

Using the CGIAR Results Framework’s sub-intermediate development outcomes (IDO}s) the team agreed to focus on all sub-IDOs and cross-cutting sub-IDOs chosen by MAIZE’s other Flagship Programs given that FP1 supports and contributes to all of them. These include the following eleven sub-IDOs and six cross-cutting sub-IDOs:

- 1.1.2 Reduced production risk;
- 1.3.1 Diversified enterprise opportunities;
- 1.3.2 Increased livelihood opportunities;
- 1.3.3 Increased value capture by producers;
- 1.3.4 More efficient use of inputs;
- 1.4.1 Reduced pre- and post-harvest losses, including those caused by climate change;
- 1.4.2 Closed yield gaps;
- 1.4.3 Enhanced genetic gain;
- 1.4.4 Increase conservation and use of genetic resources;
- 2.1.1 Increased availability of diverse nutrient-rich foods;
- 3.2.2 Agricultural systems diversified and intensified in ways that protect soils and water;
- A.1.4 Enhanced capacity to deal with climatic risks and extremes;
- B.1.2 Technologies that reduce women’s labor and energy expenditure developed and disseminated;
- B.1.3 Improved capacity of women and young people in decision-making;
- C.1.1 increased capacity of beneficiaries to adopt research outputs;
- D.1.1. Enhanced institutional capacity of partner research organizations; and
- D.1.3 Increased capacity for innovation in partner research organizations.

Other sub-IDOs were noted by the team as important to programming given that they overlap with the above sub-IDOs of focus.

Based on these areas of focus, the team agreed that this Flagship Program contributes to reducing poverty (SLO 1), improving food and nutrition security for health (SLO 2), and improving natural resource systems and ecosystem services (SLO 3) by the mean of increasing resilience of the poor to climate change and other shocks (IDO 1.1), increasing income and employment (IDO 1.3), increasing productivity (IDO 1.4), improving diets for poor and vulnerable people (IDO 2.1), enhancing benefits from ecosystem goods and services (IDO 3.2), and enhancing the cross-cutting issues of climate change (A), gender and youth (B), policies and institutions (C) and capacity development (D).

A number of research and development outcomes were identified and a pathway of change was created demonstrating the causal relationship between outcomes and sub-IDOs. During this process, partners
involved in the pathway of change were identified. Current and proposed interventions and associated outputs to support the achievements of the outcomes were mapped. Assumptions describing the contextual underpinnings of the theory as well as the risks that may have the potential to undermine success were documented.

This theory of change will be the foundation for the monitoring, evaluation and learning plan. The monitoring plan will consist of a continuous process of collection and analysis of data based on a set of indicators directly related to the performance of the CRP at the output and outcome levels; the key assumptions of the theories of change; and the critical risks. The theory of change will also be the basis for evaluating the Flagship Program as well as reflecting on lessons and program improvements.
Figure 6: Theory of Change for MAIZE FP1: Enhancing MAIZE’s R4D Impacts
<table>
<thead>
<tr>
<th>Assumptions and Risks</th>
<th>Interventions and Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Farmers are aware and have access to improved technologies</td>
<td></td>
</tr>
<tr>
<td>• Farmers see value in improved technologies</td>
<td></td>
</tr>
<tr>
<td>• Improve technologies are relevant, affordable, profitable and suitable to farmer needs</td>
<td></td>
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<tr>
<td>B. Partners have capacity, infrastructure and are willing to scale out technologies</td>
<td></td>
</tr>
<tr>
<td>• Risks:</td>
<td></td>
</tr>
<tr>
<td>o Existence of an enabling environment for scaling out</td>
<td></td>
</tr>
<tr>
<td>o Lack of and change in funding and political support</td>
<td></td>
</tr>
<tr>
<td>C. Existence of enabling policy environment and government support to make policy based on evidence</td>
<td></td>
</tr>
<tr>
<td>• Policy makers are receptive to research information and use it</td>
<td></td>
</tr>
<tr>
<td>• Risk: Frequent conflicting and competing priorities</td>
<td></td>
</tr>
<tr>
<td>D. Donors share our priorities and vision, and are willing to collaborate and share knowledge</td>
<td></td>
</tr>
<tr>
<td>• Donors have the capacity to collaborate</td>
<td></td>
</tr>
<tr>
<td>• Benefits of collaboration outweighs</td>
<td></td>
</tr>
</tbody>
</table>

| 1. Identify and share within CRP adoption constraints and incentives, and costs-benefit analysis of technologies  |
| • Outputs: Constraints, incentives and cost-benefit information and associated data; dissemination documentation  |
| 2. Evaluate difference approaches of awareness creation and dissemination and share best practices within CRP  |
| • Outputs: Best practices; dissemination documentation  |

<p>| 2. Conduct formalized needs and capacity assessments of partnering last mile providers, identify gaps and best fits and share findings within CRP  |
| • Outputs: Needs and capacity of last mile providers, gaps and best fit organizations; dissemination documentation  |
| 3. Develop and provide targeting information, targeting capacity building and extension material packages  |
| • Outputs: Information and associated data; training and associated materials; dissemination documentation  |
| 4. Conduct research on scaling out pathways to enhance dissemination  |</p>
<table>
<thead>
<tr>
<th>Assumptions and Risks</th>
<th>Interventions and Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>transaction costs</td>
<td>of adoption</td>
</tr>
<tr>
<td>• Risks:</td>
<td>o Outputs: Research</td>
</tr>
<tr>
<td></td>
<td>information and</td>
</tr>
<tr>
<td></td>
<td>associated data;</td>
</tr>
<tr>
<td></td>
<td>dissemination</td>
</tr>
<tr>
<td></td>
<td>documentation</td>
</tr>
<tr>
<td></td>
<td>3. Identify opportunities for CRP to</td>
</tr>
<tr>
<td></td>
<td>influence policy making and share</td>
</tr>
<tr>
<td></td>
<td>within CRP</td>
</tr>
<tr>
<td></td>
<td>o Outputs: Opportunities</td>
</tr>
<tr>
<td></td>
<td>documented; dissemination</td>
</tr>
<tr>
<td></td>
<td>documentation</td>
</tr>
<tr>
<td>• Risks:</td>
<td>4. Collect, document and share within</td>
</tr>
<tr>
<td></td>
<td>CRP donor intelligence (e.g.,</td>
</tr>
<tr>
<td></td>
<td>motivation, mission,</td>
</tr>
<tr>
<td></td>
<td>priorities, indicators)</td>
</tr>
<tr>
<td></td>
<td>o Outputs: donor intelligence;</td>
</tr>
<tr>
<td></td>
<td>dissemination documentation</td>
</tr>
<tr>
<td></td>
<td>• Prepare marketing /</td>
</tr>
<tr>
<td></td>
<td>communication products on research findings and</td>
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<tr>
<td></td>
<td>benefits of MAIZE products and share with donos</td>
</tr>
<tr>
<td></td>
<td>o Outputs: Policy briefs;</td>
</tr>
<tr>
<td></td>
<td>marketing / communication</td>
</tr>
<tr>
<td></td>
<td>products; dissemination</td>
</tr>
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<td></td>
<td>documentation</td>
</tr>
</tbody>
</table>

**E.** Partners see value and are willing to collaborate

- Existence of an enabling environment and government support
- Risks:
  - Lack of financial and human capacity of NARS
  - Conflict of interests
  - Over-commitment or lack of commitment
  - Staff turnover

**F.** Existence of an enabling environment for private sector involvement

- Private sector is willing to collaborate and share knowledge
- Private sector has the capacity to collaborate
- Benefits of collaboration outweighs transaction costs
- Risks:
  - Fails to see opportunities for diverse groups / interests
<table>
<thead>
<tr>
<th>Assumptions and Risks</th>
<th>Interventions and Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>o Potential for emergence of ethical issues</td>
<td>5. Conduct formalized needs and capacity assessment of partnering NARS and identify gaps</td>
</tr>
<tr>
<td>6. CPRs are willing to collaborate and share knowledge</td>
<td>o Outputs: Identified needs and capacity, and gaps</td>
</tr>
<tr>
<td>• CPRs have the capacity to collaborate</td>
<td>• Develop and provide training, services and mentoring</td>
</tr>
<tr>
<td>• Benefits of collaboration outweighs transaction costs</td>
<td>o Outputs: Training and associated materials; services documentation; dissemination documentation</td>
</tr>
<tr>
<td>• Risks:</td>
<td></td>
</tr>
<tr>
<td>o CGIAR and CRP mission drift away from mission, values, capacity, priorities</td>
<td>6. Develop and provide strategic advice to CRP on best practices in collaborating with the private sector</td>
</tr>
<tr>
<td>o Limited investment to develop capacity and collaborate</td>
<td>o Outputs: Advice; products; data; dissemination documentation</td>
</tr>
<tr>
<td>7. ARIs are willing to collaborate and share knowledge</td>
<td>• Develop and provide information on emerging marketing opportunities and on CRP products and services to the private sector</td>
</tr>
<tr>
<td>• ARIs have the capacity to collaborate</td>
<td>o Outputs: Policy briefs; information and associated data; dissemination documentation</td>
</tr>
<tr>
<td>• Benefits of collaboration outweighs transaction costs</td>
<td>7. Identify cost-effective opportunities for enhancing collaboration and complementarity with other CRPs and share within CRP, preferably via integration site plans</td>
</tr>
<tr>
<td>8. Existence of an enabling environment for collaborating, networking, communicating, knowledge sharing, innovation, critical thinking, taking risks and learning from failures where:</td>
<td>o Outputs: Opportunities documented; dissemination</td>
</tr>
<tr>
<td>o Feedback and constructive criticism is encouraged and operationalized across the institutions</td>
<td></td>
</tr>
<tr>
<td>o Time, resources and incentives exist</td>
<td></td>
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<tr>
<td>o Management provide active</td>
<td></td>
</tr>
<tr>
<td>Assumptions and Risks</td>
<td>Interventions and Outputs</td>
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<tr>
<td>-----------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>and continuous support, guidance and direction</td>
<td>documentation</td>
</tr>
<tr>
<td>o Benefits of collaboration outweighs transaction costs</td>
<td>• Share research findings with other CRPs</td>
</tr>
<tr>
<td>• Existence of an effective communication approach</td>
<td>o Outputs: Research information and associated data; products; dissemination documentation</td>
</tr>
<tr>
<td>• Risks:</td>
<td>• Contribute to joint initiative, preferably via integration site plans</td>
</tr>
<tr>
<td>o Lack of ability to retain talent and hire the right people</td>
<td>o Outputs: Knowledge; products; data; dissemination documentation</td>
</tr>
<tr>
<td>o Lack of effective tools for collaboration</td>
<td>8. Define and regularly revise a collaborative research agenda</td>
</tr>
<tr>
<td>o Internal performance evaluation processes are not adaptable to support collaboration</td>
<td>o Outputs: Collaborative research agenda (e.g., areas for research, associated institutions)</td>
</tr>
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<thead>
<tr>
<th>8.</th>
<th>9.</th>
<th>10.</th>
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<tbody>
<tr>
<td>Risks:</td>
<td>Comprehensively and regularly updated foresight and targeting approach (i.e., analysis) based on CRP needs</td>
<td>Conduct and share with CRP cost-benefit analysis of interventions</td>
</tr>
<tr>
<td>o New emerging pests and diseases</td>
<td>o Outputs: Approach; regularly updated data; FP needs</td>
<td></td>
</tr>
<tr>
<td>o Financial, social and political instability</td>
<td>• Foresight and targeting information provided to CRP</td>
<td></td>
</tr>
<tr>
<td>o Climate change</td>
<td>o Outputs: Foresight and targeting information and associated data; dissemination documentation</td>
<td></td>
</tr>
<tr>
<td>Assumptions and Risks</td>
<td>Interventions and Outputs</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
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</tr>
<tr>
<td></td>
<td>o Outputs: Cost-benefit information and associated data; dissemination documentation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Conduct analysis on research prioritization and share advice and recommendations to CRP</td>
<td></td>
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<tr>
<td></td>
<td>o Outputs: Prioritization information and associated data; dissemination documentation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Provision of technical support</td>
<td></td>
</tr>
<tr>
<td></td>
<td>o Outputs: Technical materials; training and associated materials</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Provide internal and external capacity building in the integration of gender and youth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>o Outputs: Training and associated materials</td>
<td></td>
</tr>
</tbody>
</table>

2.4 Science quality
FP1 enhances MAIZE’s R4D strategy for impact and as such takes due to cognizance of the need of scientific rigor to ensure the robustness of its scenarios, assessments and products to achieve the intended outcomes. Evidence will be a lynchpin in adjusting internal and external priorities and perceptions. FP1 strives for excellence in science and to maintain science quality, Scopus-recognized peer reviewed journals remain the preferred publication outlet for its international public knowledge goods.

FP1 encompasses a multidisciplinary team of pragmatic system thinkers and R4D professionals around maize AFS with a high contribution from the social sciences (foresight, impact assessment, gender, value chain/business development) as well as such disciplines as geography, geo-spatial sciences and modeling (crop, bio-economic).

FP1’s science occupies a unique niche – grounded in reality, multidisciplinary and with a clear international R4D focus on maize AFS. As such it contrasts and complements academia and integrating CRP’s like PIM. The diverse publication outlets reflect FP1’s niche – yet maintaining scientific quality. In a
recently commissioned external review by the CGIAR, the MAIZE lead center was recognized for having the highest field-weighted citation impact in social sciences (2.36), the highest share in top 10% highly cited papers in social sciences (41%), and the highest number of publications in agricultural and biological sciences (Elsevier, 2014). This is matched by choosing partnerships with outstanding universities and research think tanks – both within and outside the target geographies. Still, science quality in many of the target geographies is uneven and can imply significant investments in capacity development.

Within the confines of FP1’s unique niche – we continue to use proven scientific methods and adapt to the needs and resources available without compromising scientific quality. Given the multidisciplinary team many scientific methods draw across disciplinary divides including the complementary use of quantitative-qualitative approaches. Given the R4D focus and niche much of the scientific novelty is the application and adaptation of approaches. In collaboration with partners, we are exploring some of the latest methodological advances, including randomized-control trials (e.g. ongoing work around drought tolerant germplasm and weather index based insurance with UC Davis) and DNA fingerprinting for varietal tracking in impact assessment (for other examples, see Table FP5.36). Increasing availability of datasets also opens up opportunities of repurposing data. Building on MAIZE-1 and other available datasets, we are merging and analyzing complex data sets (“big data”), particularly in relation to foresight and targeting, impact assessment (e.g. Frelat et al, 2016) and gender.

FP1 builds on a body of previous phase 1 and transition work:

- **Foresight and targeting**: Ex-ante work on germplasm improvement thus far has primarily revolved around economic impact assessment of high priority abiotic (Kostandini et al., 2013; in press) and biotic (e.g., maize lethal necrosis – de Groote et al., 2016a; *Striga* – Mignouna et al, 2011.) stresses, and the potential role of biofortification for feed value (Krishna et al., 2014). Targeting work informs the scaling projects (FP3-4) – both in relation to germplasm (Hyman et al, 2013; Notenbaert et al., 2013; Homann-Kee Tui et al, 2013) and sustainable intensification (Tesfaye et al., 2015a). Climate change is an integral dimension, particularly in terms of implications for maize production in target geographies (Cairns et al., 2013; Neufeldt et al, 2013; Shiferaw et al., 2014; Stirling et al., 2014; Tambo & Abdoulaye, 2012, 2013; Tesfaye et al., 2015b) and spill-overs (Chung et al., 2014; Gbegbelegbe et al., 2014).

- **Adoption and impact**: International agricultural research has helped shape the current global maize outlook (Shiferaw et al., 2011). Previous work in SSA has shown good adoption and impact of improved CGIAR maize (Alene et al., 2009, 2015; de Groote et al., 2015). Ethiopia is a central success story (Abate et al, 2015) and case in ongoing impact assessment work, both in terms of traditional varietal studies using representative panel data (Zeng et al., 2015) as well recent explorations into the use of DNA fingerprinting for unambiguous varietal identification (ongoing, to be published in MAIZE-2). Recent published MAIZE adoption/impact work from CIMMYT and IITA includes selected germplasm studies (Beyene & Kassie, 2015; Bezu et al., 2014; Fisher & Snapp, 2014; Fisher et al., 2015; Hellin et al, 2014; Kassie et al., 2014b; Kathage et al, in press; Lunduka et al., 2012; Manda et al, in press; Snapp & Fisher, 2015; Tambo & Abdoulaye, 2012, 2013; Raghu et al., 2015) and sustainable intensification practices (Amare et al, 2012; Kassie et al., 2013, 2015a,c; Manda et al. 2016; Marenya et al, 2014; Micheni et al, 2016; Ngwira et al, 2014; Teklewold et al 2013a,b), including post-harvest (de Groote et al, 2013; Gitonga et al., 2013). Another body of published work
looks at tradeoffs and gradients associated with adoption of maize innovations, particularly sustainable intensification (Erenstein et al., 2012, 2015 special issue, multiple articles; Jaleta et al, 2013; Valbuena et al, 2012).

- **Gender and social inclusiveness**: Recent published MAIZE work from CIMMYT and IITA includes studies looking primarily at gender and germplasm (Fisher and Kandiwa 2014; Lunduka et al 2013), sustainable intensification practices (e.g. Farnworth et al 2015; Marenya et al, 2015; Ndiritu et al 2014; Teklewold et al 2013a,b; Gitonga et al 2013; Manda et al. 2016), climate change (Beuchelt & Badstue, 2013) and livelihoods and food security (Kassie et al, 2014a, 2015b; Mutenje et al. 2016).

- **Value chain opportunities**: Recent published MAIZE work from CIMMYT and IITA includes linkages to farmer’s livelihood security (Hellin et al., 2012; Frelat et al, 2016); consumer preference studies around maize (De Groote et al., 2014a,b, 2015b; De Groote and Kimenju, 2012; Gunaratna et al, in press); assessments of alternative maize markets (Hellin et al, 2013; Keleman et al, 2013) and maize uses – e.g. the potential demand for dual purpose food-feed maize varieties (Grings et al., 2013 special issue, multiple articles); opportunities related to seed supply (Kassie, G.T. et al, 2013; Kumar et al, 2012; Smale et al, 2015); opportunities related to sustainable intensification (Baudron et al 2015); and institutional innovations that interact with MAIZE innovations (Donnet et al, 2012; Fisher and Kandiwa, 2014; Fisher & Lewin, 2013; Hellin, 2012; Holden & Lunduka, 2014; Holden & Fisher, 2015; Lunduka et al, 2013; Ndegwa et al, 2015; Shiferaw et al, 2015; Tadesse et al, 2015).

### 2.5 Lessons learnt and unintended consequences

FP1 helps MAIZE achieve its impacts and contribution to SRF targets within the available resources and mandate. FP1 helps the transformation of a commodity focus in phase-1 to an AFS focus in phase-2. FP1 has been reorganized to reflect organizational learning and more strategic focus as compared to phase-1. Foresight and targeting are significantly strengthened – to help foster a more pro-active research portfolio and more rigorous prioritization in and across MAIZE FPs systematically based on strategic foresight. In part the foresight and targeting draws on the close collaboration with PIM, but includes strengthening of both internal capacity and other strategic partnerships to provide both timely and nuanced responses and a broader suite of approaches. Climate change is a clear driver taken into account – both in relation to a close collaboration with CCAFS and as cross-cutting in MAIZE-2. The Phase-1 demonstrates the importance of having an ear on the ground through the presence of staff across the main target regions and an active network of NARS partners. A tradition of collaboration and empirical realism allows FP1 to qualify and understand how changes at multiple levels are changing the R&D landscape and local AFS priorities and implications. Crisis’s grab the headlines and shape political priorities – but it is the incremental changes over time that shape the next crisis before it unfolds. FP1 aims to better understand and document these with the necessary evidence base to help reshape priorities and investment needs – including the changing R&D landscape, public-private complementarities and the public good niches that provide the highest value for money.

The CoA around adoption and impact was refocused and aligned with the MAIZE impact assessment strategy – including a clearer focus on learning and feedback loops to enhance impact. This CoA also looks into any unintended consequences of maize innovations and corresponding R&D implications for MAIZE AFS – including socio-economic, environmental and institutional. Being an integral part of the CRP provides the necessary inside views and nuances while adhering to objectiveness and scientific quality. The significance of gender (women and youth) for successful delivery is increasingly mainstreamed into the scaling work in FP3 and FP4. Resource constraints implied that the MAIZE gender team was constrained and stretched in phase 1 – but with time we were able to strengthen the gender
team during the transition phase with new bilateral resources and changes of emphasis and focus. Youth was implicitly considered as part of gender in MAIZE I – but received additional impetus in the pre-proposal call and is an area being strengthened in 2016 so as to become an integral part in MAIZE II, building on and incorporating lessons from the phase 1 Humid Tropics CRP and strategic partners. The transition phase post-harvest CoA has evolved into identifying value chain opportunities to enhance smallholder livelihoods, while farm-to-fork R4D is moved to FP5.

FP1 also drew more generic lessons from the phase 1 and transition implementation. For one, FP1 fully endorses the CRP second portfolio and the increased alignment and docking with other CRPs – a significant improvement over Phase 1 (see FP1 partnerships section). Indeed, the CRP portfolio more clearly shows the complementarities between the CRPs, in much the same was as FP1 complements the other MAIZE FPs. Still there is need to manage transaction costs and keep the eye on the ball so that we continue to deliver. There are also clear advantages of having FP1 internal to the CRP – able to provide the higher level cross-FP view, with the other FPs more thematically focused. FP1 primarily comprises social sciences – but it is not a disciplinary silo; and there are clear cross-linkages with other FPs, with some social scientists embedded in these other FPs where the level of analysis and emphasis differ – but with clear complementary roles. A surprising lesson was perhaps the continuously evolving funding portfolio and uncertainty – whereby bilateral money is proving both more substantial and less uncertain than W1/2. W1/2 still provides essential coherence to the FP1 portfolio – but its strategic use is somewhat curtailed by the annual uncertainty. It does enable to seed new areas (e.g. commissioning studies) but is inherently limited in its ability to build up the strategic in-house capacity and partnerships with the time and freedom to focus on the real strategic issues.

2.6 Clusters of activity (CoA)

CoA 1.1: Informing R4D strategies through foresight and targeting

Foresight analysis provides an important instrument to monitor and enhance the understanding of the evolving context in which MAIZE operates. Given the research-to-adoption lag, future beneficiary needs should inform our current priorities. Furthermore, we must take into account the plausible and probable biophysical, socio-economic and politico-institutional context at the time when technologies, including varietal improvement, come to fruition. Both the future needs of our beneficiaries as well as the context in which they will operate are shaped a number of factors: global drivers of change, pressures and events. At the same time, MAIZE’s diverse portfolio of innovation pipelines at different developmental stages (discovery, validation, scale-out) require us to make projections of their likely future impact and inform associated tradeoff decisions – e.g. future impacts for poor producers versus benefits for poor consumers. A better understanding of future needs and ex-ante assessments of innovations can help to position and prioritize research investments for greatest impact. In addition to the dynamic context of maize AFS, there is the spatial context calling for the identification of spatially diverse needs and opportunities and associated implications for recommendation domains and innovation targeting.

This CoA uses and develops appropriate foresight, targeting and modeling tools, drawing on increasing amounts of georeferenced data and modeling capacities and building on phase 1 achievements (see FP1 quality of science section). The global drivers of change require the use of global analysis tools while the effects of the drivers, pressures and events have varying regional, national and sub-national repercussions. This implies that different sets of tools are also used to analyze the effects at different levels of aggregation. We recognize at least four levels of aggregation where analysis is needed in order to make predictions and inform research priority setting. The first is the aforementioned global level, the second is the meso regional/national level, the third is the community/landscape level and the fourth is
the household/individual level (both resource poor producers and consumers). Each level requires different tools, techniques and methodologies, both quantitative as well as qualitative in order to assess the future for R&D.

Ex-ante impact assessment is focused on the potential contributions to CGIAR 2022 (and 2030) targets. For all major MAIZE innovation pipelines (FP2-5), product development and placement/targeting are to be based on systematic and forward-looking analyses by 2022, and assessments are to be updated and refined as innovations pass from discovery through validation and scaling-out. This CoA envisages an initial foresight exercise and subsequent updates and refinements so as to (i) identify potential opportunities/threats and game changers for maize AFS; (ii) assess how major drivers like climate change and rural transformation will alter maize AFS in the developing world; and (iii) assess future needs of maize producers and consumers and implications for maize innovations.

The analysis conducted in CoA 1.1 is closely linked to MAIZE’s other FPs. Foresight sheds light on the traits that need to be taken into account in the breeding process to meet future demands (FP2-3) and both foresight and ex-ante impact assessment are crucial in informing innovation pipelines for sustainable intensification and scaling (FP4) for nutritional, post-harvest and processing technologies (FP5). Within FP1 there is close collaboration with the other CoAs, sharing tools, techniques and methodologies and drawing on the current and historic findings related to changing AFS circumstances regarding value chains, technology adoption and social inclusiveness. Especially the gender-youth nexus, which in the past has tended to be less prominent in global and meso-level models, will receive full attention. Insights into future dietary changes will also better align MAIZE’s economic value with nutritional value and dietary diversity, considering that private actors implement many food system actions, and will link back into the breeding and agronomic technology development process through research priority setting.

CoA 1.2: Learning from M&E, Adoption and Impacts

International agricultural research contributes to agricultural growth in developing countries and the achievement of SLOs (e.g. reduction in poverty and food insecurity), although the extent of the contribution remains an empirical question and may result in unintended consequences. Agricultural research also competes with other potentially deserving investments for scarce resources. MAIZE therefore needs to rigorously document its value for money and that it deserves investment. CoA 1.2 will undertake adoption and impact studies to evaluate the merits and consequences of new MAIZE technologies in AFS, including impacts on individuals (farmers, consumers, and processors), their communities and national economies and the associated learning in terms of R&D implications.

The impact assessment envisages a two-tier assessment of MAIZE innovations. The macro level will focus on MAIZE germplasm use across the developing world, with a systematic stock taking of varietal releases, MAIZE attribution and estimated adoption. This builds on earlier and recently re-initiated global efforts (Morris et al., 2003; Morris, 2002), supplemented by regional studies (e.g. DIIVA-SSA [Alene et al., 2015; de Groote et al., 2015] and SIAC-Asia). At the micro-level, systematic impact studies will be conducted in selected target countries - to the extent possible building up from (nationally) representative and panel data; aligned with site integration and existing data sets (e.g. LSMS); and providing regional coverage. Micro-level studies will include MAIZE germplasm and sustainable intensification in maize AFS. Results from the micro-studies will be aggregated to determine the contribution of the MAIZE innovations to the national agricultural growth and poverty reduction.
Phase 1 and ongoing adoption/impact work in MAIZE by CIMMYT, IITA and partners will form a starting point for this CoA. This includes a substantial body of MAIZE studies focusing on the adoption and impacts of MAIZE germplasm and sustainable intensification practices, particularly in Africa and Asia (see FP1 quality of science section). Past studies primarily focus at the farm household level and in the new phase we foresee to extend to maize AFS. Relevant ongoing projects include components in several germplasm projects in SSA and Asia (DTMASS (including an RCT), NuME, HTMA, D/STMA) and integrated sustainable intensification projects (SARD-SC, SIMLESA) and purposive impact assessment projects (e.g. Adoption Pathways, with a large collection of panel datasets from East and Southern Africa).

Adoption studies will complement ex post impact studies – allowing for earlier learning from adoption processes. CoA1.2 will actively strengthen the necessary feedback loop between research, the agricultural development community and farmers. While the information feedback loops between the three entities has long been recognized as indispensable in agricultural R&D, the communication and transmission of information and technology from research to farmers tend to be linear with limited input from farmers or decision makers. Part of CoA1.2 research will therefore use action and participatory research approaches to inform the adaptation of maize innovations at the initial stages of their development, scaling and adoption in direct collaboration with FP3 and FP4.

- The MEIA strategy in CoA1.2 will be guided both by the pathways that lead to adoption as the (intermediate) outcome and the adoption-to-impact pathways. Identifying the latter pathways will be important to know how the impacts came about and for the associated learning and implications. Therefore future studies are proposed to address behavioral aspects underlying adoption and dis-adoption, i.e., understanding why farmers adopt and/or dis-adopt, what they are willing to pay, or how they manage risk, as well as the larger-scale questions of impacts on agricultural productivity, income, nutrition, poverty, environmental sustainability.

**CoA 1.3: Enhancing gender and social inclusiveness**

The CoA provides overall strategic leadership for gender research and guidance for systematic integration of gender and social inclusion perspectives across all MAIZE FP's. The CoA addresses a number of overarching research questions (Error! Reference source not found.) using mixed and complementary methods (quantitative and qualitative) in MAIZE gender and socio-economic research. It envisages that by 2022 gender/social inclusion lenses will be routinely applied to major MAIZE innovation pipelines and assessments. Differentiated recommendations on choice of intervention and scale-out strategies will systematically support social inclusion of women and youth in maize AFS by 2022.

Ongoing work includes the GENNOVATE initiative to document and analyze how gender norms and agency influence the ability of men, women and youth to learn about, try out, adopt and adapt new agricultural technologies. Led by MAIZE and WHEAT this is a collaborative cross-CRP, comparative, qualitative research initiative at scale and represents a methodological innovation in the area of social science in the CGIAR in general and in MAIZE in particular. Other recent work contributing to inform phase II includes strategic and integrative gender research on small-scale mechanization (Eerdewijk & Danielsen 2015), improved post-harvest storage technologies, conservation agriculture, participatory varietal selection (PVS), and seed sector development. Similarly progress has been achieved in relation to documenting gender aspects of technology adoption and impact assessments (see FP1 quality of
Selected ongoing projects (e.g. SIMLESA, DTMA, IMAS, FACASI, WEMA, CSISA) include integrative gender research, e.g. gender responsive technology development and testing in SSA, including integration of gender considerations in value-chain R4D and capacity building; gender responsive service provision and information diffusion in S Asia; assessing the life histories of women’s and men’s cultivated plots and how they have evolved over time in SSA; and action-oriented pilot projects in SSA to motivate and engage young adults in a range of improved crops, post-harvest processing and agribusiness opportunities, and to take agriculture as a viable business.

To facilitate and encourage integration of gender, youth and social inclusion in maize R4D, investments are made to strengthen gender in MAIZE frameworks and procedures, e.g. project cycle, operational policies and M&E, as well as to strengthen overall capacity to identify and address gender issues in maize AFS research in collaboration with partners (e.g. the development of a gender competency framework and modular capacity building program, led by Cultural Practice LLC; and gender equality and professional capacity enhancement, led by KIT).

MAIZE achieved a strong momentum focusing on establishing gender and social inclusion as a prioritized research area for the CRP. In Phase-II the focus will be on consolidating the systematic and rigorous application of established quantitative and qualitative gender and social research methods in the context of maize AFS research, including: a) strategic gender research which aims specifically to understand the implications of gender dynamics for maize AFS development; and b) further increasing the integration of gender analysis and –targeting in technical R4D projects of bio-physical or socio-economic focus. As part of this the concept of sex-disaggregation, understood as going beyond the level of household leadership, will be systematically applied in all people-level data collection and analysis.

**CoA 1.4: Identifying value chain opportunities to enhance smallholder livelihoods**

Market and value chain analysis provides an important instrument for identifying opportunities to enhance livelihoods in maize AFS and associated R4D implications. AFS evolve in response to demand and supply and are transformed by the consequences of globalization, urbanization, rural transformation and changing preferences, including reduced direct human consumption (in urban centers), changing maize products and processing (CoA 5.2) and increased demand for maize as animal feed (CoA 5.3) in response to rising incomes. Such an analysis goes beyond treating maize as a simple standard commodity and considers maize as a differentiated product with diverse market opportunities. These include specialty maize markets (particularly in Latin America, linked to CoA 3.3), but also Quality Protein Maize (QPM) for human and animal nutrition, vegetable maize, and white maize for food and yellow maize for the animal feed industry. As a result, MAIZE’s R4D agenda needs to be informed and adapted to major potential market opportunities and game-changers. The growth of the poultry industry in India is one such example (Hellin et al. 2015) and it has implications for the quantity and type of maize demanded. Adoption of maize AFS innovations hinges on the incentives stakeholders have in their local context, and can thus be either catapulted or thwarted by input and output value chain opportunities and constraints along with the presence or absence of supporting financial and business development service providers. Ensuring parallel deployment of new technologies and the evolution of value chains and market opportunities is key for resource poor stakeholders in maize AFS to capture a substantial portion of the value. This raises issues not just of the types of maize grown but also the interventions that are needed to make these value chains more effective, efficient, equitable and socially inclusive.
This CoA intends to assess systematically maize value chain opportunities in the target geographies and interlinkages with global markets and developments by building on previous and ongoing work (see FP1 quality of science section). A special focus is to assess the potential opportunities and game changing nature of maize utilization. This calls for strong value-chain-driven, farm-to-fork evidence to assist smallholder involvement in maize as a cash crop in Asia. Under the previous phase, partners undertook regional assessments in Asia, SSA and LA and took stock of the value chain opportunities and implications for MAIZE R4D. Other recent value chain work includes consumer preference studies around maize and assessments of alternative maize uses. This CoA draws on internal capacity at CIMMYT and IITA, while expanding partnerships including with PIM. New collaborative work with CCAFS in East and West Africa (Nigeria) explores weather index based insurance to reduce the risk faced by farmers and enhance farmer technology uptake and intensification in maize AFS, including as complement to drought-tolerant germplasm.

The main outcome of this work is to provide 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 AFS. Also, knowledge generated in this work could help better target breeding (incorporating preferred traits by farmers (men and women), processors, feed millers, agro-processors and consumers). This CoA thereby complements targeted R4D addressing value chain opportunities in FP5. Similarly this CoA identifies and assesses input value chain opportunities, which then dovetails into work related to developing seed markets and seed market segmentation under FP3; and non-seed input value chain development work, such as mechanization and associated business model development under FP4.

2.7 Partnerships

FP1 aligns with the CRP MAIZE partnership strategy. FP1 occupies a unique niche to generate international public goods to enhance MAIZE’s R4D strategy for impact. Being led by scientists from the two lead maize-centers in the CGIAR provides a distinct comparative advantage – providing a unique AFS focus and R4D perspective, and providing an objective and neutral partnership platform to link with strategic partners across the globe. Enhancing MAIZE’s R4D strategy for impact hinges on multi-disciplinary collaborative research across programs and institutions. Central to FP1’s mandate are multifaceted, inclusive and strategic partnerships within the confines of a unique AFS perspective, i.e. the “maize focus” and its theory of change (Error! Reference source not found.).

Internal to the CRP and central to its mandate, FP1 provides horizontal guidance to MAIZE and supports and contributes to all the other FPs. Whereas FP1 is inherently multidisciplinary , it has a high contribution from the social sciences, which partner with other disciplines to address strategic R4D issues in maize AFS. These internal partnerships vary by CoA. FP1’s foresight and targeting work has clear linkages with the discovery and upstream work in FP2, FP3 and FP5; as well as with the system dynamics in FP4. FP1’s adoption, learning and impact work increases in relevance from the proof-of-concept level to downstream scaling out levels in FP3, FP4 and FP5. Gender and youth are most obvious in the downstream levels of the latter 3 FPs – but need due attention in the higher levels.

External to the CRP, FP1’s most direct partners include the CGIAR, advanced research institutes (ARI’s) and national agricultural research systems (NARS) (Table FP5.3 and Annex 3.2). Within the CGIAR MAIZE aligns with AFS CRPs (e.g. WHEAT, GRISP, DCLAS) and docks with integrative CRPs (e.g. PIM, CCAFS and A4NH), both in terms of specific collaborative projects, site integration and to ensure synergies. The docking of foresight work with PIM has a particularly strong foundation around bio-economic modeling
that will be pursued. PIM thereby focuses foresight at the higher multi-commodity level whereas MAIZE brings the more granular and focused AFS level. MAIZE thereby provides a useful refinement and disaggregation of R&D implications for technologies and innovations; of the major drivers as they apply to maize AFS; and of ground level realities and agro-ecologies. New opportunities to strengthen docking with PIM beyond foresight are being pursued. Similarly there are ongoing discussions to explore new opportunities with CCAFS in relation to joint resource mobilization and with A4NH in relation to food system innovations and understanding of changing diets.

Non-CGIAR partners include an array of ARIs and NARS in target geographies (Table FP5.3 and Annex 3.2). There is a long tradition of partnerships with NARS across the target geographies – particularly strong where the CRP lead centers have staff on the ground but spilling over into neighboring geographies, particularly in SSA. Some of these partnerships are directly embedded in larger bilateral regional projects lead by other FPs – but offering active partnership networks that facilitate wide consultation and follow up, including through annual project stakeholder meetings, and linkages to policy and decision makers (e.g. NARS directors). Regional partner consultation also occurs through commissioned studies (e.g. ongoing maize markets foresight study through the ReNAPRI network in eastern and southern Africa; regional assessments in Asia, SSA and LA in phase 1), conferences/regional meetings (e.g. 2014 Asian Maize Conference) and through regional organizations (e.g. ASARECA; CCARDESA; CORAF; APAARI). Particularly the partnerships with ARIs have evolved and been strengthened during the transition phase. Guiding the partnerships are the added value of partners in terms of scientific contribution and enhancing the probability of impact, associated complementarities, and synergies with in-house capacity and needs.

2.8 Climate change
Climate change is one of the societal grand challenges and a cross-cutting theme for the CRP MAIZE overall. FP1 enhances MAIZE’s R4D strategy for impact and as such takes due cognizance of climate change and its implications, particularly for adaptation. FP1 helps assess how climate change could transform maize AFS and associated food security and resilience. Most obvious perhaps is climate change as part of foresight analysis (CoA 1.1) – an integral driver of the evolution and stability of maize production over the coming decades. Climate change also increases weather variability and the incidence of stresses and thereby the riskiness and potential returns to maize production and innovations. FP1 assesses the adoption and impacts of various climate-smart agricultural practices generated by MAIZE including improved maize germplasm (drought, heat and waterlogging tolerant), sustainable intensification and hermetic storage. FP1 also takes due cognizance of interactions between climate change and social equity, including implications for gender, social inclusion and youth in terms of differential location, asset base and/or roles in maize AFS. Finally, climate change affects maize value chains, be it in terms of the geography of production, processing and consumption or driving the demand and markets for associated innovations (e.g. weather index based insurance; agri-business models for seed and service providers). Some of the work will be pursued in collaboration with CCAFS, other work directly as an integral part of MAIZE. FP1 will share its results with decision makers and development partners and create awareness about climate change adaption prospects in maize AFS.
2.9 Gender
FP1 will align with the CRP MAIZE gender strategy, not least as FP1 is the institutional home for both the MAIZE gender team and gender strategy. It is also home to a dedicated CoA, 1.3, focused on strengthening the integration of gender, youth and social inclusion into maize AFS research. The approach combines strategic gender research and integration of gender into technical maize research across all FPs, including the other CoA’s in FP1. To support and facilitate this process a special component of the CoA is dedicated to strengthening capacity for gender responsive approaches and mainstreaming of gender into operational frameworks and procedures.

In order to strengthen the evidence base for gender analysis, FP1 has standardized sex-disaggregation in all its people-level data collection and analysis, including in relation to ex-ante and ex-post impact assessments. The findings of gender research in FP1 (both strategic and integrative) feed into and inform research priority setting and targeting across MAIZE.

Overall FP1 contributes to gender equality and social inclusion in maize AFS R4D by strengthening the evidence base through gender research, foresight analysis, adoption studies, impact assessments and value-chain development; as well as through evidence based policy recommendations and research targeting and priority setting. In addition to housing the MAIZE core gender team, FP1’s other social scientists are active gender and youth ambassadors to ensure the social inclusiveness of MAIZE, as evidenced by a number of recent publications (see FP1 quality of science section).

2.10 Capacity development
FP1 will align with the CRP MAIZE overall Capacity Development plan and CGIAR CapDev Framework. Capacity development will revolve around increasing the capability of partner organizations and beneficiaries to innovate, learn and adapt with focus on mainstreaming of strategic thinking, theories of change and gender sensitive approaches. Other key elements include increasing organizational and institutional capacity in more fully understanding of impacts of maize innovations through appropriate foresight, targeting and modelling tools and approaches, ex-ante impact assessment and adoption pathways, differential adoption and factors such as markets, assets, institutions, agro-ecologies and technology policies and farmers’ risk and preferences.

Capacity will also be enhanced through sharing findings within the CRP, the provision of targeting information and extension material packages and other innovative training and learning. In conducting a collaborative research agenda and research on scaling out pathways to enhance dissemination of adoption, partner’s capacity will be improved through exchange of information, lessons and insights and outputs. The dissemination of research information and associated data, marketing and communication products on research findings and benefits, policy briefs will also contribute to partners’ capacity development as well as the provision of policy advice to multiple audiences (CRPs, multilateral organizations, donors, local and regional governments) to influence policy-making.

FP1 uses on-the-job collaboration, fellowships and exchange workshops, knowledge sharing methods and tools with a focus on mainstreaming strategic thinking, theories of change, use of a gender lens and multi-disciplinary approaches, and analytical rigor. In particular, the FP1 will contribute to develop capacity in equity and inclusion by improving the capacity of young women and men to participate in decision-making and to facilitate their access to markets and value chains opportunities and job opportunities. FP1 also actively pursues opportunities to integrate students (preferably PhD) in the CoA’s – welcoming internships and particularly thesis research.
2.11 Intellectual asset and open access management
FP1 will align with the CRP MAIZE intellectual asset and open access management, and as such adhere to the associated CGIAR and institutional principles. FP1 generates international public goods to enhance MAIZE’s R4D strategy for impact and the underlying principle is to make these as easily and widely available. Under FP1, scientists develop tools for data management, stewardship and analysis, to improve modeling and make better use of empirical data. These will be designed with OA/OD in mind (e.g. provide access). Researchers will make their well-documented yet adequately anonymized and non-confidential raw data (e.g. household surveys) available to other scientists through Dataverse. Prior to uploading to Dataverse data may be shared on a case by case basis through a data sharing agreement. Although the focus is on international public goods, any underlying confidential data - including sensitive private sector perspectives and trade data - will be respected and treated as such and associated publications will be adequately synthetic and anonymized. Publications are a major FP1 output and these will be made easily accessible. To maintain science quality, Scopus-recognized journals remain the preferred outlet, and to the extent possible papers will be published as open access therein. Where resources limit the possibility of open access, efforts will be made to facilitate access to the underlying research through pre-prints and individual requests within the allowed space. To ease access, main findings will also be shared through other communication media, including policy briefs with adequate cross-referencing to the underlying detailed studies.

2.12 FP management
FP1 is managed jointly between the two lead centers – with both joint FP coordination and co-CoA leads (Table FP5.4). The co-leadership allows both centers to have a clear co-leading role and provides clear focal points within each organization for each CoA and the FP as a whole. Co-leadership is further warranted by the geographic complementarities between the two lead centers. Co-leadership also eases integration with MAIZE’s other FPs – critical in view of FP1 providing horizontal guidance.

2.13 Budget summary (To be completed)

FP2: Novel Diversity and Tools for Increasing Genetic Gains
2.1 Rationale, scope
FP2 harnesses advances in science and new technologies to develop and validate maize-specific tools and to provide novel raw materials that are mainstreamed in FP3 to enhance breeding efficiency and germplasm enhancement. Such novel tools and methods, including (i) the discovery and deployment of allelic diversity and molecular markers for key traits, (ii) the development of more accurate, high-throughput phenotyping protocols, (iii) the development and mainstreaming of new data analysis methods, (iv) the development and optimization of breeding methods (e.g. genomic selection and doubled haploids), and (v) tools that simplify storage and use of more comprehensive data sets will accelerate the rates of genetic gain in FP3 breeding activities. As a result, FP2 is an essential “tool discovery, validation and deployment” step in the impact pathway of MAIZE, linking priority setting (FP1) to germplasm development with broad genetic base and scaling out products to farmers (FP3), use of such diverse germplasm within the sustainable intensification of maize-based systems (FP4) and value addition (FP5) activities.
Significant progress in tool development and mainstreaming has been achieved during MAIZE Phase I and through the following projects:

1. MasAgro Bioversidad (Seeds of Discovery), resulting in genotyping-by-sequencing of 90% of the CGIAR maize landrace accessions, plus phenotypic information for core sets.
2. Drought Tolerant Maize for Africa (DTMA) and Water Efficient Maize for Africa (WEMA), using and learning from marker-assisted recurrent selection for drought tolerance in maize as well as using association analyses of drought tolerant germplasm from diverse sources to promote access to novel alleles for accelerated genetic gain.
3. Genomics and Open-source Breeding and Informatics Initiative (GOBII), pioneering the use of high density genomics information in mainstream breeding in the public sector.
4. The Integrated Breeding Platform (IBP) allowing the implementation of breeding applications in the public sector, including NARS and companies in low- and middle-income countries.
5. Maize Doubled Haploids – Africa: making maize doubled haploid technology accessible to NARS and seed companies in Africa.

2.2 Objectives and targets

The theory of change (ToC) underlying FP2 (Figure 7) shows how FP2 outputs contribute to specific sub-DOs, especially: a) enhanced genetic gains (through tools and methods that enable more efficient management of breeding programs, new/additional genetic variation and its use, increased selection intensity, and decreased cycle time in breeding programs); b) increased conservation and use of genetic resources (databases and informatics tools that enhance accessibility of genotypic, phenotypic and other data, facilitating enhanced use of genetic resources, including those held in germplasm banks); c) enhanced capacity to deal with climatic risks and extremes (through FP3); d) enhanced institutional capacity of partner research organizations (open access tools, e.g. for electronic data capture or for data analysis and decision support; methods for enhancing efficiency in breeding; tools and methods for diversity assessment and identification and use of beneficial alleles; and e) enhanced collaboration with partner organizations to develop research outputs (through capacity building courses, workshops, graduate student mentorship, visiting scientists, etc.).

Key performance indicators for FP2 include:

- Number of breeder-ready markers/high-value haplotypes for prioritized traits identified and validated (under FP2) and deployed in breeding programs (FP3)
- Reduction in cost of DH development process based on research undertaken in FP2
- New tropicalized haploid inducer lines developed, disseminated and used by MAIZE partners
- Decision-support tools developed, disseminated and used by MAIZE partners
- New source germplasm developed and used in breeding programs
- Number of public/private institutions trained on enabling tools for increasing genetic gains
- Number of public/private institutions implementing novel breeding strategies developed under FP2

Target Countries/Geographies and First Users

The scope of FP2 is global. The first users of the outputs of FP2 will be MAIZE FP3 breeders, including CIMMYT, IITA, NARES and private sector partners across SSA, Asia and LA.
2.3 Impact pathway and theory of change

The FP Novel Diversity and Tools’ theory of change was developed during a workshop with the Flagship Program teams from both MAIZE and WHEAT CRPs. A participatory approach was used to capture all views, experiences and known evidence into the theory of change. The workshop participants were able to increase their understanding of the CGIAR Strategy and Results Framework and awareness of results-based management concepts. The workshop was also structured to encourage sharing and learning on a variety of topics and across both CRPs.

Using the CGIAR Results Framework’s sub-intermediate development outcomes (IDOs) the team agreed to focus on two sub-IDOs and three cross-cutting sub-IDOs:

- 1.4.3 Enhanced genetic gain;
- 1.4.4 Increase conservation and use of genetic resources;
- A.1.4 Enhanced capacity to deal with climatic risks and extremes;
- B.1.2 Technologies that reduce women’s labor and energy expenditure developed and disseminated; and
- D.1.1. Enhanced institutional capacity of partner research organizations.

Other sub-IDOs were noted by the team as important to programming given that they overlap with the above sub-IDOs of focus. Regarding the sub-IDO 1.4.3 related to enhanced genetic gain, the team noted that this sub-IDO encompasses all elements of gain sought by the CRP, including yield, abiotic, biotic and quality traits.

Based on these areas of focus, the team agreed that this Flagship Program contributes to reducing poverty (SLO 1) and improving food and nutrition security for health (SLO 2) by the mean of increasing productivity (IDO 1.4) and enhancing the cross-cutting issues of climate change (A), gender and youth (B) and capacity development (D).

A number of research and development outcomes were identified and a pathway of change was created demonstrating the causal relationship between outcomes and sub-IDOs. During this process, partners involved in the pathway of change were identified. Current and proposed interventions and associated outputs to support the achievements of the outcomes were mapped. Assumptions describing the contextual underpinnings of the theory as well as the risks that may have the potential to undermine success were documented.

This theory of change will be the foundation for the monitoring, evaluation and learning plan. The monitoring plan will consist of a continuous process of collection and analysis of data based on a set of indicators directly related to the performance of the CRP at the output and outcome levels; the key assumptions of the theories of change; and the critical risks. The theory of change will also be the basis for evaluating the Flagship Program as well as reflecting on lessons and program improvements.
Figure 7: Theory of Change for MAIZE FP2: Novel Diversity and Tools for Increasing Genetic Gains
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<thead>
<tr>
<th>Assumptions and Risks</th>
<th>Interventions and Outputs</th>
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<tbody>
<tr>
<td><strong>A</strong></td>
<td>Develop and provide training to breeders in new methods</td>
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<tr>
<td>Enhanced genetic gain encompasses all elements of gain sought by the CRP (e.g., yield, abiotic, biotic and quality traits)</td>
<td>Outputs: training and associated materials</td>
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<tr>
<td>Breeders are adequately funded and are willing to adopt and adapt documented germplasm and tools</td>
<td>Disseminate new documented germplasm by demonstrating yield gain potential via open access channels</td>
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<td>- Risks:</td>
<td>Outputs: documented germplasm, data, dissemination documentation</td>
</tr>
<tr>
<td>o Relevant climate predictions are not precise</td>
<td>Develop marketing approaches, methods and skills to share tools and documented germplasm developed by FP2</td>
</tr>
<tr>
<td>o Unanticipated combinations of abiotic stresses occur</td>
<td>Outputs: marketing approaches, methods, and associated dissemination documentation; training and associated materials</td>
</tr>
<tr>
<td>o Unanticipated pests and/or diseases appear (biotic) requiring new research in germplasm and tools</td>
<td>Identify and implement institutional incentives for knowledge sharing (e.g., data sharing measures) and incentivize via employee performance review, including support for publication</td>
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<td>Conducive environment for capacity building</td>
<td>Outputs: measures for knowledge sharing, knowledge, dissemination documentation, employee performance review</td>
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<td>Existence of effective communication and dissemination capacity and systems</td>
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<td>Effective assessment of the needs and capacity of partners (internal and external)</td>
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<td>Risk: Staff turnover reduces capacity building efforts</td>
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<td><strong>B</strong></td>
<td>Develop and implement a capacity building strategy and plan</td>
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<td>There will be continuous demand for documented germplasm and tools</td>
<td>Outputs: Capacity building strategy and work plan, associated capacity building documentation</td>
</tr>
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<td>Technologies are cost-efficient</td>
<td>Provide appropriate infrastructure support</td>
</tr>
<tr>
<td>Crop researchers are adequately funded and are willing to use documented germplasm and tools</td>
<td>Outputs: technical advice, infrastructure (e.g., hand held data logger, labs)</td>
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<tr>
<td>Feedback loops exist to ensure effective communication between CRPs scientists, crop researchers, breeders, and genebanks</td>
<td>Provide research support services</td>
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<tr>
<td>Strong collaboration exists between CRPs scientists, crop researchers, breeders, and genebanks</td>
<td>Outputs: documentation associated with services (e.g., double-haploids, markers, phenotyping)</td>
</tr>
<tr>
<td>Risks: Lack of uptake due to the existence of disincentives</td>
<td>Technical backstopping</td>
</tr>
<tr>
<td>CGIAR has the lobbying power – and uses it - to influence increased</td>
<td>Outputs: documentation associated with backstopping (e.g., training, IT tools, biometrics)</td>
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<tr>
<th>Assumptions and Risks</th>
<th>Interventions and Outputs</th>
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<tr>
<td>international exchange of germplasm</td>
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<tr>
<td>• Target partner countries have/move towards international germplasm exchange policies and practices</td>
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<td>• Availability of resources and existence of capacity for dissemination, training and backstopping</td>
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<tr>
<td>• Funders acknowledge need for holistic solutions</td>
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<tr>
<td>• Scientists have understanding of the needs of beneficiaries and of the context in which they live</td>
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<tr>
<td>• Availability of resources and time to conduct needs and capacity assessments</td>
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<tr>
<td>• Risks:</td>
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<tr>
<td>o Donor funding and accountability structure may inhibit innovation</td>
<td></td>
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<tr>
<td>o Relevant intellectual property landscape might change</td>
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<td>o Intellectual property issues may constrain use and dissemination of germplasm and tools</td>
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<tr>
<td>• Existence of an enabling environment allowing scientists to take risks, innovate and learn from failures</td>
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<td>• Scientists have multidisciplinary curiosity</td>
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<tr>
<td>• Risks:</td>
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<tr>
<td>o Financial, social and political instability</td>
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<tr>
<td>o New emerging pests and diseases</td>
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<td>o Climate change</td>
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<tr>
<th>Interventions and Outputs</th>
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<tr>
<td></td>
<td>• Identify and improve accession and passport information</td>
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<td>o Outputs: accession and passport data</td>
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<td></td>
<td>• Rationalize dynamic core sets</td>
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<td></td>
<td>o Outputs: sets</td>
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<tr>
<td></td>
<td>• Explore and complete global diversity in other collection</td>
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<tr>
<td></td>
<td>o Outputs: accession and passport data, dissemination documentation</td>
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<tr>
<td></td>
<td>• Disseminate characterization of germplasm</td>
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<td></td>
<td>o Outputs: characterized germplasm, dissemination documentation</td>
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<td></td>
<td>• Create databases and consolidate data to manage the information</td>
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<td></td>
<td>o Outputs: databases, data</td>
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<td></td>
<td>• Develop and provide training and services (e.g., backstopping)</td>
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<tr>
<td></td>
<td>o Outputs: training and associated materials; services documentation</td>
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<td></td>
<td>• Support partners to properly plan for sustainably taking over complex tools (e.g., Green Global Foundation)</td>
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<td>o Outputs: advice, tools, dissemination documentation</td>
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<td></td>
<td>• Develop and implement tool deployment strategies and specialists</td>
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<tr>
<td></td>
<td>o Outputs: deployment strategies, training and associated materials</td>
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<td></td>
<td>• Build customer satisfaction and feedback loop between partner researchers and CRP and between FPs</td>
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<tr>
<td></td>
<td>o Outputs: surveys or other customer satisfaction tools, and associated responses</td>
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<tr>
<td></td>
<td>• Conduct formalized needs and capacity assessment</td>
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<tr>
<td></td>
<td>o Outputs: Identified needs and capacity</td>
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<td></td>
<td>• Develop and share value proposition/business models</td>
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<td>o Outputs: models and associated dissemination documentation</td>
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<td>Assumptions and Risks</td>
<td>Interventions and Outputs</td>
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<tr>
<td>- Develop and share an integrated holistic product and process description (e.g., protocol and documentation; training and application; documented germplasm, data and markers; accession and passport data) and incentivize via employee performance review</td>
<td>- Develop and share an integrated holistic product and process description (e.g., protocol and documentation; training and application; documented germplasm, data and markers; accession and passport data) and incentivize via employee performance review</td>
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| - Prepare and share comprehensive germplasm development documentation as a service to next users (including meta data development for IWIN)  
  - Outputs: protocols and associated dissemination documentation, training and associated materials, germplasm data and markers, accession and passport data | - Prepare and share comprehensive germplasm development documentation as a service to next users (including meta data development for IWIN)  
  - Outputs: protocols and associated dissemination documentation, training and associated materials, germplasm data and markers, accession and passport data |
| - Develop communication channels and networks (internal and external) to share product description  
  - Outputs: communication channels and materials; networking tools | - Develop communication channels and networks (internal and external) to share product description  
  - Outputs: communication channels and materials; networking tools |
| - Advocate (jointly with CRP FPs and other CRPs) for open access to data and documented germplasm  
  - Outputs: advice, position papers | - Advocate (jointly with CRP FPs and other CRPs) for open access to data and documented germplasm  
  - Outputs: advice, position papers |
| - Develop/refine breeding approaches for targeted environments and beneficiaries (e.g., incorporate GS, DH, hybrids, gene editing)  
  - Outputs: breeding approaches | - Develop/refine breeding approaches for targeted environments and beneficiaries (e.g., incorporate GS, DH, hybrids, gene editing)  
  - Outputs: breeding approaches |
| - Improve existing and develop new phenotyping tools (e.g., remote sensing, sensory, image-based non-invasive) and other tools as deemed appropriate  
  - Outputs: phenotyping and other tools | - Improve existing and develop new phenotyping tools (e.g., remote sensing, sensory, image-based non-invasive) and other tools as deemed appropriate  
  - Outputs: phenotyping and other tools |
| - Improve existing, develop and perform genotyping tools (e.g., sequencing, GBS)  
  - Outputs: genotyping tools | - Improve existing, develop and perform genotyping tools (e.g., sequencing, GBS)  
  - Outputs: genotyping tools |
| - Characterize breeding target environments (e.g. agro-ecological zone) and target beneficiaries  
  - Outputs: breeding target environments characterized, breeding target beneficiaries | - Characterize breeding target environments (e.g. agro-ecological zone) and target beneficiaries  
  - Outputs: breeding target environments characterized, breeding target beneficiaries |
<table>
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<th>Assumptions and Risks</th>
<th>Interventions and Outputs</th>
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<td>identified</td>
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<tr>
<td>• Conduct high quality phenotyping in well managed field environment, including confined field trials</td>
<td>o Outputs: phenotyping trial data</td>
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<tr>
<td>• Biotechnology to generate new diversity (e.g., genome modification, genome editing, mutation)</td>
<td>o Outputs: germplasm data</td>
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<tr>
<td>• Perform pre-breeding (e.g., wide-crossing, targeted pre-breeding driven by trait discovery, using different approaches, use of exotics)</td>
<td>o Outputs: pre-breeding germplasm data</td>
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<td>• Discover, document and share characterization of germplasm driven by traits, biotic, abiotic factors, including quality and agronomic needs</td>
<td>o Outputs: germplasm data and associated dissemination documentation</td>
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<tr>
<td>• Discover, document and share markers for unique alleles/haplotypes</td>
<td>o Outputs: marker data and associated dissemination documentation</td>
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<td>• Fostering effective networking with other initiatives, especially upstream</td>
<td>o Outputs: Scientific information regularly shared and received</td>
</tr>
<tr>
<td>• Develop and implement integrated germplasm information system (genealogy, phenotypic, genotypic, sensor, and environmental data)</td>
<td>o Outputs: Integrated germplasm information system</td>
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### 2.4 Science quality
Examples of novel and cutting-edge science in FP2 include:
- Establishment of multi-disciplinary trait teams to improve communication and collaboration through stages of the discovery-validation-deployment pipeline of new tools from FP1 to FP5 (across FP2).
- Pioneering work and collaboration with other CRPs (DCLAS, GRiSP, WHEAT) and proposed platforms (Genetic Gains and Big Data) on informatics tools to integrate complex, large data sets into decision support tools in the frame of the IBP (CoA 2.1).
• Development and validation of cutting-edge, novel biometrics analysis methods, especially in the area of genomic selection (CoA 2.1).
• Contribution to the development of the tropical maize reference genome (CoA 2.3).
• Utilization of improved DH inducer lines and optimized doubling protocols to reduce DH development cost (CoA 2.2).
• Implementation of peer-reviewed haplotype advancement strategy to ensure rigorous and unbiased scrutiny of scientific results supporting deployment decisions (CoA 2.2 and 2.3)
• Identification and use of molecular tools to modernize and accelerate resistance breeding programs (CoA 2.3)
• Implementing scale-appropriate state-of-the-art seed chipping technology through strategic partnership to enable significant reduction in tissue sample collection cost and turn-around (CoA 2.2 and 2.3)
• Implementation and development of enabling tools to accelerate utilization of elite temperate germplasm and landrace accessions in tropical elite breeding pipelines (CoA 2.2, 2.3 and 2.4).
• Utilization of gene editing technology to create novel variation for the breeding pipeline (CoA 2.3)
• Understanding mechanisms of polygenic resistance to the parasitic weed *Striga*, for pyramiding genes to achieve durable resistance through FP3 germplasm development efforts (CoA 2.3).

2.5 Lessons learnt and unintended consequences

Major lessons learned from previous research: a) research and resources must be invested to reduce the costs of doubled haploids and make the technology attractive to users and a sustainable, integrated component of the breeding pipeline; b) significant improvements in database management coupled with efficient, user-friendly decision-support tools will be necessary to routinely use high volume genotypic and phenotypic data collected by modern plant breeding programs; c) genomic selection (GS) has not been consistently effective for very diverse and unrelated populations; implementation of GS will therefore be slowed while careful coordination and planning with breeding teams develops, augments, and updates appropriate training sets for accelerating breeding gains; and d) significant reduction in the cost of DNA extraction and genotypic data generation will be required to enable large-scale and routine use of molecular tools within the breeding pipeline targeting low- and middle-income countries.

2.6 Clusters of activity (CoA)

FP2 Cluster of Activity (CoA) Structure

FP2 is organized in four CoAs that define an impact pathway (Figure 7). These CoAs collaborate to validate and provide breeding programs with tools and models to enhance breeding efficiency and the rate of genetic gains in support of MAIZE’s mission to increase the profitability of resource-poor maize farming systems, reduce their production risk and improve input use efficiency:

• **CoA 2.1: Informatics, database management and decision support tools.** CoA 2.1 provides the lead for data management and stewardship. With data densities escalating on both the genomics and phenotyping sides, the ability to manage and apply novel tools to extract knowledge from individual and combinations of large and complex data sets is key to the success of FP2 and MAIZE.

• **CoA 2.2: Development of enabling tools for germplasm improvement.** High throughput phenotyping methods, doubled haploids, and molecular and genome based selection tools for germplasm improvement are designed, improved, validated and deployed for use in breeding activities.
- **CoA 2.3: Unlocking genetic diversity through trait exploration and gene discovery.** CoA 2.3 works with the Genebank Platform and FP3 to characterize and explore the genomic diversity of maize to identify and develop genetic diversity for use by breeding programs. Mechanisms associated with polygenic resistance to parasitic plants will be characterized for strategic pyramiding of different mechanisms in crop varieties. The application of genetic engineering tools, including transgenics and gene editing, will be explored to further the success of CoAs 2.2 and 2.3.

- **CoA 2.4: Pre-breeding: Development of germplasm resources.** Bridging germplasm pre-packages novel alleles and allelic combinations derived from unimproved genetic resources for key traits in elite genetic backgrounds to accelerate germplasm development in FP3. CoA 2.4 validates and applies tools developed by CoAs 2.1, 2.2, and 2.3 in pre-breeding activities to produce key-trait-enriched germplasm for use by breeding programs.

CoA 2.2 and 2.3 have overlapping trait targets and coordinated research and deployment strategies. CoA 2.2 focuses discovery efforts within elite and improved germplasm while CoA 2.3 concentrates efforts on discovery within highly diverse gene bank accessions which are less adapted and less suitable for direct use in modern breeding programs as well as adapted germplasm with polygenic resistance to parasitic plants. This presents unique challenges to discovery efforts, and these will be addressed specifically in CoA 2.3. As CoA 2.3 and 2.4 identify and refine valuable haplotypes from gene bank accessions, CoA 2.2 will work in conjunction to refine and streamline them for deployment into FP3 elite breeding programs.

**CoA 2.1: Informatics, database management and decision support tools**

CoA 2.1 sources and adapts integrated systems and tools for storing and data retrieval, as well as informatics tools for processing and analyzing data to support the research and applied breeding work of MAIZE; increasingly, MAIZE implements pioneering large data volume applications (such as the sequencing of germplasm bank accessions). This CoA develops and deploys standards, tools, and systems that integrate diverse and quickly evolving data types to help enhance genetic gain and increase the conservation and use of genetic resources. The work involves multiple partners with diverse and highly specialized expertise; for example, the Integrated Breeding Platform (IBP) is leading the development of a generic breeding management software while the James Hutton Institute in the U.K. is developing web-based visualization tools to interpret complex genomics and phenomics data. Many activities in this CoA go across crops. Strategic interventions, issues and challenges addressed by CoA 2.1 are addressed through two components:

1. **Data management and interoperability to enable knowledge extraction:** The CGIAR is rapidly developing open-access “germplasm data banks” to complement its well established germplasm bank resources. Centralized and documented databases are necessary to store the data generated through MAIZE diversity analysis and breeding research. MAIZE uses cost-benefit analyses to decide on investments in data management and long-term storage using various options of accessible formats and software. Approaches are being developed to automate data annotation using standard terminology and internationally recognized standards (where possible) for phenotypic, genotypic, environmental, management, and other key data types by implementing standards-compliant software, protocols and policies. Data sharing and co-analysis platforms, including the ‘plant breeding’ API, are acquired or built to facilitate knowledge extraction from MAIZE’s data sources and to enable workflows to be saved and shared. Prioritized research with partners for Phase-II is directed at developing automated pipelines for high-throughput-phenotyping image analysis,
annotation, and conversion into data points that can be utilized for breeding, stored or linked with other phenotypic data.

2. Informatics tools to mainstream efficient decision making and accelerate genetic gains: Given escalating data volumes, new tools need to be adapted or developed that help breeders make selection decisions quickly and allow mainstreaming of cutting-edge breeding applications. This includes tools for using diverse data from or for genomic selection (GS) and high-throughput phenotyping in the development of selection indices, three-way and multi-way interaction models, the definition of heterotic patterns, and parent selection. Statistical models and user-friendly software that MAIZE plans to mainstream include:
   - Genomic-enabled prediction and genomic selection in genetically diverse populations (Pérez and de los Campos, 2014)
   - Genomic selection using high-throughput phenotyping information (de los Campos et al., 2009, 2010; Crossa et al., 2010, 2013a, 2013b; Perez-Rodriguez et al., 2012).
   - Increased accuracy of predictive models by incorporating genotype by environment interaction effects, weather data, high density molecular marker data and pedigree information (Burgueño et al., 2012; Jarquin et al., 2014; Lopez-Cruz et al., 2015).
   - New statistical genomic models based on non-normal distributions that will more efficiently exploit the categorical response traits without the need to make transformations that are, in general, inefficient and complicate breeder’s decision (Montesinos-Lopez et al., 2014).
   - New methods for GWAS analysis that incorporate information from experimental designs.
   - Statistical analyses to assist gene discovery in germplasm bank accessions, assist introgression of favorable alleles/genes/haplotypes in elite varieties, and better understand the genetic architecture of breeding-targeted traits.
   - Basic trait exploration and gene discovery, e.g. genome browsers, crowd-source candidate gene exploration, in silico hypothesis testing, and investigation of gene function to inform allele mining, gene editing and use of genetic resources.

**CoA 2.2: Development of enabling tools for germplasm improvement**

CoA 2.2 accelerates breeding cycles and improves trait heritability in the breeding pipelines by: a) making doubled haploid (DH) technology more affordable; and b) developing publicly available tools to mainstream genomic and molecular approaches in maize breeding programs. Strategic interventions include:

1. **Enhancing the efficiency of doubled haploid (DH) technology**: In Phase-I, MAIZE has made the DH technology accessible to NARS, small- and medium-sized breeding programs in low- and middle-income countries. In Phase-II, optimization of the DH process will aim to reduce the cost of DH line development by more than 30% through a) haploid inducers with higher haploid induction rate; b) novel haploid selection systems that enable a reduction in land and labor requirements for haploid identification; and c) protocol optimization to improve the chromosome doubling efficiency and reduce the haploid seedling mortality. Strategies to integrate DH technology with marker-assisted breeding and genomic prediction will be implemented to expand population size, increase selection intensity, accelerate breeding cycle and maximize genetic gain.

2. **Enabling marker-assisted breeding for prioritized traits**: In conjunction with CoA 2.3, FP3 and the CRP on A4NH, CoA 2.2 will enable marker-assisted breeding for biotic and abiotic stress tolerance and nutritional quality traits that are prioritized geographically by regional FP1 and FP3 teams with
local partners. Globally prioritized traits include drought tolerance, heat tolerance, and resistance to turcicum leaf blight (TLB), gray leaf spot (GLS), and Striga. In collaboration with A4NH, provitamin A content is a prioritized target for Central America and SSA (Semagn et al., 2015). Tar spot complex resistance is a prioritized target for tropical and sub-tropical regions of Latin America. Resistance to maize lethal necrosis (MLN; Mahuku et al., 2015; Gowda et al., 2015), Striga, maize streak virus (MSV) (Nair et al., 2015), and nitrogen use efficiency (NUE), are prioritized traits for SSA. Validating markers for MLN resistance, especially for MCMV, is a high priority for eastern Africa. Accelerated pre-emptive resistance breeding is a high priority for West Africa, southern Africa and South Asia. Because of the urgency and importance of MLN in eastern Africa, accelerated three-season per year nurseries are being implemented to enable improvement of susceptible elite African lines through marker-assisted backcrossing and also to rapidly enrich breeding populations for MLN resistance through marker-assisted recurrent selection (MARS). Banded leaf and sheath blight (BLSB) resistance, downy mildew resistance and waterlogging tolerance are prioritized trait targets for Asia (Prasanna et al., 2010, 2014). CoA 2.2 will continue to prioritize target traits in conjunction with stakeholders and respond to emerging needs.

Identifying and deploying large effect haplotypes for important traits enables substantial increases in population sizes and higher selection intensity. Together with CoA 2.3, CoA 2.2 establishes a comprehensive tropical maize trait pipeline to enable widely used forward breeding applications. The trait pipeline encompasses: a) tropical maize genomics enabling tools; b) structured discovery populations as maize research community resources (trait focused NAM, MAGIC, AM panels); c) organization of trait-focused teams with peer-reviewed haplotype promotion criteria and advancement strategies; d) fine-mapping and haplotype tailoring approaches for high-value haplotypes; e) a communications strategy to enhance uptake and use of forward breeding opportunities in FP3; f) development of high-throughput seed chipping capacity through strategic partnerships; and g) continued engagement with service providers and technology platform developers to lower genotyping costs.

3. **Genomic knowledge to enhance breeding efficiency**: CoA 2.2 will combine genetic relationships estimated from molecular markers into a Global Tropical Maize Germplasm Matrix to assist breeders in developing new breeding populations and hybrids based on genome composition and heterotic patterns of parents. It will accelerate strategic use of temperate germplasm for tropical maize improvement. Within the context of a broad temperate x tropical global breeding scheme, haplotypes for validation and forward breeding will be prioritized using signature of selection evidence for regions coming from elite ex-PVP temperate germplasm. Similarly, important haplotypes from tropical breeding programs which demonstrate signatures of selection within stress tolerant recurrent selection populations will be prioritized as forward breeding targets for retention in temperate x tropical populations. Loci conditioning white kernel color will be useful for utilizing yellow temperate lines in breeding pipelines aimed at elite tropical white maize varieties.

4. **Optimizing genomic selection approaches and their routine application in breeding programs**: The primary strategy for GS will be to develop training sets comprised of populations with adequate relatedness to enable prediction of performance of progenies from new populations having similar ancestry. This strategy will require coordination with FP3 regional breeding teams to prioritize key germplasm groups to target for GS and to establish standards for phenotypic data collection of training set populations as well as intensive interaction with CoA 2.1 and the proposed Genetic Gains Platform to ensure that data management and GS prediction analysis pipelines result in useful and timely prediction reports to FP3 breeders. The strategy will increase genetic gain by enabling
substitution of genomic prediction data for phenotypic data during initial testing stages within the breeding pipeline. Substitution of phenotypic data with genomic predictions will eliminate one or even two seasons of testing, shortening both the product development timeline and recycling time of elite parents. Reduced cycle time will have a direct bearing on long-term genetic gain in the FP3 breeding programs. CoA 2.2 proposes to develop capacity for genomic prediction with sufficient accuracy to replace up to 50% of the stage 1 testing effort by 2021. Priority traits for genomic prediction include yield under drought and optimal conditions, flowering time, harvest moisture, and plant and ear height. Disease related traits will also be prioritized regionally. The GS strategy will support rapid cycling of elite multi-parental populations as a mechanism for maximizing available genetic diversity for breeding programs lacking sufficient linkage to broader teams to enable leveraging of information across breeding programs.

CoA 2.3: Unlocking genetic diversity through trait exploration and gene discovery

CoA 2.3 applies the best genotyping, targeted phenotyping, and informatics approaches to characterize and facilitate the use of maize genetic resources by researchers and breeders. Maize landrace accessions, populations and wild relatives held by the CGIAR and collaborating partner organizations will be explored to identify germplasm, haplotypes and alleles of higher potential value for breeding. Special attention will be placed on traits with limited genetic variation within elite or improved breeding lines available to CoA 2.2. Collaborative efforts will also be made with external partners to characterize specific mechanisms associated with resistance to Striga among adapted maize inbred lines to provide the basis for future breeding of maize in FP3 for durable resistance to Striga. Strategic interventions addressed by CoA 2.3 include:

1. **Assess maize genebank resources and adapted germplasm to identify germplasm sources of specific value:** CoA 2.3 evaluates genetic resources (landraces, populations, wild relatives) using cutting edge genotypic, phenotypic, GIS, passport and pedigree analysis to identify potential germplasm sources with valuable genetic variation for prioritized traits (priorities obtained from other FPs). Systematic assessment includes definition of dynamic trait- and diversity-focused core sets and germplasm panels, selection-sweep analysis to identify common genomic signatures potentially associated with desired characteristics, identification of underutilized genepools, and identification of novel germplasm complementary to existing elite materials. CoA 2.3 undertakes phenotypic characterization of core sets, panels or otherwise-selected genebank resources to narrow down and identify the highest value materials for germplasm development (CoA 2.4) and assist identification of genomic regions of value from novel sources. This CoA will also characterize specific mechanisms associated with resistance to Striga among maize inbred lines developed through long-term breeding efforts using laboratory based bio-assays and genetic analysis.

2. **Identification of genomic regions of value from novel sources:** CoA 2.3 will use novel germplasm sources to identify genomic regions associated with prioritized traits including biotic and abiotic stresses, nutritional and quality traits, and end-user quality traits (e.g. processing or culinary traits). This work is achieved through association and structured population mapping and analysis of specific gene motifs associated with stress resistance within genotypic data. Users in FP3, FP4 and FP5 teams requested that we focus on rare large-effect alleles for traits having limited useful native variation within the elite germplasm pool (e.g., kernel methionine, provitamin A stability), traits with limited breeding sources of beneficial variation (e.g. MCMV, Striga), and traits of high value for production stability (heat, drought, fertilizer use efficiency). High-value haplotypes from novel
germplasm sources will be validated using haplotype-based selection and phenotypic evaluation of uncharacterized germplasm as well as transgenic, cisgenic and gene editing approaches before being deployed, initially in CoA 2.4 and subsequently other CoA and FPs.

3. **Tropical maize genomics resource development**: CoA 2.3 also develops genomics-enabling reference tools to enhance research and development of tropical maize. Filling gaps in the current maize reference genome and developing SNP markers with improved coverage of genetic variation are key research issues. The current maize reference genome was built upon temperate maize inbreds, including B73. It is estimated that more than 40% of the tropical maize sequences cannot be mapped onto the current reference genome, which means that genotyping and MAS based on the current reference genome are significantly biased and less effective when used for tropical maize. CoA 2.3 will contribute to the development of tropical maize genome(s) and will collaborate with external partners to ensure that maize pan-genome and hapmap construction efforts adequately represent publicly available tropical maize variation.

4. **Genetic modification technologies (e.g. transgenic, cisgenic, gene editing) to develop and validate novel genetic variants for target traits**: Genetic modification technologies will be used to validate function and assess the potential value of allelic variants identified through mapping or candidate gene analysis. Gene editing methods, mainly clustered regularly interspersed short palindromic repeat (CRISPR)-associated nuclease 9 (CRISPR-Cas9), will be employed to modify native genes to impact high-value traits including herbicide tolerance, disease resistance, N use efficiency, and possibly drought and heat tolerance. The organism with the edited gene is considered to be native in genetic composition because it contains no trace of the foreign DNA. Opportunities to implement this technology in-house as well as in partnership with industry will be pursued.

5. **Optimizing genomic selection approaches for application in pre-breeding programs**: CoA2.3 will work in close partnership with CoA 2.2 and CoA2.4 to optimize GS approaches to maximize the capture of useful novel genetic variation for complex traits in landrace based populations. Application of GS models in landrace populations offers specific challenges compared with elite germplasm based GS. For complex traits such as heat and drought stress GS offers a potential approach to maximize the efforts of pre-breeding. This work will rely largely on the use of simulation and exploitation of existing data with targeted phenotyping and genotyping employed to validate approaches.

**CoA 2.4: Pre-breeding: development of germplasm resources**

Phenotyping of maize landraces in the framework of CoA 2.3 has identified useful genetic variation in maize landraces for target traits such as drought tolerance (Cooper et al., 2014; Cairns et al., 2013b), MLN resistance (Wangai et al., 2012; Mahuku et al., 2015), resistance to tar spot disease complex and grain high-anthocyanin content. In CoA 2.4, those landraces identified with interesting variation for targeted traits are currently being used as donors in developing lines with novel haplotypes that can be used by breeders in their elite line breeding programs. Additional traits that have been prioritized and which await additional resources for their implementation include heat tolerance (Cairns et al. 2013a,b, Deryng et al., 2014, Lobell et al., 2011), Fusarium ear rot resistance (Munkvold et al., 1997; Hung and Holland, 2012) and combined drought and heat stress tolerance (Cairns et al., 2013b) and banded leaf sheath blight (BLSB).
Through its breeding efforts, CoA 2.4 develops and deploys early generation lines, inbred lines and backcross populations with novel haplotypes for priority traits that also have yield potential and desirable agronomic characteristics. CoA 2.4 develops methodology for effective and efficient use of maize genetic resources in breeding that includes validation and implementation steps. Genomic selection and other strategies that accelerate the process of moving useful alleles from landrace germplasm while selecting against deleterious and less favorable alleles, will be explored. CoA 2.4 will begin releasing early generation material to breeders in 2017 including fully tested BC1S2 lines with novel haplotypes for resistance to tar spot disease complex and fully tested BC1S2 lines with novel haplotypes for drought tolerance. Additionally, early generation breeding material with putative resistance to the component viruses of MLN will be released. However, because of the urgency in identifying novel alleles for MLN resistance, this particular breeding material will be released to the breeders in East Africa before being fully tested for yield potential and other agronomic characteristics. Additional releases will occur annually for the above mentioned traits plus lines for heat tolerance and lines for kernel high-anthocyanin content. All lines and breeding material released will be accompanied by the corresponding genotypic data characterizing the novel haplotypes.

2.7 Partnerships
Strategic Partnerships including docking with other CRPs

FP2 relies heavily on partnerships with advanced research institutions, leading service providers and the proposed Genetic Gains and Genebanks Platforms (see Table 6 and Annex 3.2). Partnerships with advanced research institutions include the University of Hohenheim for continuous refinement of DH technology for the benefit of partners in the low- and middle-income countries and Cornell University on the identification of novel high value allelic variation in maize landraces and implementation in MAIZE of the GOBII project. CoA 2.1 partners with the Integrated Breeding Platform (IBP) developers and other CRPs on the specific tailoring and implementation of the Breeding Management System (BMS). MAIZE FP2 has established joint research and enabling technology platform development partnerships with other CRPs, especially WHEAT, GRiSP, and DCLAS. The GOBII project, a proposed component of the Genetic Gains Platform, is a showcase example of cooperation among these CRPs, involving five major crops. It is already generating interest from alternate crops, and the pioneering work done within GOBII is expected to benefit other non-focus crops within a ten year timeframe. Similarly, efforts are underway with the same CRPs to develop a shared high-throughput low-plex genotyping facility which could support the mainstreaming of forward breeding strategies across crops and institutions, complementing current collaborations with private sector, ARI and CG-private partner high density marker service providers (Diversity Arrays Technology, Cornell University, SAGA). The Seeds of Discovery Project (MasAgro Biodiversidad), jointly undertaken between MAIZE and WHEAT, shares the development of strategies, genotyping platform use, learning, bio-informatic approaches and visualization tools. MAIZE and WHEAT are also in the planning stages of forming collaboration with Monsanto to establish high-throughput automated seed chipping capacity under a humanitarian license.

2.8 Climate change
New text needed:

2.9 Gender
The focus of this Flagship can appear far removed from the farmer and consumer interface. Even so, although the relevance of the gender dimension may seem to become clearer as we move further
down-stream in the technology development process, the concern with end-user needs, challenges and preferences remains pertinent at the upstream level. This is namely where key decisions regarding overall direction and priorities of research are made, which, in turn, have bearing on what (- and whose) issues will be addressed. Relevant research questions for FP2 include:

- How can down-stream gender research and -analysis findings in the technology development continuum inform up-stream targeting and decision making?
- How can research on the gendered nature of maize production leverage and add value to the analysis of native trait variation and trait pipeline development?
- How can we ensure that efforts to increase genetic gain benefits both men and women maize farmers and consumers in particular contexts?

FP2 will draw on research on the traits and trait combination preferences of men and women maize farmers and consumers in particular contexts, generated in FPs 1, 3, and 5, to inform its targeting and priority setting. Building on this and progress achieved in Phase I, (for FP2 e.g. trait pipelines for high beta-carotene, high lysine; and specialty traits of particular cultural or income related importance to certain groups; and for FP 1 De Groote et al 2013), the FP will consolidate the consideration of trait combinations of particular interest to women farmers in its portfolios. This may also include research on novel trait variation and molecular pipelines that address nutritional quality, antioxidants, and other issues, for example herbicide tolerance (for reduction of drudgery). In these regards, FP2 aligns closely with FP3, with inputs from FP1 on priority setting and trait targeting. Gender preferences and gender implications of target traits are carefully considered in conjunction with FP3 when deciding on appropriate traits to focus on.

2.10 Capacity development

FP capacity development activities will focus on increased breeding efficiency and effectiveness by integrating plant breeding and genomics-derived technologies. The capacity development activities will cover the improvement of the capabilities of future research leaders as well as upgrading and broadening of the knowledge of existing ones through the acquisition of new capabilities on key areas including genetics, genomics, statistics, experimental design, data management and phenotyping methodologies to facilitate the harnessing of the potential of the advanced technologies to design and more efficiently manage breeding experiments.

One important objective of the FP will be to improve capacity in data management, sharing and analysis, as this should take root and become an integral part of maize improvement program and contribute to the sub-IDOs: Enhanced genetic gains through the use of appropriate tools and methods and the efficient management of databases and informatics tools that enhance accessibility of genotypic, phenotypic and enhances use of genetic resources and other data, in compliance with the CGIAR Open Access Policy.

Capacity will be enhanced with the implementation of informatics, database management and decision support tools, particularly through the ability to manage and apply novel tools to extract knowledge from individual and combinations of large and complex data sets. Innovative training and associated materials will be developed to train breeders in enabling tools for germplasm improvement. The dissemination and sharing of new documented germplasm by demonstrating yield gain potential via open access channels, marketing approaches, methods, and associated dissemination documentation will contribute to skills and competency development. Other activities that will support skills development include research support services and technical backstopping.

Different models of training will be used in order to develop and maintain up-to-date knowledge and skills of staff in different areas of specialization including, hands-on experience through coaching
and mentoring, workshops, technical short-term courses and long-term postgraduate training, post-doctoral and visiting scientists’ schemes, knowledge sharing tools and methods, design and delivery of innovative learning materials, guidelines, common tools and protocols. Capacity development efforts will need to be effectively coordinated among FP2 and FP3 to avoid duplication and ensure complementarities, synergies and mutual learning.

2.11 Intellectual asset and open access management
New text needed: Discoveries with potential for licensing to commercial companies will be patented before being published, for example, additional sources of sulfonylurea resistance and fusarium resistance.

2.12 FP management
New text needed:

2.13 Budget summary (To be completed)

FP3: Stress Tolerant and Nutritious Maize
2.1 Rationale, scope
Maize is the major source of food security and economic development in sub-Saharan Africa (SSA) and Latin America and the Caribbean (LA), and has become a dominant crop in Asia. Average annual growth rate of the harvested maize area from 1993 to 2013 was 2.7% in Africa, 3.1% in Asia, and 4.6% in the Caribbean (FAOSTAT, 2016). Even though the growth in area was accompanied by 2.4 to 5.6% increases in production, grain yields in these regions are still low with high year-to-year variability because of the adverse effects of drought, sub-optimal soil nitrogen, waterlogging, and heat and soil acidity/Aluminum toxicity, besides high incidence of diseases, insect-pests, and parasitic plants. Increases in temperature and decreases in precipitation due to climate change have been projected to have the greatest effect in SSA, Asia, and LA, with SSA and South Asia being the most vulnerable (Smale et al., 2011; Zaidi et al., 2014). The predicted changes in temperature and precipitation, especially in SSA and Asia, will further accentuate the intensity and frequency of drought, increasing vulnerability of smallholder farmers to high risks associated with farming under rainfed conditions (Cairns et al., 2012, 2013; Masih et al., 2014; Shiferaw et al., 2014; Shi and Tao, 2014).

The diversity of production environments, biotic and abiotic constraints, consumer preferences for grain color and texture, farming systems, and socio-economic circumstances in Africa, Asia, and Latin America presents significant challenges for maize breeding in the tropics, and highlights the need for appropriate targeting of maize germplasm. Maize breeders at CIMMYT and IITA initially created germplasm pools, populations and composites from diverse source germplasm and improved them through many cycles of recurrent selection for adaptation to diverse production environments in the developing world. These germplasm pools formed the genetic base from which open-pollinated varieties (OPVs) with high yield potential and tolerance to specific stresses were developed and released (Vasal et al., 1997; IITA, 1992). To achieve these, research activities have been carried out at experimental stations in the major regions where the specific stresses are endemic and breeding could thus be done effectively. Over the last 20
years, more emphasis has been placed on the development of maize hybrids because of increasing areas planted to these hybrids (Aquino et al., 2000) and emergence of numerous national seed companies in the developing countries, including in Africa. The improved broad-based maize populations and pools have therefore been sources of inbred lines with considerable genetic diversity (Menkir et al., 2005, 2010; Warburton et al., 2008; Semagn et al., 2012) that have been made accessible to public and private sector breeders for inbred line improvement and hybrid development.

MAIZE in Phase-I has been successful in developing and deploying an array of climate-resilient and nutritionally enriched maize hybrids/synthetics in SSA, Asia and LA, through various projects, including the Drought Tolerant Maize for Africa (DTMA), Improved Maize for African Soils (IMAS), Water Efficient Maize for Africa (WEMA), Heat Tolerant Maize for Asia (HTMA), Abiotic stress Tolerant Maize for Asia (ATMA), Affordable, Accessible, Abiotic stress tolerant maize for Asia (AAA), MasAgro-Maize, and the Maize HarvestPlus (in collaboration with A4NH). Through the DTMA project alone, more than 200 distinct drought tolerant maize varieties were released across SSA, with significant adoption (Fisher et al., 2015). In 2014, over 52,000 metric tons of certified seed of diverse drought tolerant (DT) maize hybrids and improved OPVs were produced and made available to farmers by seed companies and community-based seed producers. In recognition of such successes, the CGIAR IEA Team Report (April 2015) on MAIZE noted that the “Research design and approaches are innovative and sometimes state-of-the-art. Processes and partnerships are designed to ensure that latest scientific thinking is reflected in methodology and analysis. Outputs, people and processes of RS2 (Stress resilient and nutritious maize) are of exceptionally high quality compared with any public breeding effort for maize. Internal processes to assure science quality appear to be robust.”

MAIZE FP3 in Phase-II will build on the successes and lessons learned during Phase-I, and will implement a cohesive breeding and seed systems strategy with defined target trait and product profiles for SSA, Asia and LA (Annex 3.9 and Annex 3.10). FP3 is designed around six specific CoAs: 3.1: Climate-resilient maize with abiotic and biotic stress tolerance; 3.2: Tackling emerging trans-boundary disease/pest challenges (e.g., MLN); 3.3: Nutritional quality and end-user traits in elite tropical maize genetic backgrounds; 3.4: Precision phenotyping and mechanization of breeding operations; 3.5: Seed production research and recommendation domains; 3.6: Stronger maize seed systems. The grand challenges addressed by FP3 through these six CoAs are indicated in Table 1.

### 2.2 Objectives and targets

#### Strategic Relevance

Intensive and proactive efforts are needed to sustain and enhance productivity gains and economic returns in maize to minimize the adverse effects of constantly evolving and often location/region-specific biotic and abiotic stresses, accentuated mainly by climate change. Maize is largely (about 80%) grown as a rainfed crop in SSA, Asia and LA, and is particularly vulnerable to an array of abiotic and biotic stresses; consequently, yields are usually less than half of those under irrigated systems that are targeted production areas for private sector investment (Shiferaw et al., 2011; Zaidi et al., 2014). In Asia, the rainfed maize area is projected to increase at a rate of 1.8% per year, six times the projected rate of increase of irrigated areas.

Climate change is expected to further increase the frequency and severity of not only abiotic stresses, especially in SSA, Asia and LA, but also the pest and disease outbreaks, such as the maize lethal necrosis (MLN) in eastern Africa (Mahuku et al., 2015; Prasanna, 2015), as well as the geographical distribution of invasive and parasitic weeds (Table 2 in Appendix 3). Pre-emptive strategies that focus on assembling
and utilizing diverse sources of tolerance to multiple stresses for broadening and diversifying the genetic base of adapted germplasm will be pursued in MAIZE Phase-II to enhance and sustain maize yields and income in the face of dynamic changes in abiotic and biotic stresses and associated shifts in the economic reality of the maize supply chain.

Over the last 10 years, maize breeders at CIMMYT and IITA used elite x elite crosses to generate new inbred lines, hybrids and synthetics to make faster genetic gains for greater impact under varying projects. Considering the potential effect of this approach on narrowing the genetic base that may slow the rate of genetic gain from selection and increase the risk of vulnerability of maize to new disease and pest outbreaks as well as climate change, novel germplasm with distinct ancestry will be continually introgressed into elite germplasm in MAIZE Phase-II for developing and delivering unique parental lines with new allelic combinations to support both NARS and the private sector to assemble these into more attractive products for deployment. In addition, integration of high throughput and novel phenotyping tools, doubled haploid (DH) technology coupled with forward breeding (using breeder-ready molecular markers for key traits developed in MAIZE Phase-I), mechanization at key breeding sites, and rapid-cycle genomic selection will form the core components in MAIZE FP3 in Phase-II to accelerate genetic gains. These tools will be particularly critical for multi-stage selection to combine tolerance to abiotic stresses with resistance to major diseases, insect-pests and parasitic weed Striga, and to enhance maize productivity gains and competitiveness in each of the target regions.

**Expected Contributions to CGIAR SRF**

MAIZE FP3 primary outcomes include five specific sub-IDOs: 1.1.2. Reduced production risk; 1.3.3. Increased value capture by producers; 1.3.4. More efficient use of inputs; 1.4.1. Reduced pre- and post-harvest losses, including those caused by climate change; and 2.1.1. Increased availability of diverse nutrient-rich foods (see section 2.3). FP3 also contributes to three cross-cutting sub-IDOs, namely A.1.4. Enhanced capacity to deal with climatic risks and extremes; C.1.1. Increased capacity of beneficiaries to adopt research outputs; D.1.1. Enhanced institutional capacity of partner research organizations.

Based on these areas of focus, MAIZE FP3 contributes to reducing poverty (SLO 1) and improving food and nutrition security for health (SLO 2) by the mean of increasing resilience of the poor to climate change and other shocks (IDO 1.1), increasing incomes and employment (IDO 1.3), increasing productivity (IDO 1.4), improving diets for poor and vulnerable people (IDO 2.1), and enhancing the cross-cutting issues of climate change (A), gender and youth (B), policies and institutions (C), and capacity development (D). Thus, the theory of change underlying FP3 is strongly aligned with the CGIAR SRF; section 2.3 clarifies how FP3 R&D outcomes contribute through MAIZE’s sub-IDOs to reduced poverty, improved food and nutrition security for health, and improved natural resource systems and ecosystems services SLOs. Progress toward the sub-IDOs will be measured and documented through relevant indicators and metrics.

<table>
<thead>
<tr>
<th>Target Sub-IDOs</th>
<th>Nature of FP3 contributions</th>
<th>Indicators and targets</th>
</tr>
</thead>
</table>
| 1.1.2 Reduced production risk | • Improved multiple stress-tolerant maize varieties with better yield and stability adopted by smallholder farmers in stress-prone rainfed environments.  
  • New MLN resistant maize hybrids developed and deployed in SSA. | • Kg/ha/year improvement in mean yield of improved MAIZE hybrids relative to baseline checks in optimum and stress-prone environments of the tropics  
  • Number of MAIZE varieties released by seed enterprises and national programs  
  • % change in replacement of old and less-productive cultivars  
  • % change in income attributable to yield, yield |
<table>
<thead>
<tr>
<th><strong>A.1.4 Enhanced capacity to deal with climatic risks and extremes</strong></th>
<th><strong>B.1.1 Increased availability of diverse nutrient-rich foods</strong></th>
<th><strong>C.1.1 Improved decision-making capacity of women and young people</strong></th>
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<tbody>
<tr>
<td><strong>1.3.3 Increased value capture by producers</strong></td>
<td><strong>1.3.4 More efficient use of inputs</strong></td>
<td><strong>D.1.1 Enhanced institutional capacity of partner research organizations</strong></td>
</tr>
</tbody>
</table>
| - Improved varieties suiting the needs of the processing industry.  
- Through hybrid deployment in targeted areas, provides opportunities for more farmers to become improved seed producers. | - Water and nutrient use efficient improved maize hybrids developed and deployed in target geographies | - Co-designing and testing of improved maize varieties with a range of stakeholders.  
- Well-targeted short- and long-term training of NARES scientists. |
| - Number of varieties released/commercialized for niche markets of the processing industry.  
- Increase in income of the maize seed growers  
- Income increase by 75-100%/unit area/year due to higher value of harvested seed produce. | - Number of drought-tolerant and N use efficient maize cultivars released, and adopted by the farmers.  
- Increase in rate of genetic gain for drought tolerance and NUE in lowland tropical agro-ecologies. | - Number of scientists, especially women and stakeholders.  
- Proactively embedding gender and youth lens in breeding and seed systems partnerships.  
- Inclusive business models in maize-based seed systems.  
- Number and proportion of partner institutions and seed companies applying gender-responsive business practices  
- Quality of strategies developed for bridging gender gaps in maize seed value chains.  
- Number of scientists, especially women and young, hosted and trained on maize breeding and seed systems.  
- Number of public/private institutions implementing novel breeding strategies developed under MAIZE.  
- Knowledge into use by NARES and other organizations engaged in maize R&D. |
| - Number of varieties released/commercialized for niche markets of the processing industry.  
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- Number of scientists, especially women and young, hosted and trained on maize breeding and seed systems.  
- Number of public/private institutions implementing novel breeding strategies developed under MAIZE.  
- Knowledge into use by NARES and other organizations engaged in maize R&D. |
| - Number of pre- and post-harvest stress resistant improved maize cultivars released, and adopted by the farmers in the target geographies. | - Multiple pre- and post-harvest stress-tolerant improved maize varieties adapted to SSA, Asia and LA. | - Number of scientists, especially women and stakeholders.  
- Proactively embedding gender and youth lens in breeding and seed systems partnerships.  
- Inclusive business models in maize-based seed systems.  
- Number and proportion of partner institutions and seed companies applying gender-responsive business practices  
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- Number of public/private institutions implementing novel breeding strategies developed under MAIZE.  
- Knowledge into use by NARES and other organizations engaged in maize R&D. |
| - Multiple pre- and post-harvest stress-tolerant improved maize varieties adapted to SSA, Asia and LA. | - Nutritious maize hybrids/varieties with superior agronomic performance and desirable gender-informed traits (processing properties, palatability and storability) developed and deployed in targeted geographies in SSA, Asia and LA. | - Number of scientists, especially women and stakeholders.  
- Proactively embedding gender and youth lens in breeding and seed systems partnerships.  
- Inclusive business models in maize-based seed systems.  
- Number and proportion of partner institutions and seed companies applying gender-responsive business practices  
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- Knowledge into use by NARES and other organizations engaged in maize R&D. |
2.3 Impact pathway and theory of change

The FP Stress Tolerant and Nutritious Maize’s theory of change was developed during a workshop with the MAIZE Flagship Program team. A participatory approach was used to capture all views, experiences and known evidence into the theory of change. The workshop participants were able to increase their understanding of the CGIAR Strategy and Results Framework and awareness of results-based management concepts. The workshop was also structured to encourage sharing and learning on a variety of topics.

Using the CGIAR Results Framework’s sub-intermediate development outcomes (IDOs) the team agreed to focus on five sub-IDOs and four cross-cutting sub-IDOs:

- 1.1.2 Reduced production risk;
- 1.3.3 increased value capture by producers;
- 1.3.4 More efficient use of inputs;
- 1.4.1 Reduced pre- and post-harvest losses, including those caused by climate change;
- 2.1.1 Increased availability of diverse nutrient-rich foods;
- A.1.4 Enhanced capacity to deal with climatic risks and extremes;
- B.1.2 Technologies that reduce women’s labor and energy expenditure developed and disseminated;
- C.1.1 Increased capacity of beneficiaries to adopt research outputs; and
- D.1.1 Enhanced institutional capacity of partner research organizations.

Other sub-IDOs were noted by the team as important to programming given that they overlap with the above sub-IDOs of focus. Regarding sub-IDOs A.1.4 and B.1.2 related to climate change, and gender and youth, the team indicated that these cross-cutting issues would be integrated largely through a focus on relevant traits and tools.

Based on these areas of focus, the team agreed that this Flagship Program contributes to reducing poverty (SLO 1) and improving food and nutrition security for health (SLO 2) by the mean of increasing resilience of the poor to climate change and other shocks (IDO 1.1), increasing incomes and employment (IDO 1.3), increasing productivity (IDO 1.4), improving diets for poor and vulnerable people (IDO 2.1), and enhancing the cross-cutting issues of climate change (A), gender and youth (B), policies and institutions (C), and capacity development (D).

A number of research and development outcomes were identified and a pathway of change was created demonstrating the causal relationship between outcomes and sub-IDOs. During this process, partners involved in the pathway of change were identified. Current and proposed interventions and associated outputs to support the achievements of the outcomes were mapped. Assumptions describing the contextual underpinnings of the theory as well as the risks that may have the potential to undermine success were documented.

This theory of change will be the foundation for the monitoring, evaluation and learning plan. The monitoring plan will consist of a continuous process of collection and analysis of data based on a set of indicators directly related to the performance of the CRP at the output and outcome levels; the key assumptions of the theories of change; and the critical risks. The theory of change will also be the basis for evaluating the Flagship Program as well as reflecting on lessons and program improvements.
Figure 8: Theory of Change for MAIZE FP3: Stress Tolerant and Nutritious Maize
<table>
<thead>
<tr>
<th>Assumptions and Risks</th>
<th>Interventions and Outputs</th>
</tr>
</thead>
</table>
| **A** | Communicate with farmers in target areas to obtain feedback on product needs  
- Outputs: Communication materials, documented needs |
| • Farmers see value in and have access to improved traits  
• Other inputs and optional crop management are available and applied  
• Existence of a feedback loop regarding farmers’ needs  
• Existence of an enabling policy environment and government support  
• Risk: Variability of local prices and instability of global prices | • Promote improved seeds using farm demos and field days to increase farmers’ awareness; organized around innovative plots and involving both women and youth  
- Outputs: Dissemination and marketing information; training documentation; training sessions |
| **B** | • FP3 products better than what is available on the market  
• Partners see value and are willing to promote new products  
• Existence of a feedback loop regarding farmers’ needs  
• CIMMYT guidelines are synchronized with partner requirements  
• Risks:  
  - Slow variety replacement by partners  
  - Marketing strategy overshadows and slows new product adoption | • Seed companies and farmers’ evaluations (feedback survey) and research on cost-benefits of tools and approaches  
- Outputs: evaluation results; cost-benefit data of tools and approaches |
| **C** | • Quality and availability of improved varieties are attractive to buyers and producers  
• Risks:  
  - Changes in consumer preferences  
  - End users do not see value in improved traits  
  - Variability of local prices and instability of global prices | • Provide improved products and information to FP4  
- Outputs: products, dissemination documentation |
| **D** | • Existence of enabling policy environment and government support to speed-up improved variety release  
• CGIAR influence national decision-makers  
• Risk: Lack of financial and human capacity of seed regulators | • Formalize and implement an inclusive pipeline advancement process  
- Outputs: documented process, data on products needed |
| **E** | • Partners see value and are willing to attend training provided by CRP, and apply knowledge  
• Existence of enabling environment (e.g., regulatory framework) for germplasm movement  
• Partners have human and financial capacity and the willingness to host trials  
• Existence and availability of information regarding | • Apply the guidelines for product allocation  
- Outputs: documented guidelines, data on prioritized products |
| | • Provide product profiles  
- Outputs: product profiles |
| | • Seek feedback regarding their needs  
- Outputs: Survey results and information needs |
| | • Demonstrate CIMMYT products  
- Outputs: Dissemination and marketing product information |
| | • Provide capacity development to seed regulators on breeding realities, value addition, timelines, and research and development  
- Outputs: policies briefs, technical advice, dissemination information |
| | • Advocate for domestication and harmonization of legislative systems across |
| **F** | Existence of viable seed companies  
    - Continued demand for seed  
    - Seed companies see value and are willing to adopt new maize technologies  
    - Existence of an enabling policy environment for seed production  
    - Risks:  
      - Existence of fake or counterfeit seed in market  
      - Poor production methods lead to low seed quality on market |
|---|
| **G** | Existence and availability of improved technologies with good production characteristics  
    - Seed systems specialists have human and financial capacity and necessary infrastructure (e.g., storage) to adopt improved varieties  
    - Risk: Lack of market for end users |
| **H** | Partners have the human and financial capacity and necessary infrastructure to exchange and use germplasm  
    - Germplasm and data is relevant and suitable to user needs  
    - Existence of appropriate tools, infrastructure and enabling environment (e.g., regulatory framework) to allow for exchange and utilization of germplasm  
    - Risk: National regulators increase importing and exporting fees |
| **I** | Existence of conducive policy environment, especially with regards to the SMTA, within CGIAR to collaborate with seed companies  
    - Existence of enabling regulatory frameworks within target countries  
    - Technologies will remain of interest for public-private partnerships  
    - Strong collaboration within the CGIAR, CRP and FP regions  
    - Outputs: policy briefs, technical advice, dissemination information. |
| **5** | Provide training and backstopping  
    - Outputs: Training and backstopping materials  
    - Provide data and germplasm exchange services (e.g., double haploid)  
    - Conduct joint evaluation of hybrids and varieties and share results  
    - Develop and share guidelines for advanced trials  
    - Develop and share improved hybrids and varieties for target environment  
    - Outputs: data and improved varieties, dissemination documentation |
| **6** | Exchange of data and information  
    - Outputs: Data and information, dissemination documentation  
    - Provide capacity development and infrastructure  
    - Outputs: Training materials, training sessions, dissemination documentation, infrastructure information and services  
    - Supply improved germplasm and initial breeder seed  
    - Outputs: germplasm and associated data, breeder seed and associated data  
    - Provide support for variety release, registration and commercialization, and production of pre-basic and basic seed  
    - Outputs: data, information, dissemination and marketing documentation |
| **7** | Provide seed-system specialists with elite }
### Exchange and Use Knowledge
- **Risk:** Limited investment to develop capacity and collaboration

### Existence of conducive policy environment
- Especially in regards to the SMTA and Nagoya Protocol, for free movement and use of seed
- New technologies can be easily applied within breeding
- Tools are user-friendly and support is available
- Partner breeding teams see value and are willing to adopt new technologies, methodologies, approaches and genetic resources
- Partners have the human and financial capacity and necessary infrastructure to adopt
- **Risk:** Policy and existing legal frameworks impede the movement and use of seed and render partnership breeding impossible

### Products are effective under sustainable intensification practices
- **Risks:**
  - Financial, social and political instability
  - New emerging pests and diseases
  - Climate change

### Seed materials and supporting data
- Outputs: Elite seed materials and data, dissemination documentation
- Joint decision-making meetings
  - Outputs: Meetings minutes and record of decisions

### Product advancement
- Outputs: Products data and information, dissemination, marketing documentation, data allowing breeders to make informed parental decisions for subsequent cycles of breeding with increased genetic gain

### Create forums for data/information exchanges and decision making
- Outputs: Data/information exchange forums

### Provide support to improve breeding processes and utilization of new technologies that ultimately increases genetic gain
- Outputs: Training, guidance, processes

### Disseminate summarized data
- Outputs: data, dissemination documentation

### Collaborative partnerships to create an enabling environment for research
- Outputs: data and information about partnerships, dissemination documentation

### Provide capacity development
- Outputs: training materials, training sessions

### Establish and share standards and options
- Outputs: standards and options, dissemination documentation

### Incorporate new breeding technologies and tools (physiological, statistical, molecular, data management) to increase breeding efficiency
- Outputs: New technologies and tools
<table>
<thead>
<tr>
<th>Provide utility and functionality of tools to FP2 (feedback)</th>
<th>Novel genetic resources incorporate into breeding program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outputs: Survey results (use and functionality), feedback documented and shared</td>
<td>Outputs: new breeding products</td>
</tr>
</tbody>
</table>

### 2.4 Science quality

The FP3 team will continue to impose high standards on its R4D in Phase-II through improved breeding information/data management, precision phenotyping, mechanization/automation of breeding operations, crop modeling, remote sensing, and multidisciplinary synergies. Some of the major areas of focus in different CoA are indicated below:

**CoA 3.1:**
- Targeted introgression of novel alleles and allelic combinations for broadening and diversifying the genetic base of elite maize germplasm adapted to different mega-environments.
- Identifying target markets/geographies with comparative advantage of MAIZE varieties, and addressing the client needs through strategic introgression of essential traits in adapted backgrounds (strategic positioning/targeting of MAIZE germplasm)
- Characterizing and using diverse sources of resistance to MLN-causing viruses, including CIMMYT and IITA germplasm accessions, exotic germplasm from USA and Thailand, temperate-tropical introgression lines and in breeding strategies.
- Realignment of breeding program for future using GIS tools to characterize future maize mega-environments and identify suitable screening sites for (using climate analogues) for MAIZE partners.
- Routine incorporation of breeder-ready markers for key maize diseases to increase the size of the (phenotypically) untested layer of the breeding pipeline, allowing faster genetic gains
- Continuous evaluation of genetic gains integrated into the breeding pipeline to monitor the efficiency of the pipeline, providing quantitative feedback on the impact of new technologies integrated into the pipeline.
- Rapid cycling of bi-and multi-parent populations through marker-assisted recurrent selection (MARS) and genomic selection (GS) to accumulate desirable alleles influencing complex traits.
- New statistical predictive models that increase precision of genomic selection for stress tolerance, and help to gain a better understanding of genotype x environment x management (G x E x M).
- Judicious use of the transgenic approach for improving specific biotic and abiotic stress tolerance traits in close partnership with humanitarian license providers, NARS and regional organizations.

**CoA 3.2:**
- An effective maize pest/pathogen/parasitic weed surveillance and monitoring system established in SSA
- A “Community of Practice” (CoP) among relevant phytosanitary agencies in SSA and LA, implementing harmonized protocols for effectively detecting and prevent trans-boundary movement of maize pathogens (e.g., MCMV) through commercial seed lots.
- Reliable and cost-effective diagnostic protocols for curbing the spread of pathogens (e.g., MCMV) through seed implemented by NPPOs and commercial seed companies.
• A dedicated MAIZE pathogen/pest/parasitic weed web portal (linked to other knowledge hubs of regional organizations), and data management system (toolbox) with core databases, established under MAIZE Atlas.

CoA 3.3:
• Robust, high-throughput tools/techniques for assessing different nutritional (protein, oil, starch, lysine, tryptophan, etc.) and end-use quality traits (kernel hardness, kernel size, color, neutral detergent fiber, acid detergent fiber, etc.) to speed up the varietal development process.

CoA 3.4:
• Precision phenotyping sites, including well-equipped benchmark phenotyping sites and complementary satellite phenotyping sites, in partnership with public and private sector partners.
• Digital platform (proximal and remote) on unmanned aerial vehicle (UAVs) equipped with various high resolution cameras (hyper-spectral, multi-spectral, thermal, RGB etc., depending on targeted traits) in support of high-throughput phenotyping and real-time data capture.
• Dissecting stress tolerance using new phenotyping tools/methods for informed selection decisions and for constituting new breeding populations for marker discovery.
• New high throughput phenotyping tools for breeder preferred traits, including plant height, phenology, stand count and yield components, developed and disseminated.
• Increased signal-to-noise ratio through the use of UAV-based platforms to rapidly identify field variation which will be incorporated into trial designs.
• Incorporation of near-real time phenotyping data submission for better data return and remote monitoring of trials.

CoA 3.5:
• Inclusion of gender and socio-economic considerations when designing crosses for developing products and seed production research and determining recommendation domains.
• Information database on seed producibility/yield of MAIZE-derived hybrids, web-based dissemination of potential seed technology practices and recommendations domains, and a targeted approach to product development intrinsically linked to deployment.
• Research into the economics of seed production of single cross, three way and double cross hybrids.

CoA 3.6:
• Enhancing the impact of MAIZE products/germplasm through new partnership models, including MAIZE x private sector combinations in commercial hybrids, as well as for breeding new germplasm.
• Deployment of a new seed system management software in regional hubs, linked to institutional phenotypic and genotypic databases, to streamline inventory management, routine QC/QA operations, phytosanitary regulation compliance, and shipment tracking.

Cross-cutting:
• Using GIS, remote sensing, and high-resolution digital tools for characterizing and fine-mapping tropical maize mega-environments, mapping the incidence and severity of major abiotic/biotic stresses, identifying ideal regions for maize seed production, hybrid deployment and commercialization, and modeling and risk mapping of trans-boundary diseases/pests (CoA 3.1 to 3.5, in collaboration with FP1).
• Mainstreaming DH, precision phenotyping tools, mechanization of breeding operations, molecular markers and genomic prediction, breeding informatics for discovering novel genetic variation, and improving heritability, reducing cycle time, and increasing selection intensity (across CoA 3.1-3.3).
• Portfolios of best-bet options, including variety and management options, developed for key stakeholders (CoA 3.1 and 3.6)
• Application of remote sensing in yield quantification to assist seed producers in evaluating seed quantities prior to harvest to assist in the development of marketing plans (CoA 3.1 and 3.6)

2.5 Lessons learnt and unintended consequences

• A large phenotyping network is crucial to the development of widely adapted climate resilient maize varieties: Conventional breeding is essentially a numbers game; the more experimental lines screened across locations the greater the chance of identifying superior genetic variation. A key component of the success of plant breeding in the past century has been the increased scale of field testing. For example, the recent AquaMax hybrids of DuPont-Pioneer were tested on almost 11,000 on-farm trials. In SSA the maize seed sector is dominated by small- and medium-sized companies with limited breeding capacity and geographic scope. National breeding programs face financial constraints and often operate on a small scale within a relatively small geographic region. A large-scale testing network allows more robust estimates of phenotypic performance, faster development of broadly adapted varieties, and maximize the benefits of limited resources for genetic improvement over a large geographical area by allowing breeders to extrapolate data from similar agro-climatic zones. Furthermore, under climate change, target environments for breeding products may change and new traits will be required; a large network allows MAIZE partners to screen in environments currently not available within their internal network. Over two-thirds of the MAIZE collaborative testing network is envisioned to be hosted on the partner sites; this will help build national, and therefore regional, capacity for maize breeding and successful product development.

• A dynamic maize breeding pipeline that is able to respond to the changing climate is key to ensuring farmers have access to improved maize varieties with appropriate trait combinations: The emergence of MLN in eastern Africa as a sudden and major threat to maize production and livelihoods of smallholders has been a major lesson in MAIZE Phase-I. The large-scale vulnerability of breeding materials as well as commercial maize varieties in SSA posed a great challenge, and also taught us how to quickly add a new trait to the existing pipeline and breed new products in an accelerated manner for reaching the seed companies in the target environments. The rapid response of MAIZE in Phase-I in tackling the MLN challenge through a multidisciplinary and multi-institutional strategy received widespread international appreciation, and highlighted the importance of CGIAR-led breeding and R4D initiatives in protecting the farming communities from the present and future threats. MAIZE FP3 in Phase-II will further intensify efforts to proactively put in place measures to deal with transboundary pests/pathogens (as outlined under CoA 3.2), besides fast-tracking breeding for multiple stress-tolerant and genetically diverse improved maize varieties (through CoA 3.1).

• Faster validation and deployment of new technologies required for increasing genetic gains: Breeding must not follow a “business as usual” approach and must continuously validate and deploy new technologies. In MAIZE Phase-1 several new technologies were developed, validated and deployed which have significantly increased the throughput and speed of breeding pipelines including DH and MARS. The lessons learned in the re-organization of breeding pipelines to incorporate such traits will serve as a benchmark for future technologies that are maturing. The incorporation of new technologies into the breeding pipeline is a three phase process; discovery, validation and deployment. Historically breeding programs have been slower in the final stages of this process (deployment); for example the process between the discovery of a major QTL for MSV (msv1) to its deployment in the breeding program was 20 years. In contrast breeder-ready markers for MLN tolerance are expected to be deployed in 2017, with four years between discovery and deployment.
• **Quantification of genetic gains should be integral part of breeding programs, and is essential to measure and monitor breeding progress and efficiency:** Success in breeding for multiple-stress tolerance is ultimately determined by measuring improvement in grain yield of hybrids and OPVs achieved in stressful growing environments relative to the yield potential of farmer-preferred hybrids and OPVs. Estimates of genetic gain are useful to assess progress toward MAIZE objectives and to identify important agronomic and physiological traits associated with realized genetic improvement. During Phase-I, CIMMYT and IITA Maize Programs in SSA undertook era studies to assess the genetic gains made in the stress-prone environments; these results provide the baseline for MAIZE Phase-II. The results highlighted the need to increase gains under low N stress, historically a trait with less phenotyping capacity compared to drought stress. Monitoring genetic gains, however, needs to be an integral and routine part of the MAIZE breeding programs worldwide. In addition to monitoring overall progress toward product performance targets, MAIZE in Phase-II will also use disaggregated cohort analysis to monitor genetic gain estimates for different breeding approaches. This activity will inform resource allocation decisions on long-term to optimize progress. Individual breeding programs in different target geographies will similarly be assessed both using genetic gain measures from cohort analysis as well as line and hybrid advancement rate in common trials (stage 3 and stage 4).

• **Focus on specific individual traits with many separate breeding pipelines will not necessarily lead to successful commercial products that meet farmers’ requirements:** Screening of advanced breeding and commercial products with moderate to high levels of drought tolerance revealed MAIZE partners have been successful in establishing decentralized tropical maize breeding and testing networks in the target regions/continents; this proved highly effective in addressing issues related to specific adaptation, and enabled establishment of a strong pipeline of products. However, particular emphasis has to be laid on defining MAIZE product profiles that aggregate key traits and with comparative advantage in specific agro-ecologies in SSA, Asia and Latin America in Phase-II for greater impacts. Accordingly, for Phase-II, the target traits and product profiles for each of the regions (and specific agro-ecologies within each) have been identified and reflected in the Appendix 3; Tables 1-3. To accomplish this, breeding pipelines will have to rapidly adapt and incorporate new diversity and trait combinations to enhance genetic gains for multiple stress tolerance and nutritional quality, besides improved grain yield. There are now significant opportunities to breed for multiple stress tolerance and increase genetic gains using novel tools/techniques that were identified and validated in Phase-I and are now ready for large scale deployment. Mature technologies for deployment include doubled haploid (DH) and molecular markers for key biotic stresses (e.g., MSV, MLN). Through DTMA and WEMA, the potential of marker assisted recurrent selection (MARS) to increase gains in grain yield under drought stress and optimal conditions was also demonstrated using bi-parental populations. Also, novel germplasm, including temperate introgression, can be incorporated at a much wider scale in the MAIZE breeding pipeline to increase genetic gains.

• **Modification of tropical maize plant architecture to enhance yield potential needs access to and integration of novel genetic variants:** Introgression of temperate maize germplasm into adapted breeding materials has proven useful in MAIZE Phase-I for improvement of yield potential, standability, and shortening maturity and plant stature. Furthermore, tropical inbred lines introduced from Thailand with much higher levels of resistance to MLN have been identified for introgression into elite inbred lines adapted to SSA. MAIZE FP3 in Phase-II will further emphasize on targeted introduction of genetically diverse inbred lines as promising sources of potentially new beneficial alleles/haplotypes that can be recovered easily in genetic backgrounds adapted to the tropics/sub-tropics. The availability of high-throughput phenotyping tools, DH technology, and breeder-friendly
molecular markers developed in MAIZE Phase-I will facilitate introgression/recovery of an array of alleles/haplotypes in superior genetic backgrounds fairly quickly and makes them available for further use in breeding to improve agronomic and adaptive traits for broad adaptation to diverse mega-environments.

- **Need to significantly increase the rate of maize variety turnover in SSA:** Results from the 2013 DTMA adoption monitoring survey indicated that the average age of hybrids in SSA is nearly 13 years whereas OPVs are more than 19 years old. This is in stark contrast with the data for maize varieties from the evolved seed sector in the US or some regions in Asia, where the average age of hybrids is about 5-6 years. Approximately 78%, 75%, and 64% of maize varieties grown in Angola, Mali and Ghana are 15 years or older. Catete, Amarelo, and Branco Redondo were released in Angola in 1957, 1959 and 1967, respectively, but accounted for nearly 65% of the total maize area grown in parts of Huambo, Bie, Kwanza Sul, Kwanza Norte, Lunda Norte, and Malange. About 12% of all maize plots in Tanzania were planted to Staha, an OPV released in 1983.

- **Affordability and timely availability of quality seed:** Affordability and timely availability of quality seed of improved varieties is a major bottleneck in several countries in the developing world, especially in the remote or less favorable markets. MAIZE, in active partnership with both public and private sector institutions (especially local SMEs) has to intensify efforts to develop/strengthen the seed sector in these less-privileged areas. Considering the constraints of the resource-poor maize smallholders in the stress-prone remote geographies, there is a continued need to provide options for low-cost improved maize seed, including three-way hybrids.

- **Quickly bridge the knowledge and adoption gaps among men and women to facilitate access to improved varieties and foster women’s participation across maize value chains:** Beyond fostering farm level adoption, we need to understand and strengthen women’s participation across maize value chains – as producers of seed, in processing, distribution, promotion, and in seed retail. We also need to enhance capacity for gender-responsive research and development through strengthening gender awareness and competencies among the staff, integrating gender in partner training, fostering women’s participation in training, and building a community of practice on gender and maize systems. MAIZE FP3 in Phase-II will strive for a stronger and equitable maize seed systems where scientists understand and develop products that meet diverse needs and preferences; where men and women have equal opportunities to learn about and adopt new products; where men and women participate and benefit from entrepreneurial opportunities within maize value chains; where seed companies thrive and increase their profits by effectively targeting women; where strategic research addresses substantive gender issues; where individuals are gender aware; and where monitoring and impact assessment are used as tools for learning and improvement of research and development strategies.

- **Need to systematize and institutionalize germplasm exchange and trialing in Asia:** CGIAR’s global seed exchange is largely controlled by biodiversity regulations of countries in which they operate. In the context of Asia, germplasm exchange (mainly export but also import) in several countries is highly regulated and procedurally slow. Maize is a crop with high genotype-by-environment interaction; to make breeding progress, it is highly essential that new germplasm be tested in as many environments (even within target ecologies) as resources would allow. The slow logistics of germplasm exchange has been one of the biggest impediments that needs to be effectively and quickly addressed. Asia’s breeding strategy hinges on newer models of international germplasm exchange and evaluation. Thus, an increased need for germplasm movement is envisaged not just through existing projects but through initiatives that will bring private sector germplasm into the public domain.
• **Capacity building**: Building capacity of the partners through short-term and long-term training courses and technical backstopping is essential to increase genetic gains and increased frequency of varietal turn-over. At the end of MAIZE Phase-I nearly every national program partner in SSA has at least one scientist with a PhD degree (through work done at CIMMYT/IITA). Short-term training courses and on-site visits have increased both data return and quality in the breeding program, thereby increasing the strength of MAIZE breeding pipeline. Sensitizing partners to trait requirements in the target environments has also increased the regional strength. For example, extensive training and partnership for low N stress has resulted in at least five seed companies developing low N phenotyping sites for their product development pipeline.

### 2.6 Clusters of activity (CoA)

FP3 consists of six Clusters of Activities (CoAs). CoA 3.1 focuses on developing multiple-stress tolerant improved maize cultivars based on the identified product profiles for different target agro-ecologies in SSA, LA and Asia, where MAIZE has a comparative advantage. Developing improved varieties with MLN resistance for SSA, and increasing genetic gains for stress-prone environments in the tropical/sub-tropical maize-growing regions are also key areas of focus of Coa 3.1. Coa 3.2 is critical for tackling the existing/future threats to maize food security, especially in the developing world, such as MLN and *Striga* in SSA. The initiatives proposed in CoA 3.2 will significantly complement the breeding and product development activities under CoA 3.1 and 3.3 while building the capacity of the local institutions to be well-prepared for pest/pathogen challenges of the future, exacerbated by the changing climates. CoA 3.3 focuses on developing improved maize varieties with enhanced nutritional quality or end-use traits preferred by producers/processors/consumers. This CoA will also develop, validate and deploy robust, high-throughput tools/techniques for assessing different nutritional and end-use quality traits to speed up the varietal development. CoA 3.4 focuses on two major ways to increase genetic gains through breeding programs, viz., high-throughput and reasonably precise field-based phenotyping, and mechanization/automation of breeding operations, besides establishing well-equipped regional phenotyping hubs to provide phenotyping support to NARS and SMEs. Thus, this CoA forms the technical foundation for the MAIZE breeding-oriented CoA 3.1 and 3.3. CoA 3.5 will provide the bridge between product development (through CoA 3.1 and 3.3) and product delivery (through CoA 3.6), by testing the seed producibility of the improved maize hybrids and providing seed production recommendations to reduce the cost of goods sold (COGS). CoA 3.6 will implement innovative models for rapidly scaling-up and scaling-out improved maize cultivars in the target geographies, in close collaboration with the private sector and farmer-producer groups.

All the six CoAs in general, and CoA 3.1, 3.3 and 3.4 in particular will be closely linked to the Genetic Gains Platform (validation and deployment of new knowledge/tools/services in maize breeding programs), MAIZE FP1 (e.g., meta-level technology targeting; impact assessment of improved varieties; gender and social inclusion; ME&L), and FP2 (novel tools/technologies for enhancing genetic gains, such as molecular markers for key traits, DH, and genomic selection; novel germplasm for trait improvement; breeding management system). Coa 3.1 and 3.3 will provide promising maize germplasm for targeted environments and cropping systems to FP4 (Coa 4.3), and will receive feedback on their performance through G × E × M analyses. Products from CoA 3.3 (nutritious maize; varieties with specific end-use traits) will form the core for developing novel technologies/processes/products through FP5 (Adding value to the maize producers, processors and consumers).
CoA 3.1: Climate resilient maize with abiotic and biotic stress tolerance

CoA 3.1 offers opportunities for research, targeted at public and private sector users, to increase the development and scaling-out of improved varieties and farmer-participatory research to enhance adoption and utilization of improved maize varieties, thereby contributing to food and nutritional security, income and other livelihood outcomes, fostering gender equity and youth inclusion. The MAIZE Phase-II will build on the long-term achievements in the development of a diverse array of abiotic and biotic stress tolerant maize germplasm with continual introduction of novel alleles to generate new maize varieties and hybrids with much higher levels of tolerance to multiple stresses. Considering the heterogeneity among target regions and diverse demands of the stakeholders, breeding for stress resilient maize under MAIZE FP3 has identified priority target traits and product profiles (see Appendix 1, Table 1-3, in this document). Strategic interventions through CoA 3.1 will include:

1. **Targeted products with packages of traits relevant to smallholders in the tropics:** Product profiles have been redefined for SSA, Asia and LA based on stakeholders’ feedback during Phase-I, and breeding programs have been reorganized to fast-track development of new germplasm with combinations of appropriate key traits for different regions. This is particularly important since (a) breeding for tolerance to one stress (e.g., drought) may not necessarily translate into tolerance to another stress (heat/waterlogging/cold); (b) a trait-based breeding focus does not fully meet the requirements of the maize production environments in each region, and (c) stagnation or decline in input use, coupled with expansion of maize production into new areas, warrants new target traits for suitability of maize in different cropping systems. Furthermore, most MAIZE partners do not have GIS capacity required to realign their breeding programs to future environments. Given the time taken between the development of improved varieties and adoption by farmers in the target environment, MAIZE will develop key GIS information which can be incorporated into breeding pipelines. This will help to ensure new varieties contain traits required for future environments ensuring both yield gains and offsetting predicted losses under climate change. MAIZE does not only incorporate stress tolerant genes through conventional and molecular marker-assisted breeding, but also conducts focused R4D on transgenic approaches for stress resilience in maize, based on traits prioritized by partners in SSA. The approach is to introduce such transgenic traits under humanitarian license in partnership with technology providers (e.g., Monsanto, DuPont-Pioneer). The tropically adapted maize germplasm developed at CIMMYT serves as an important platform for introgression of transgenes for identified traits. The requisite infrastructure for Confined Field Trials (CFTs) have been established in Phase-I under the WEMA and IMAS projects in selected countries, including Kenya, Uganda, South Africa, Tanzania and Mozambique, for safe introduction and evaluation of transgenic maize. Through the WEMA project, MAIZE made the first major test of transgenes for drought tolerance and Bt-based insect-pest resistance, with requests for commercial release currently in process in SSA.

2. **Strengthening breeding pipelines through the integrated deployment of novel tools/technologies that enhance genetic gains:** The breeding pipeline must be flexible to rapidly incorporate new traits and technologies to effectively tackle emerging diseases (e.g., MLN in eastern Africa) as well as expanding threats, such as invasive and parasitic weeds and heat stress. In MAIZE Phase-I, besides successfully adapting DH technology (Prasanna et al., 2012), novel markers associated with genes conferring tolerance to abiotic stresses (drought, heat, waterlogging and low N), resistance to biotic stresses (MLN, MSV, TLB, GLS, tar spot complex, downy mildew), and enhanced nutritional quality (provitamin A, kernel Zn) have been identified, validated and marker assays developed (Prasanna et al., 2013a; Babu et al., 2013; Nair et al., 2015; Gowda et al., 2015; Semagn et al., 2015). Higher rates
of genetic gains are required to increase current yields and offset potential losses under climate change. Marker-assisted recurrent selection (MARS) and genome-wide selection (GS) have already been incorporated into the breeding pipeline, reducing cycle time and allowing selection intensity to be increased (Beyene et al., 2014, 2016a,b). In MAIZE Phase-II, both existing and new markers associated with major traits will be deployed with complementary technologies, including precision phenotyping, environment characterization and management, DH, and Breeding Management System, to combine tolerance to multiple stresses and enhance genetic gains and breeding efficiency.

CoA 3.2: Tackling emerging trans-boundary disease/pest challenges

Trans-boundary diseases, insect pests, and parasitic weeds pose a serious challenge to agriculture, and adversely affect international efforts to improve food security, reduce poverty and malnutrition, besides acting as barriers to trade since quarantine and other measures taken to prevent the spread of pathogens/insect-pests also lead to reduced access to international and regional markets. The emergence and rapid spread of MLN in eastern Africa has posed a serious challenge to the food security and livelihoods of maize-based farming communities, as well as the commercial maize sector in the region (Prasanna, 2015; Mahuku et al., 2015). Without adequate controls, MLN can become a continent wide problem. For many smallholder farmers in SSA, the parasitic weeds *Striga* infestation is increasing and thus threatens to achieve sustainably high productivity in maize, particularly in drought affected areas with limited input use. Similarly, the Larger Grain Borer (LGB, *Prostephanus truncatus*) is another example of a post-harvest trans-boundary grain insect pest (originating from LA) that spread rapidly in Africa, causing an estimated 15% loss of maize harvests (Golob, 2002). Effectively controlling the spread and impact of trans-boundary diseases, pests and parasitic weeds is a complex challenge, and can only be addressed through several concurrently implemented strategies. In MAIZE Phase-II, while intensifying breeding for genetically diverse, MLN, *Striga*, and LGB-resistant maize germplam with desirable adaptive traits and deploying the improved varieties through public and private sector partners (through CoA 3.1 and 3.6), intensive inter-institutional efforts will be launched on the following:

1. Establishment of an effective surveillance and monitoring system, including periodic surveys of diseases, insect-pests, and parasitic plants to identify emerging threats, and designing and developing and implementing a pro-active strategy to rapidly respond to such threats within FP2, FP3 and FP4;
2. Setting-up and operating a “community of practice” among phytosanitary agencies in SSA for implementing harmonized protocols for monitoring emerging pests and pathogens of maize, particularly MLN-causing pathogens in commercial seed lots;
3. Supporting the commercial maize seed sector in SSA (especially SMEs) in implementing harmonized protocols for MLN-free seed production
4. Effectively leveraging existing networks and partners worldwide for building the local capacity in SSA for MLN-free seed production, disease/pest diagnosis and management.

CoA 3.3: Introgressing nutritional quality and end-user traits

Maize alone contributes over 20% of total calories in human diets in 21 countries, and over 30% in 12 countries that are home to more than 310 million people. However, “hidden hunger”, characterized by chronic deficiency of essential vitamins and minerals (micronutrients), is particularly severe in SSA, Asia and specific regions in LA, where many people do not consume enough essential micronutrients to lead healthy and productive lives (Bouis et al., 2011). Significant progress has been made in developing, testing, and deploying biofortified maize, especially Quality Protein Maize (QPM) and provitamin A-
enriched maize worldwide in collaboration with A4NH (Atlin et al., 2011; Babu et al., 2013). These biofortified maize varieties are particularly impactful in rural areas with limited access to dietary supplements and fortified foods (Chomba et al., 2013). Emphasis in MAIZE Phase-II under CoA 3.3 will be on:

1. **Novel biofortified maize varieties with value-added traits**: Efforts will be intensified in MAIZE Phase-II to boost agronomic performance and combine nutrients including provitamin A, methionine, high oil, and kernel Zn in both non-QPM and QPM backgrounds for greater impact on nutritional status of the poor, especially pregnant women, nursing mothers, weaning and pre-school children, low-income urban centers and the urban unemployed. Molecular markers associated with alleles regulating flux in the carotenoid biosynthetic pathway and the DH technology will be utilized to accelerate the rate of genetic gain in increasing nutrient levels and stacking multiple nutrients in elite tropical maize genetic backgrounds.

2. **Introgressing relevant end-use quality traits**: Developing and deploying maize varieties with relevant end-use quality traits can promote diverse uses of maize in food/feed sector (Grings et al., 2013), increase income generating opportunities for farmers and processors, reduce the labor requirement of women at household level, and contribute to the reduction of waste. Greater emphasis will be placed in MAIZE Phase-II on developing maize varieties with prioritized end-use quality traits (Table 3b) for enhanced use of maize as food/feed, storability (stover quality, kernel carotenoid stability), processing (kernel hardness, color, size, etc.) and palatability (biophysical and biochemical traits for food and feed) (linked to FP5 in maize value chains).

3. **Specialty maize for improving smallholders’ income opportunities**: There is increasing market demand for specialty maize in urban and peri-urban areas, including blue maize varieties (Hellin et al., 2013), sweet corn, popcorn and baby corn. Local breeders demand access to such breeding germplasm and wider genetic diversity from CGIAR centers. Specialty maize varieties, meeting end-use quality standards, linked to relevant markets, can potentially provide smallholder farmers with additional income, besides promoting in-situ conservation of unique genetic resources grown by farmers in LA.

**CoA 3.4: Precision phenotyping and mechanization of breeding operations**

High throughput and precision of phenotypic data is key for accelerating genetic gains, developing more robust and impactful products, and getting better returns on investment in crop improvement programs. Field-based high-throughput and precise phenotyping, using low cost, easy-to-handle tools, should become an integral component of the breeding pipeline, especially for NARS and SME seed companies (Prasanna et al., 2013b; Araus and Cairns, 2014). In MAIZE Phase-II, the focus will be on following areas:

1. **Developing/validating and using new phenotypic innovations in selection decisions**: Digital and hyperspectral imaging approaches will be used to more quantitatively and rapidly collect data on key agronomic traits, including stand count, anthesis date, senescence index, leaf area/biomass index, canopy architecture, nitrogen stress index as well as disease and pest damage ratings. Novel phenotyping tools will be utilized in combination with methods for characterizing and controlling variation within a field site, adopting appropriate experimental designs, selecting the right traits, and properly integrating heterogeneous datasets, analysis, and application. This will also have strong linkages to the phenotyping and bioinformatics modules from the Genetic Gains Platform for inputs on high throughput/remote-sensing phenotypic data capture, storage, and analysis. Also, this
CoA will also have linkage with CoA 2.3 due to the need to facilitate automated image analysis coming from the trials and to mainstream the analyzed results into institutional databases, especially BMS.

2. Establishing well-equipped regional phenotyping hubs to provide phenotyping support to NARS and SMEs: Improvement in phenotyping protocols and the use of available low-cost phenotyping tools will help NARS and SMEs to be more efficient in their breeding programs with reduced cost of labor. Well-equipped regional phenotyping hubs, ideally linked to site integration hubs across CRPs/Centers, will enable economies of scale for collection of precision phenotypic data at different (abiotic) stress intensities. Regional hubs will be used for testing new phenotyping technologies and protocols prior to dissemination. The phenotyping hubs will also offer practical training to scientific and technical personnel from NARS and SMEs on new developments in field-based phenotyping technologies.

3. Mechanization of maize breeding operations: With high-throughput genomic and phenotypic approaches becoming main-streamed in breeding programs and new challenges emerging (such as MLN in Africa), the area of maize breeding activities has increased in support of greater selection intensities and genetic gains. As a result, CGIAR maize breeders routinely plant and manage more than 150,000 rows in each of the key regional breeding locations. To effectively cope with increased volume of operations and to improve breeding efficiency, CoA 3.4 will focus on mechanization and automation of the whole breeding cycle through (i) automated seed preparation and seed treatment; (ii) planting field trials and breeding nurseries, (iii) state-of-the-art phenotyping, data collection and trait scoring, (iv) fully mechanized and automated harvest, and (vi) modern post-harvest operations. Trial operations will be streamlined and mechanized to the extent that 3-4 well-qualified (MSc) technicians should be able to manage >100,000 trial plots with 100% electronic data collection. Training of NARS and SMEs with smaller-sized maize breeding operations, targeted co-investments by MAIZE as well as respective organizations, will enable adoption of selected mechanization approaches for trial and nursery operations.

CoA 3.5: Seed production research and recommendation domains

MAIZE works with over 200 local seed companies that are crucial to bring improved maize seed to the 40-50% of farmers that are inadequately served by the established seed sector. Information on seed production potential (producibility) of parental lines and hybrids is critical for successful adoption of these products by small and medium-sized seed companies. They rely on high seed yields which often need to be produced under rainfed conditions. Seed production research is therefore an integral component of MAIZE, and will be conducted in close partnership with seed company partners. Key considerations are the female parent yield, synchrony in flowering of the male and female parents, and the agronomic characteristics of the inbred lines and single-crosses. In MAIZE Phase II, the focus will be on: (a) evaluation of parental lines of hybrids for yield, herbicide sensitivity, and other desirable agronomic traits; (b) seed production studies across a range of target seed production environments in collaboration with public/private sector partners; (c) web-based documentation and dissemination of the recommendation domains with NARS and seed company partners for cost-effective seed scale-up; (d) development of source populations for male sterility (through CoA 3.1) to make seed more affordable by reducing the cost of seed production; (d) development of male sterility-based seed production systems; and e) identifying and adopting the best male : female ratios to increase seed production per unit area.
CoA 3.6: Stronger maize seed systems

Delivering low-cost hybrids and open-pollinated varieties to smallholder farmers with limited market access requires that indigenous SMEs be supported with information on and access to new products, adequate and reliable supplies of breeder and foundation seed, and training in techniques of quality seed production and seed business methods. This CoA strengthens emerging local/national/regional seed enterprises in SSA, Asia and LA to become increasingly market-oriented, diverse and dynamic, so as to provide smallholders with greater access to affordable improved maize seed. Strategic interventions through CoA 3.6 (with knowledge, product and feedback flows from FP1 and other CoAs in FP3) will include:

1. **Improve the availability and affordability of MAIZE derived novel varieties in target geographies:**
   The uptake of improved maize seed by smallholder farmers is a function of the cost of seed and expected returns from investment compared to existing varieties. Keeping this in view, the core activities under this component will be: (i) catalyze active replacement of old and obsolete maize varieties, especially in SSA, with new climate-resilient cultivars; (ii) supplying improved maize varieties generated in FP3 that can be produced easily in large quantities at low-cost and with superior agronomic performance compared to local checks to the NARS, private sector and NGOs in SSA, Asia and LA; (iii) facilitating multi-location farmer-participatory testing to identify women and men farmer-preferred improved maize varieties; (iv) databases with multi-location on-station and on-farm trial data with GIS-based environmental characterization for technology targeting; (v) licensing and targeted deployment of identified pre-commercial maize varieties/hybrids through appropriate NARS and private sector partners committed to provide quality seed to smallholders in the target areas/countries; (v) catalyzing scale-up and delivery of quality seed for prioritized products in the target geographies through public/private seed company partners for accelerated replacement of less-productive varieties in the market; and (vi) develop mechanism(s) for seed company partners to accelerate replacement of maize varieties with inferior traits, such as lower grain yield, disease and insect-pest susceptibility, vulnerability to major abiotic stresses, etc. as well as less-productive varieties that have been on the market for more than 15 years.

2. **Promote sustainable early generation seed (breeder seed, pre-basic seed, and foundation seed) supply systems, especially in SSA:** This will be accomplished by: (i) disseminating comprehensive information on seed producibility and descriptor data for pre-commercial MAIZE hybrids to seed scale-up partners, including community-based seed producers (linking with CoA 3.5); this data will be generated in the target agro-ecologies by the MAIZE seed systems team; (ii) promoting cost-effective seed production practices (developed under 3.5); (iii) identifying and supporting women-owned foundation seed production companies; (iv) testing different models for sustainable third-party production and provision of foundation/basic seed of MAIZE hybrids to SME seed companies; and (v) supporting development of sustainable capacities of key local seed regulatory agencies and SMEs for Quality Control/Quality Assurance (QC/QA) covering the entire seed value chain.

3. **Catalyze the sustainable commercialization, marketing, and promotion of new varieties to enhance both local production and adoption:** The increased adoption rates of improved varieties depends not only on the accessibility and availability of such products, but also on sustained demand for new and better seed. Effective communications, marketing and product promotion strategies are key elements for achieving widespread/enhanced adoption of and impacts from the improved maize seed. This will be accomplished by: (i) improving small-scale
farmers’ knowledge of new maize varieties along with complementary crop and land management practices; (ii) generating information on technology adoption patterns and key drivers, to inform marketing strategies (in collaboration with FP1); (iii) building the capacities of SME seed companies in business management and marketing strategies (business planning, demand forecasting, branding, market segmentation, product mapping, distribution network mapping, logistics, etc.); (iv) promoting community-based sustainable local production of improved seed with the requisite quality (in areas difficult to reach through seed companies); and (v) developing linkages among seed companies, farmers/community-based organizations, financial institutions and end-user markets. The deployment of new seed system management software in CRP-managed regional maize seed hubs in Africa, Asia and LA, linked to institutional phenotypic and genotypic databases, will underpin these efforts. Better software can help prevent errors in seed production and shipment by facilitating routine QC operations and promoting proper phytosanitary and IA/IP regulation compliance. It will also contribute to streamlined seed increase procedures, inventory management, and shipment tracking. SMEs can be trained to implement the successful open-source seed management software adopted by the CRP hubs.

4. **Gender-responsive approaches to promote women’s participation across the maize seed value chain:** Women account for up to almost half of all seed purchase in some countries (e.g. Zambia) and up to 90% of grain (e.g. Kenya). Huge gender gaps also exist in entrepreneurship along the maize seed value chains. To address gender inequities within the seed value chain, including access to improved seed, the focus will be on: (i) fostering equal access by women and the socially disadvantaged to inputs for new varieties/technologies (training; demo plots; financing; information; seed; etc.); (ii) providing seed company partners with tools and guidelines for gender-responsive promotion activities; (iii) giving priority to development partners who commit to inclusive approaches; (iv) conducting gender capacity assessments for partners and providing support for gender integration into seed business development; and (v) organizing exchange visits/short-term training for women entrepreneurs along the entire value chain.

5. **Farmer producer groups as a vital component for technology-scaling and as one of the key pathways for reaching women and youth:** Strong local level farmers’ and women’s groups make it possible to transfer knowledge on new varieties and sound management practices, for developing effective approaches for improved seed delivery, for fostering output market linkages, and for transferring nutrition and utilization skills and messages. We propose to document and strengthen existing farmers’ groups in order to foster rapid technology adoption and, more importantly, to reach women and youth at scale in all key geographies. Partners such as seed companies, agrodealers, and stockists will be encouraged to deploy their materials through farmer groups.

6. **A consortium-based approach in SSA for targeted product development and deployment:** Based on the success achieved in MAIZE Phase-I through the International Maize Improvement Consortium (IMIC) in Asia and LA, we will establish and implement an ESA-wide IMIC. Maize seed trade in Africa has remained at low level until recent years. The proliferation of variety releases under different initiatives has helped a rapid increase of seed companies in Africa. As of March 2015, there were about 110 seed companies in ESA. The bulk of those are fledgling small national companies (producing <500 tons per year). However, there are a good number of regional and transnational seed companies (e.g., SeedCo, Klein Karoo, Syngenta, Pioneer, etc.) which have been operating in the sub-regions over the last several decades. The growing demand for improved seed also indicates good potential to further attract the involvement of large companies. IMIC-Asia and IMIC-LA suggest that there is a good possibility for both large
and SME companies to be part of the consortium, with a win-win approach. The objectives of the consortium are: a) to create a forum for public-private partnership in maize R&D, especially to enhance the genetic gains in the stress-prone environments of the tropics; b) to facilitate targeted development and collaborative testing of improved hybrids with multiple stress tolerance; and c) to strengthen the capacity of maize breeders/technical personnel in partner institutions in modern breeding techniques.

2.7 Partnerships
The maize breeding programs at CIMMYT and IITA are strongly linked and have developed broad regional maize breeding and product testing networks, comprising more than 100 collaborating institutions from the public sector, private seed companies, and NGOs. MAIZE also engages several advanced research institutes and universities (e.g., Purdue University, University of Wisconsin, University of Minnesota, USDA-ARS, Ohio State University, EMBRAPA, CAAS, University of Hohenheim, University of Barcelona, Wageningen UR, Flinders University, etc.); in conducting collaborative research using cutting-edge science for developing stress tolerant and nutritious maize germplasm. One of the major strengths of MAIZE is the strong partnership with the private sector to develop and deploy products adapted to SSA, Asia and LA for greater impact. A further major strength of MAIZE is providing direct linkages between national programs and advanced research institutes, to accelerate the transfer of new technologies and foster partnerships. These efforts are fully aligned with the CGIAR Principles on the Management of Intellectual Assets. Large multinationals (e.g., DuPont-Pioneer in IMAS and HTMA-Asia; Monsanto in WEMA; Syngenta in AAA-Asia) collaborate as providers of distinct germplasm, knowledge and other technologies that are acquired under humanitarian licenses. Local regional, national and subnational seed companies receive elite breeding materials, pre-commercial hybrids and training to develop and deploy products for commercialization and in support of their own fledgling research programs. Special efforts are made to continuously forge new strategic partnerships, through germplasm exchange as well as joint projects, with advanced research institutions/universities, as well as multinationals with maize breeding strength to capture the complementarity of germplasm, broaden the genetic diversity and access intellectual property for public use. Particular focus will be laid on the partnership with farmers, youth and the socially disadvantaged in participatory evaluation of improved maize cultivars in target environments as well as to gain a better insight into their distinct needs for breeding and developing gender-responsive products.

Docking with Other Agri-Food Systems CRPs, and Integrating Programs and Platforms
FP3 shares a significant number of breeding and testing locations with other rainfed crops and associated Agri-food systems (AFS) CRPs, especially WHEAT, DCLAS and RTB, and including with CGIAR centers and NARS. So far this has mostly leveraged use of facilities. Phase-II aims at more strongly leveraging phenotyping competencies and best practices, in particular with a view to rapidly translate insights of extensive research in major crops (maize, wheat, rice) to smaller crops with lower research intensities.

Genetic Gains Platform: FP3 will have strong linkages with the Genetic Gains Platform. Some of the key tools for cross-cutting areas, such as phenotyping and breeding decision-making, will be validated and deployed in FP3. FP3 team in turn will also help determine priorities for new tools to this platform to guide its work over time.

Genebanks Platform: MAIZE FP3 will align strongly with the Genebanks Platform, extending tools for phenotyping, genotyping maize germplasm for unlocking useful traits, and utilizing genetic resources in breeding for target traits.
**CCAFS:** Some of the areas where MAIZE FP3 and CCAFS can mutually enrich each other in Phase-II include: (a) participatory evaluation of abiotic and biotic stress-resilient maize hybrids within climate-smart villages (CSVs) under heterogeneous production and socio-economic conditions; and (b) linking the environment characterization and crop modeling work under CCAFS, with the work on maize physiology and breeding under MAIZE FP3.

**A4NH:** In Phase-I, MAIZE and A4NH shared expertise on the development, testing, and scale-out of provitamin A and kernel Zn enriched maize hybrids. During Phase II, MAIZE will explore the feasibility and genetic variability for additional stacking of nutritional traits, for potential development within A4NH.

### 2.8 Climate change

Yield loss and year-to-year variability in most of the target MAIZE areas are related to climate-induced stresses. Climate projects show maize yields are likely to further reduce in many of these areas (IPCC, 2014; Tesfaye et al., 2015). Breeding programs targeting large regions with highly heterogeneous environments tend to subdivide the region into several relatively homogenous areas, known as mega-environments, where germplasm will perform similarly. Climate projections show that the demarcation of these mega-environments will change in several areas. In order to address changing environments and offset potential losses under climate change maize breeding pipelines must take into account changes in future environments, and the trait combinations within these environments required to maximize yields. To address this FP3 will incorporate the outputs of GIS climate and crop modelling to identify future environments to both identify future stresses, hotspots of vulnerability and phenotyping sites suitable for screening for these future environments (analogue sites). Current phenotyping sites within MAIZE countries may not provide the environments required for the development of climate resilient maize and the identification of analogue sites within phenotyping networks will be crucial. This process will be particularly pertinent for countries whose current internal phenotyping networks do not contain screening sites representative of future target environments. Breeding pipelines will target key trait combinations required for future target environments. This process will be dynamic with advances in GIS continuously incorporated into breeding programs to refine target environments and align product folios, building on the lessons learned in phase I. These actions will ensure products coming out of MAIZE breeding programs will provide farmers with the most appropriate maize varieties for their environments.

### 2.9 Gender

FP3 puts priority on ensuring that product development addresses the needs and preferences of both women and men farmers of different social groups. To support the ambition of reaching 50% of female participation in PVS activities, on-farm trials and demos and farmer field days in Phase II, FP3 will institutionalize the MAIZE guidelines for integrating gender into PVS (REF). This will furthermore contribute to streamlining and standardizing the systematic sex-disaggregation in data collection and analysis related to farmer feedback to maize genetic improvement. In addition, based on Phase I findings related to gender and maize seed sector development (REF Kandiwa Kenya; Tegbaru Nigeria, Kandiwa Women seed comp) and the Gender strategy for maize seed sector development (Kandiwa et al) FP3 will raise the investment in gender responsive seed sector development. Relevant gender research questions for FP3 include:
What are the needs, preferences and constraints of men and women maize farmers with regards to maize varietal traits? In what ways are these similar for men and women; and in what ways are they different? To what extent is this considered in the maize improvement process?

What shapes men and women farmer’s ability to access, use and benefit from improved maize varieties?

Under what conditions do women and men small scale maize farmers engage with the seed retail sector? Which kinds of maize seeds, what quantities, and what frequency? What factors do they consider when acquiring seed? What are the challenges they face in relation to acquiring improved maize seed. In what ways and to what extent do these aspects differ between men’s and women’s maize seed acquisitions?

How do small and medium size seed companies and agro-dealers perceive and segment their markets? How do they address gender as a customer attribute? What constraints are faced by agro-dealers and by women farmers?

How do farmers, especially women, access information about seed? What are key issues for developing gender sensitive variety promotion and decision support information?

2.10 Capacity development

Capacity development efforts of FP3 and FP2 will need to be effectively coordinated to prevent duplication. The two FPs should join efforts in the training of current and new breeders and technicians to enhance the use of biotechnology (molecular markers, genomics, etc.) and other modern tools to both meet immediate needs and for the long-term strengthening of advanced breeding capacity. Capacity development in FP3 will include specific activities on outreach and extension to provide information on traits that are being incorporated into new varieties, training in new advances in technology that accelerate the development of new and improved maize cultivars, and the importance of these new traits and characteristics with regard to farming practices, product development and enhancement, and market acceptance. The effort will also integrate training in management practices to ensure that the performance of the new varieties is optimized in the appropriate growing conditions.

Another key element is the improvement of small-scale farmers’ knowledge of new maize varieties along with complementary crop and land management practices, enhancing the capacities of SME seed companies in business management and marketing strategies (business planning, demand forecasting, branding, market segmentation, product mapping, distribution network mapping, logistics, etc.). Also partners’ knowledge will be strengthened through the dissemination of tools and guidelines for gender-responsive promotion activities. Local production of improved seed will be supported by short-term training, training, demo plots and information on quality seed. Exchange visits and short-term training for women entrepreneurs along the entire value chain will be organized. Knowledge exchange tools will be used to disseminate data and studies such seed production studies across a range of target seed production environments.

Technical backstopping will be provided to improve breeding processes and the utilization of new technologies that ultimately increases genetic gain. New breeding technologies and tools (physiological, statistical, molecular, data management) to increase breeding efficiency will be disseminated. Targeted capacity building activities should include organization of both short- and long-term visiting scientist fellowships and post-graduate research support (with at least 50% fellowships/support to women and youth), training of NARES and private-sector breeders/technicians in new areas of research (e.g., DH-based breeding; molecular breeding for developing climate resilient and nutritious maize; precision phenotyping, environmental characterization and experimental error control; mechanization of breeding operations; MLN diagnosis and management), techniques of quality seed production and
development and web-based dissemination of relevant training modules. The capability of partners in the NARES to conduct research and training in their own countries will be strengthened.

2.11 Intellectual asset and open access management
Under FP3, scientists will validate/deploy new tools for data management, data stewardship (including open-access), and data mining or analysis to enhance breeding efficiency that results in faster genetic gains. These will be designed with OA/OD in mind, from a technical and user perspective. As often as possible, the data generated in FP3 will be collected and stored according to CRP standards using CRP tools to facilitate its regular export to established data sharing platforms. As much of these data will be collected from both public and private sector partners, all projects with partners shall include robust data sharing and intellectual asset management agreements to ensure that the rights to data and intellectual assets, including germplasm, and the responsibility for the curation and sharing of data are clearly established. MAIZE FP3 researchers will make well-described raw and/or analyzed data available to the public through CRP-approved OA/OD repositories and data warehouses, such as Dataverse, or through public portals such as Ensembl Plants. MAIZE germplasm will be disseminated, based on international regulations, and Standard Material Transfer Agreement (SMTA).

2.12 FP management
MAIZE FP3 will be co-led by scientists from the two lead centers in the CGIAR (CIMMYT and IITA), with significant expertise and track-record in generating impacts through maize breeding and product deployment in the target geographies, especially Africa, Asia and Latin America, providing a distinct comparative advantage over any other institution operating in these regions. Since FP3 is geographically widespread, co-leadership allows both centers to have a clear roles and responsibilities in specific target geographies, with CIMMYT coordinating the MAIZE FP3 work in Asia, LA and ESA, and IITA doing the same in WCA. Co-leadership also eases integration with MAIZE FP3 with other FPs and CRPs/Platforms, including site integration. Details of the leadership capacity, technical expertise and track record of the MAIZE FP3 team (including CoA 3.1 to 3.6 Co-leads) are provided in Annex 3.8. The FP3 leadership team also has long-term and successful partnerships with a wide array of public and private institutions that add value at different levels, including discovery research, validation/proof of concept, and deployment/scaling-up.

2.13 Budget summary (To be completed)

FP4: Sustainable Intensification of Maize-based Systems for Better Livelihoods of Smallholders
2.1 Rationale, scope
Strategic efforts to boost maize productivity can increase smallholders’ food and income security, while also improving livelihoods, natural resource integrity, equity, nutrition and health, and resilience against biophysical or socio-economic shocks, all of which are urgent development priorities. Most smallholder maize farmers' livelihoods do not however depend exclusively on maize. Rather, their farming systems are generally characterized by complex strategies that integrate crop and livestock production, often
with increasing reliance on off-farm income, and a strong risk management component that can hamper the adoption of innovations that focus on maize yield alone.

Working in in high-poverty concentration maize-based systems Latin America, East and Southern Africa, and in both subsistence and smallholder market-integrated systems in South Asia, FP4 focuses on sustainable intensification (SI) research. SI encompasses a number of dimensions, including (a) production of more food, feed, fuel and/or fiber per unit of land, labor, and/or capital used, particularly by closing yield gaps and increasing yield per unit of time and area, (b) conservation of critical agroecosystem regulatory and provisioning services, and (c) farming system resilience to shocks and stresses, including those posed by climate change and poorly functioning markets, while (d) seeking to address social justice, gender equity, and youth inclusivity, and human well-being (Loos et al., 2014; Pretty et al., 2011; Vanlauwe et al., 2014; Zurek et al., 2014). Research within FP4 therefore offers the potential to simultaneously address a number of sustainable development objectives, all of which are central to SI. These include eliminating poverty and hunger, improving access to clean water, facilitating responsible production and consumption, addressing climate change, and protection of natural areas from conversion to agricultural use, while reversing land degradation.

Understanding smallholder farmer livelihood strategies (including their human, natural, social, financial, physical capital) and capturing the complexity of maize-based systems (specifically their trajectories in response to external drivers of change such as access to input/output markets, population and land pressure, changing demographic dependency ratios, and climate change) are prerequisite to co-develop technologies and management practices suitable for resource-poor farmers, while adapting and integrating them into smallholders’ diverse farming systems. Through this process, improved agronomic practices and innovations can be brought to scale. Such innovations must be assessed not only on their potential to increase maize productivity, but also in terms of overall farm productivity, profitability, stability and resilience, market risks, nutritional outcomes, as well as the interest and capacity (knowledge, financial) of individual farmers to sustainably adapt and adopt innovations (López-Ridaura et al., 2002; Tittonell et al., 2005). Technical innovations applied to maize also interact with other production units and institutions within smallholder farming systems, especially when resources such as land, labor, and capital are in short supply. While co-developing interventions, it is also important to acknowledge that there is no one-size-fits-all solution to address livelihood constraints. Within smallholder farming communities, different families and family members have varying levels of access to land, labor, and capital resources (Tittonell et al., 2010). Farmers’ production objectives may range from subsistence to commercial, which consequently influences their interest in intensified farming practices.

These tensions and interactions result in tradeoffs or synergies (Tittonell et al., 2015). The overarching hypothesis underlying the research conducted under FP4 is that trade-offs between investments in different fields and crops, crops and livestock, labor allocation alternatives, and between short- and longer-term benefits are to be expected when smallholders adapt and adopt SI approaches, and that in order successfully scale-up SI interventions, these trade-offs must be continuously monitored, minimized, and reflected on in order to simultaneously leverage observed synergies. Improving the livelihoods of a section of society or household should not occur at the cost of another. FP4 embraces this complexity, providing interdisciplinary expertise and analysis that focuses on specific objectives and targets, all of which strongly contribute to the CGIAR Strategic Results Framework, and ultimately to the Sustainable Development Goals of ending poverty, hunger, and gender inequity, while responding to the
call to protect terrestrial ecosystems and biodiversity, through the development of a more sustainable agriculture and improved food and nutrition security.

FP4 is designed around four mutually-reinforcing clusters of activities (CoAs):
4.1 Multi-scale farming system framework to better integrate and enhance adoption of sustainable intensification options;
4.2 Integration of technological and institutional options in rural livelihood systems;
4.3 Multi-criteria evaluation and participatory adaptation of cropping systems;
4.4 Partnership and collaborations models for scaling.

This structure, while similar to the one utilized in the MAIZE-I extension (2015 and 2016), has proven itself efficient to articulate the complex and diverse R4D challenges related to SI research conducted from a systems analytical perspective. As highlighted by the recent external review of MAIZE, this structure provides clear benefits in terms of economies of scale, mobilization of a critical mass of diverse scientific expertise, overall quality and relevance of FP4 research, knowledge and product flows between disciplines, institutions, and geographies of interest. Given the funding characteristics of this flagship (less than 3% funding originating from W1/2 in 2016 and unlikely to dramatically change in the future), it is imperative that this structure assists in the prioritization of limited W1/2 resources to the most strategic components of the flagship to distill and put scientific knowledge into action through W3/bilateral projects.

2.2 Objectives and targets
FP4’s primary outcomes will be measured in MAIZE’s comprehensive Results-Based Management Framework, and include three SRF sub-IDOs: a) more efficient use of inputs, b) yield gaps closed through improved agronomic and animal husbandry practices, and c) agricultural systems diversified and intensified in ways that protect soils and water (detailed below; see section 2.3). FP4 also contributes to the five cross-cutting issues sub-IDOs, namely a) enhanced capacity to deal with climatic risks and extremes, b) improved decision-making capacity of women and young people, c) increased capacity of beneficiaries to adopt research outputs, d) enhanced institutional capacity of partner research organizations, and e) increased capacity for innovations of actors involved in SI. The theory of change underlying FP4 is aligned with the CGIAR SRF, clarifying how the FP’s R&D outcomes contribute through MAIZE’s sub-IDO’s to the reduced poverty, improved food and nutrition security for health, and improved natural resource systems and ecosystems services SLOs. Progress toward the sub-IDOs will be measured and documented through indicators and metrics appropriate to SI goals.

Table 7: Progress Indicators towards sub-IDOs – FP3

<table>
<thead>
<tr>
<th>Sub-IDOs</th>
<th>Nature of FP contribution</th>
<th>Key indicators</th>
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| More efficient use of inputs   | (1) Increased labor use efficiency through scale-appropriate mechanization and integrated weed management.  
(2) Increased water use efficiency in irrigated systems through reduced tillage, crop diversification, and decision support tools for irrigation scheduling  
(3) Efficient precipitation use in rainfed systems through adoption of conservation agriculture (CA)  
(4) Increased nutrient use efficiency through Integrated Soil Fertility | (1) Labor use efficiency (gender and age disaggregated)  
(2) Water productivity at field, farm, landscape levels  
(3) Nutrient use efficiency field, farm, landscape levels  
(4) Land degradation/erosion/soil health indicators at the field, farm, and landscape levels including populations and proxies for critical soil faunal species  
(5) Field and farm productivity (yields, |
Appropriate indicators and metrics for monitoring progress towards the SI of maize-based farming systems is paramount to FP4’s success. FP4 is currently working with the International Institute of Applied Systems Analysis (IIASA) and AfricaRISING to develop a comprehensive SI indicator and monitoring framework. Two broad types of indicators are envisioned, including contextual/informative indicators that will be monitored in alliance with FP1 (e.g., potential envelope for adoption of a particular technology, stability of adoption trends given market and political fluctuations, etc.), and impact indicators that are aligned with validating the MAIZE ToC and with W3 donor requirements (e.g., hectares and farmers utilizing SI approaches, involvement of private sector enterprises, poverty reduction, smallholder access to services, all with an emphasis on understanding why indicators may vary for women and youth). Because FP4’s interventions seek to catalyze change in maize agri-food systems through indirect actors (e.g., the private sector) and processes (e.g., market development, institutional change, capacity development for innovation generation) that may take time to mature, ‘process’ change indicators (farmers’ and the private sector’s awareness of, and demand for SI approaches, progress towards critical levels of adoption to spur spontaneous change, shifts in institutional support, etc., all of which are mapped onto region specific impact pathways) will also be monitored to assess the development of an environment that enables the scaling of SI interventions, as indicated below.
Process indicators will be complemented with multi-criteria SI indicators of relevance to science quality, with emphasis on bridging yield gaps, resource use efficiency, and indicators of beneficial biological and ecological processes at the field level. Moving to the farm and landscape levels, measures of food security, land conversion reduction, land rehabilitation, biodiversity, ecosystem services, and livelihood measures including food security and nutrition, particularly of women and young children, income, investment (land, labor, cash), assets and social networks (capacity) will be included. Lastly, institutional indicators will also be recorded, for example, private sector investment in extension, incorporation of MAIZE technical material into public and private extension systems, university curricula, etc. Large economies of scale and improved M&E&L are expected from more harmonized approaches, better definitions and development of SI indicators and metrics across CG centers, CRPs, and in response to donor requirements (see Table 7). In particular, cost-efficiency will be achieved by utilizing proxy data, creditable inference methods, through use of secondary data (where appropriate), and remote sensing, within the framework under development with IIASA.

2.3 Impact pathway and theory of change

The FP Sustainable Intensification’s theory of change was developed during a workshop with the Flagship Program teams from both MAIZE and WHEAT CRPs. A participatory approach was used to capture all views, experiences and known evidence into the theory of change. The workshop participants were able to increase their understanding of the CGIAR Strategy and Results Framework and awareness of results-based management concepts. The workshop was also structured to encourage sharing and learning on a variety of topics and across both CRPs.

Using the CGIAR Results Framework’s sub-intermediate development outcomes (IDO) the team agreed to focus on three sub-IDOs and five cross-cutting sub-IDOs:

- 1.3.4 More efficient use of inputs;
- 1.4.2 Closed yield gaps through improved agronomic and animal husbandry practices;
- 3.2.2 Agricultural systems diversified and intensified in ways that protect soils and water;
- A.1.4 Enhanced capacity to deal with climatic risks and extremes;
- B.1.3 Improved capacity of women and young people in decision-making;
- C.1.1 increased capacity of beneficiaries to adopt research outputs;
- D.1.1. Enhanced institutional capacity of partner research organizations; and
- D.1.3 Increased capacity for innovation in partner research organizations.
Other sub-IDOs were noted by the team as important to programming given that they overlap with the above sub-IDOs of focus. The team identified several of the cross-cutting sub-IDOs as part of the research and development outcome component of the impact pathway, noting their importance in contributing to the achievement of immediate and intermediate outcomes.

Based on these areas of focus, the team agreed that this Flagship Program contributes to reducing poverty (SLO 1), improving food and nutrition security for health (SLO 2) and improving natural resource system and ecosystem services (SLO 3) by the mean of increasing incomes and employment (IDO 1.3), increasing productivity (IDO 1.4), enhancing benefits from ecosystem goods and services (IDO 3.2) and enhancing the cross-cutting issues of climate change (A), gender and youth (B), policies and institutions (C), and capacity development (D).

A number of research and development outcomes were identified and a pathway of change was created demonstrating the causal relationship between outcomes and sub-IDOs. During this process, partners involved in the pathway of change were identified. Current and proposed interventions and associated outputs to support the achievements of the outcomes were mapped. Assumptions describing the contextual underpinnings of the theory as well as the risks that may have the potential to undermine success were documented.

This theory of change will be the foundation for the monitoring, evaluation and learning plan. The monitoring plan will consist of a continuous process of collection and analysis of data based on a set of indicators directly related to the performance of the CRP at the output and outcome levels; the key assumptions of the theories of change; and the critical risks. The theory of change will also be the basis for evaluating the Flagship Program as well as reflecting on lessons and program improvements.
Figure 8: Theory of Change for MAIZE FP4

SLOs

1. Reduced Poverty

2. Improved food and nutrition security for health

3. Improved natural resource system and ecosystem services

IDOs

1.3 Increased incomes and employment

1.4 Increased productivity

3.2 Enhanced benefits from ecosystem goods and services

Sub-IDOs

1.3.4 More efficient use of inputs

1.4.2 Closed yield gaps through improved agronomic and animal husbandry practices

3.2.2 Agricultural systems diversified and intensified in ways that protect soils and water

Cross-cutting Sub-IDO – A.1.4 Enhanced capacity to deal with climatic risks and extremes

4.10 Smallholder farmers adopted and adapted SI practices and products

4.9 Smallholder farmers increased their capacity to adopt and adapt SI practices and products (associated with crosscutting sub-IDO)

Cross-cutting Sub-IDO – C.1.1 Increased capacity of beneficiaries (i.e., smallholder farmers) to adopt research outputs

R&D Outcomes

4.6 Private sector (and public sector) increased provision of services to smallholder farmers to increased their ability to adopt SI practices and products

4.2 Donors, policy-makers (local, regional and national), advocacy NGOs and private sector increased investment and improved enabling environment for adoption of SI practices and products

4.7 Actors in SI increased participation in feedback loops via monitoring, evaluation and sharing of lessons learned

4.8 Actors in SI increased consideration and integration of gender and social inclusion into policies, processes and practices

4.5 Universities increased integration of SI principles into educational programs and research

4.4 NARS increased use of participatory approach in system research

4.3 Local and regional actors (NGOs, farmer groups, extension agents, private sector) increased promotion of SI practices and products

FP3 Theory of Change
### Assumptions and Risks

<table>
<thead>
<tr>
<th>Assumptions and Risks</th>
<th>Interventions and Outputs</th>
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<tbody>
<tr>
<td><strong>A</strong></td>
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<tr>
<td>- SI practices and products are adaptable to other environment and systems.</td>
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<tr>
<td>- Smallholder farmers see benefits and are able to adopt/adapt SI practices and products</td>
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<td><strong>B</strong></td>
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<tr>
<td>- Smallholder farmers see value in achieving more efficient use of inputs, closing yield gap, and diversifying and intensifying agricultural systems</td>
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<tr>
<td>- Smallholder farmers are aware and have access to SI practices and products</td>
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<td><strong>C</strong></td>
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<tr>
<td>- Actors in SI are willing and able to participate in research, capacity building and/or improving the enabling environment for adoption of SI practices and products</td>
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<td>- Alignment of common interest among actor in SI</td>
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<td>- Actors in SI act to contribute to gender responsiveness and social inclusion</td>
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<td><strong>D</strong></td>
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<tr>
<td>- Private sector recognize the importance of SI practices and products</td>
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<td>- Risks: business interest negatively effects the adoption of SI practices and products; potential for emergence of ethical issues</td>
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<tr>
<td>- Donors, policy-makers, advocacy NGOs and private sector have interest and power to share the enabling environment</td>
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<tr>
<td>- Risk: Frequent conflicting and competing priorities negatively effects the research in and adoption of SI practices and products</td>
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<td><strong>F</strong></td>
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<tr>
<td>- Co-research processes lead to integration of SI principles into educational programs and research</td>
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<td><strong>G</strong></td>
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<td>- CRP has understanding of the institutional landscape and has the means to influence it</td>
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<td><strong>H</strong></td>
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<td>- Actors in SI are reached, the right message is delivered and understood</td>
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<td>- Existence of need and incentive for intensification</td>
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<td>- SI practices and products address locally important challenges and opportunities</td>
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<tr>
<td>- Organization sufficiently recognizes or incentives the importance of networking, communicating, knowledge sharing, innovation, necessity of rebranding and critical thinking</td>
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### Interventions and Outputs

- **Research:**
  - Technological options for sustainable intensification of cropping systems
  - Sustainable farming systems and livelihood intensification strategies
  - Enabling policies and sustainable intensification landscape
  - **Outputs:** technologies, policies, decision support tools, extension programs, publications

- **Develop and implement communication and marketing strategy**
  - **Outputs:** Communication and marketing strategy

- **Develop and implement a partnership/networking strategy**
  - **Outputs:** Partnership/networking strategy

- **Provide training (on the job, workshops, short and long term training)**
- **Arrange exchange visits**
- **Brokering (management and dissemination) of knowledge (to all partners)**
- **Contribution to the development of decision support materials**
- **Contribute to business promotional materials**
- **Business model development**
  - **Outputs:** training material, promotional products, decision support tools, communication products

- **Creating of innovation platforms**
- **Gender and social inclusion analysis and identification of appropriate interventions**
- **Gender and social inclusion sensibilization workshops**
  - **Outputs:** innovative platforms, gender responsive and socially inclusive interventions, gender and...
2.4 Science quality

FP4 builds on a solid scientific foundation from MAIZE Phase-1. The peer-reviewed publication list from the lead-CGIAR team (CIMMYT SIP and SEP programs under MAIZE, WHEAT and CCAFS) during 2012-Jan2016 period is given below. It comprises 195 publications (many in journals having an impact factor above 2), and a number of additional high-impact journals in which one publication was logged, for example *PNAS* and *Energy* (9.674 and 4.844, respectively). A large majority of these publications are co-authored by CGIAR colleagues and collaborating scientists from ARIs and NARS. The contribution of HT scientists to Phase II will further strengthen the scientific team involved in FP4.

Journals in which the SI team has published more than twice since January 2012 (representing only 59% of all publications registered).

<table>
<thead>
<tr>
<th>Journal</th>
<th>Number of pubs (co-)authored by SI group</th>
<th>Journal H-index</th>
<th>Impact Factor (2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Crops Research</td>
<td>35</td>
<td>89</td>
<td>2.976</td>
</tr>
<tr>
<td>Agriculture, Ecosystems &amp; Environment</td>
<td>14</td>
<td>67</td>
<td>2.906</td>
</tr>
<tr>
<td>Agricultural Systems</td>
<td>13</td>
<td>110</td>
<td>3.402</td>
</tr>
<tr>
<td>Soil and Tillage Research</td>
<td>9</td>
<td>84</td>
<td>2.622</td>
</tr>
<tr>
<td>Crop Protection</td>
<td>6</td>
<td>67</td>
<td>1.493</td>
</tr>
<tr>
<td>Food Security</td>
<td>6</td>
<td>13</td>
<td>1.495</td>
</tr>
<tr>
<td>Experimental Agriculture</td>
<td>6</td>
<td>28</td>
<td>1.079</td>
</tr>
<tr>
<td>Food Policy</td>
<td>4</td>
<td>55</td>
<td>1.192</td>
</tr>
<tr>
<td>International Journal of Ag. Sustainability</td>
<td>4</td>
<td>15</td>
<td>1.659</td>
</tr>
<tr>
<td>Renewable Agriculture and Food Systems</td>
<td>4</td>
<td>29</td>
<td>1.355</td>
</tr>
<tr>
<td>Advances in Agronomy</td>
<td>3</td>
<td>74</td>
<td>3.893</td>
</tr>
<tr>
<td>Agricultural Water Management</td>
<td>3</td>
<td>70</td>
<td>2.286</td>
</tr>
<tr>
<td>Crop Science</td>
<td>3</td>
<td>100</td>
<td>1.575</td>
</tr>
<tr>
<td>Journal of Agricultural Economics</td>
<td>3</td>
<td>36</td>
<td>1.278</td>
</tr>
<tr>
<td>Nature Climate Change</td>
<td>3</td>
<td>50</td>
<td>14.547</td>
</tr>
</tbody>
</table>

There is a clear evolution regarding the scope of SI publications. In the early CRP-I period, focus was placed primarily on field level research. But since then, the publication portfolio has evolved to a more balanced one including increasingly SI oriented systems research at the farm/landscape level, utilizing multi-criteria analyses, modeling, and the stronger application of systems oriented methodological approaches to addresses the complexity of SI challenges (as seen from the number of papers in *Agricultural Systems* and *Agriculture, Ecosystems, and Environment*). Lessons learned in Phase-I indicated that interdisciplinary collaboration sheds light on the key factors limiting the successes of SI interventions, while also highlighting new opportunities for research and development to overcome them. To this end, the FP4 SI team is comprised of a mix of soil scientists, systems agronomists, farming
systems analysts, and researchers involved in innovation systems and adoption research. By CoA, key research themes in include:

**CoA 4.1:** Dealing with farming systems complexity (without being lost in it) is major challenge of this flagship. It therefore must be supported by quality and relevant systems research. This challenge cannot be addressed by CGIAR expertise alone; rather, our approach relies on strong collaboration with key ARIs (see partnership section). Major research foci will be developed on:

- Clear articulation between FP1 and FP4 on down- and up-scaling information from global to landscape and farm levels (and back) for better identification and targeting of site/farm specific intensification options combining social, economic, agroecological criteria (relying on data science, data fusion, remote sensing, and modeling), and making greater use of field level agronomy data through contextual and geospatial analyses
- Development of SI indicators and metrics and various scales/levels. Feasibility and cost/benefit of such baseline studies and indicator will also to be realistically assessed in the first year of Phase-II.
- Systems-oriented research has been critiqued as more of an academic exercise than a guiding tool for development. This CoA purposefully breaks with this trend by utilizing systems analytical tools to generate actionable information to be fed into scaling efforts through CoAs 4.2 and 4.4.

**CoA 4.2:** Bringing SI to fruition requires research into the efficacy and efficiency of different multi-stakeholder participation modalities in the identification, experimentation with, and evaluation of socio-technical options (that is, technologies and/or new institutional arrangements). This CoA integrates insights generated by ex-ante studies (CoA 1.4), multi-scale farming systems research (CoA 4.1) and multi-criteria cropping systems research (CoA 4.3) on the integration of socio-technical options for SI. It focuses on the incentives/drivers of such integration through research on:

- Understanding agricultural innovation systems and, particularly, the role of multi-stakeholder interaction mechanisms – notably Innovation Platforms – in generating socio-technical options for sustainable intensification. What makes them success or fail?
- Understanding farmers’ and other stakeholders’ decision-making processes on the integration of socio-technical options, in the context of diverse rural cultural and livelihood systems
- Understanding the impact of different socio-technical options from the farm to institutional scale.

**CoA 4.3.** This CoA aims to reduce yield gaps while improving the efficiency of crop production by harnessing ecosystem services and limiting environmental externalities. Key research themes include:

- How do cropping systems perform when subjected to multi-criteria evaluation of their agronomic and economic productivity/efficiency, environmental impact and sociocultural appropriateness? How can they be improved?
- How can nutrient use efficiency be improved in the context of smallholder agriculture? How can ecosystem services be leveraged to build soil quality while reducing GHG emissions?
- How do the genotype products of FP3 perform in the context of smallholders’ diverse management strategies, as assessed through networks of G × E × M trials?
- How can rainwater use efficiency be improved using appropriate species and methods for dead and live mulching, and timing and method of sowing, in combination with CA? How can irrigation be made more efficient through targeting and scheduling using remote sensing tools?
- What are the benefits biologically diverse maize-based rotations for smallholders? What options reliably boost cropping intensity and contribute to high yields and profits unit area⁻¹ time⁻¹?
What role do relay and intercrops with nutritious leafy vegetables and dual-purpose legumes have in the context of increasingly land-scarce smallholder agriculture?

- How can farm machinery be made more energy efficient and appropriate for smallholders?
- Can an understanding of the ecological structure and dynamics of weed communities in maize-based cropping systems and landscapes improve integrated weed management efforts? How can environmentally sensitive and labor saving weed management practices be fine-tuned?

CoA 4.4: This CoA addresses key research themes related to scaling up the products the other CoAs, by focusing on the following meta-questions:

- What factors, including modes of brokerage and facilitation, enable successes in scaling-up? What are the drivers and determinants of scaling up? What are the impact, obstacles, opportunities and critical success factors?
- How effective and efficient are the business models of rural enterprises in providing supporting goods and services that foster adoption, adaptation and scaling-up of improved technologies?
- What kind of support services, capacities, policies, and modes of delivery are needed to link farmers to input-output markets that have the strongest links to, and ability to influence the maize agri-food system?
- What are the most suitable business models that strengthen the ability of poor women farmers and youth to access and benefit supporting goods and services provided by SMES?
- How does do public sector extension, private sector partnerships, ICT approaches, etc. compare in different country contexts? What are the costs and benefits of different scaling modalities?
- What should be the role of the public/private/NGO sectors in providing market-oriented services to smallholder farmers? How inclusive are these services with consideration to women and youth in particular?

2.5 Lessons learnt and unintended consequences

Multi-scale farming system framework to better integrate and enhance adoption of sustainable intensification options: a) smallholder farming systems and communities are diverse and that diversity strongly impacts the adoptability of SI interventions in maize-based systems. ‘One-size-fits-all’ or silver bullet solutions are not viable (Baudron et al., 2014b; Valbuena et al., 2012; Vanlauwe et al., 2007), b) tools and methods for better targeting are needed, as are clear metrics to understand the contribution of interventions smallholders’ livelihoods (Frelat et al., 2016), c) despite noticeable research achievements over the last 20 years, there is still need for better understanding smallholder farming systems, their diversity and trajectories (which drive adoption of SI interventions), and the possible feedback mechanisms between farming systems and their operating landscapes, and d) the development of guidelines for complex knowledge sharing and dissemination is crucial to engage stakeholders in developing and implementing SI interventions (Andersson and D’Souza, 2014).

Integration of technological and institutional options in rural livelihood systems: a) limits of participatory approaches in terms of their scalability and that solely on-farm testing of SI interventions, b) there is poor understanding of the efficacy and efficiency of innovation platforms and systems in terms of scaling SI interventions, and that more research is needed on the principles and dynamics of locally embedded and sustainable innovations systems, and d) the low success of ICT4Ag interventions requires rethinking. ICT tools that are not designed around clear end-user needs are likely to fail. Rather, collaboratively developed tools may hold greater promise, but this calls for new modes of engaging farmers as technical partners.
Multi-criteria evaluation and participatory adaptation of cropping systems: a) the fact that plot-level or single-criteria (e.g., yield or cost-benefit alone) assessment of SI interventions, while intrinsically important, do not provide comprehensive or robust assessment. Understanding farmers’ perceptions, farmer diversity, and farm-level trade-offs and synergies with cropping system technologies and management approaches is essential, and can be evaluated through multi-criteria and multivariate assessment of agronomic, economic, social, and environmental data, b) efforts to reconcile nutrient and water use efficiency with high-yielding production should be matched with \( G \times E \times M \) assessments, through modeling efforts, and c) significant opportunity exists to harness ecosystem services to contribute to more stable and resilient cropping systems.

Partnership and collaborations models for scaling: During Maize Phase-1, improved germplasm and technologies for sustainable intensification and value chain options have been deployed in SSA, LAC and SA through an array of key projects such as DTMA, CSISA, MasAgro, FACASI, SIMLESA, WEMA and IMIC-Asia. Deployment of germplasm and SI technologies, was achieved through innovation platforms, farmer organizations, public-private partnerships and public sector extension. Private sector partnership was found to be crucial in South Asia in particular, with evidence of over $1 million of private investment to make scale-appropriate farm machinery available to smallholders. Experience and lessons from Phase 1 suggest that this CoA should focus on the processes that help create a favorable environment R4D that enables scaling and innovation, building on information (multi-scale framework), opportunities (participatory testing cropping system technologies) and incentives (integration technological and institutional options), as outlined earlier. This CoA will have clear actionable outcomes as well as a strong research agenda that primarily focuses at higher-level institutional and partnership interactions beyond the farmer alone, by increasing the capacity of actors (ToC ID O.1.1) and institutions (ToC ID O.1.3) involved in R4D (i.e. the pre-requisites for enabling sustained innovation).

General lessons also from Phase-I highlight the need to understand and address the social context in which agriculture takes place, especially its gender and youth dimensions, and the implications hereof for research and development interventions (Beuchelt and Badstue, 2013; Farnworth et al., 2015). Lack of opportunity and resources, rigid social norms and traditions, power relations, assumptions and domestic and caring responsibilities are factors that can limit especially women’s and youth’s abilities to engage with new opportunities for agricultural innovation (van Eerdewijk and Danielsen, 2015).

Additional lessons learnt from other CRPs (WHEAT, DS, HT, RTB, CCAFS) are presently actively shared across and MAIZE CRP (amongst others) has earmarked 2016 budget to distill those lessons, to identify/consolidate legacy products, and review benchmark sites integration. This constitutes a promising first step to an active ‘community of practices’ across CRPs on farming systems research, something that was certainly weak during CRP Phase I.

2.6 Clusters of activity (CoA)

Moving SI from science into action and impact is a complicated process that requires navigation of both biophysical and socioeconomic research agendas. For this reason, FP4 consists of four Clusters of Activity (CoA), each led by scientists competent in their respective CoAs, and established interdisciplinary collaborative relationships. This structure reduces the risk of SI research becoming a purely biophysical or agronomic endeavor, while drawing on the unique skills of the FP4 team in their respective disciplines through integrated systems analytical approaches. While CoA 4.1 provides a farming system analytical framework to prioritize constraints and interventions towards the SI of maize-based farming systems, and CoA 4.3 evaluates such targeted interventions, using multiple tools and
criteria, CoA 4.2 provides the necessary decisions support tools and institutional environment to ensure that validated interventions provide livelihood and landscape benefits derived from SI. CoA 4.4 then provides innovative models for scaling products and outcomes from CoA 4.2 to considerable farming populations and maize-based areas.

The above four CoAs are tightly interlinked by integration of knowledge and feedback loops for methodological improvement (e.g. 4.1 will integrate information on agronomic performance from 4.3 into systems analysis and will, in return, provide targeting and prioritization guidelines for cropping systems scale research in specific agro-ecologies through 4.3). CoA 4.1 will interact with CoA 1.1 by using meta-level targeting information and will provide feedback for systems analysis information, CoA 4.2 will institutional landscape insights to leverage scaling research and interventions under CoA 4.4. CoA 1.4, which monitors adoption figures and process indicators will receive feedback for methodological improvement and design, feeding back into FP4’s Monitoring Framework for SI. Finally, CoA 4.3 will use promising germplasm for targeted environments and cropping systems from CoA 3.1 and provide feedback on their performance considering G × E × M analyses (Herrera et al., 2013).

Figure 9. Articulation of FP4 CoAs and knowledge/product flows and feedback loops between FPs/CoAs. CoA 4.1 and 4.3 provide targeting information on and cropping systems opportunities, respectively, and operate at different analytical scales (region, landscape, farm, and field), while integrating research from CoAs 1.1 and 3.1. CoA 4.2 operates as the central node by which farmer decision-making and instructional incentives can be assessed, providing feedback loops to CoA 1.4. This results in the
identification of scalable research products and technologies that are extended through research results that inform scaling processes in CoA 4.4.

**CoA 4.1 Multi-scale farming system framework to better integrate and enhance adoption of sustainable intensification options**

CoA 4.1 provides an overarching methodological and farming systems analytical and operational framework to guide the targeting of technical as well as institutional interventions for SI (what, where, for whom and how) (Baudron et al., 2014a; Delmotte et al., 2016; Giller et al., 2010). This takes into account the specific environmental and socio-economic contexts, household resource endowments and production objectives, as well as the most limiting production factors (land, labor, nutrient, water, finance) at the farm/household and landscape scale and aims at identifying interventions for farming households and communities to move towards SI, based on the principles of maximizing resource use efficiencies, minimizing trade-offs between productivity and natural resource integrity, and integrating diversity at farm and community scale. The analytical framework will allow understanding and prioritizing actual and potential demand for SI options across geographies with contrasting socio-economic and biophysical environments and within geographies according to farm household characteristics, assets and objectives.

The overall goal of this CoA is to provide tools and approaches for the spatially explicit assessment of SI options at different scales to (i) allow more effective delineation of extrapolation domains across geographies and for impact assessment (van Bussel et al., 2015; van Wart et al., 2013) underpinned by the agro-ecological spatial framework from the Global Yield Gap Atlas, (GYGA, www.yieldgap.org), (ii) better target SI option within geographies by capturing the spatial variability and processes relevant to the performance and adoption/adaptation of SI option by farm households and local actors, and (iii) underpin responsible scaling strategies, thereby recognizing that assets and objectives vary between households within a community and between communities within a landscape and that livelihood improvements of one household or community should not result in declining livelihoods for others.

This CoA will deliver the following outputs:
(1) Participatory and multivariate approaches for categorizing farming communities in functional or structural farmer typologies, including their trajectories in time and distribution in space;
(2) The analysis of large data sets including geo-spatial, remote sensing and climate models and their analysis through data mining techniques to quantify basic metrics to support targeting SI options;
(3) Farm level system analytical tools and participatory approaches for targeting interventions within heterogeneous farms, recognizing farmers resources and production objectives, as well as identifying and analyzing trade-offs and synergies among SI options and criteria for assessment of SI options;
(4) Modeling tools and metrics to understand the variability of farming systems, landscapes and SI options and their performance under multiple criteria; and
(5) Landscape level analysis of SI options and their effect on local food security, resource conservation and ecosystems services.)

All the above will be supported by common economic and efficiency analyses and more innovative metrics to assess the performance and livelihood dimensions of farming systems such as nutritional aspects of sustainable intensification options, landscape functions and ecosystem services.
CoA 4.2 Participatory approach to adapt and integrate technological components

As an enabling institutional context is a necessary condition for agricultural change (Hounkonnou et al., 2012), this CoA aims to understand the incentives and decision-making processes at the farm and institutional landscape scale that drive the integration of SI technologies in diverse rural livelihood systems. The combined technology and institutional environment focus of CoA 4.2 builds on previous research, which revealed that plot-level assessments of SI technologies, while intrinsically important, are not enough to sustain change. Institutional constraints shape the applicability of SI technologies (Andersson and D’Souza, 2014; Schut et al., 2015). They therefore constitute prerequisite conditions for smallholder farmers’ integration of new technologies into their livelihoods (Giller et al., 2015; Sumberg, 2005).

The main goal of the CoA is to better understand why so few ‘proven’ technologies have gone to scale, and to find solutions to improve their adoption. Focusing on technology and the institutional arrangements required for smallholder integration, it develops and implements methodologies to locate and evaluate SI technologies within the context of institutional arrangements, together with farmers and other stakeholders in targeted MAIZE geographies. CoA 4.2 seeks to identify scalable products – combinations of SI technologies, decision-support tools and (complementary) new institutional arrangements beyond the CRP’s research sites, through different scaling modalities as studied and developed in CoA 4.4.

In conjunction with the CRP Roots, Tuber and Bananas (notably CoA 5.4 of this CRP), and building on agricultural systems research within CRP-phase I MAIZE and the systems-focused CRP Humid Tropics, CoA 4.2., will develop analytical frameworks, methodologies and tools including:

1. Tools and methods for the assessment of agricultural (innovation) systems for SI within multi-stakeholder configurations through Rapid Assessment of Agricultural Innovation Systems (RAAIS) tools (Schut et al., 2015, 2014) and the design and implementation of new institutional arrangements and experiments with agricultural system stakeholders;

2. (ICT-based) decision-support tools for farmers, service providers and development actors, embedding advances in ICT and remote sensing tools, appropriate data formats, information provision channels, and data consolidation;

3. New quantitative and qualitative methods for the assessment of the (uneven) integration of socio-technical SI options into diverse livelihood systems (addressing inequality effects), thereby acknowledging that agricultural change is an assembly of both socio-institutional and technical components, and that adoption is not a linear process in both spatial and temporal terms, (Sumberg et al. forthcoming); and

4. Mixed method approaches for the multi-scale assessment of SI options at farm and landscape levels, building on a combination of remote sensing, survey/panel, and qualitative data CoA 4.2.

CoA 4.3 Development and field testing of crop management technologies

This CoA provides proof of concepts, know-how, and knowledge of cropping systems interventions that reduce yield gaps and that are suitable for the agro-ecological systems in which MAIZE works. The core hypothesis underlying SI is that productivity can be increased while reducing environmental externalities and smallholder poverty (Godfray et al., 2010; Pretty and Bharucha, 2014). Maize is a potentially high-yielding and nutrient demanding crop; enhancing N use efficiency is a critical goal for (a) reducing yield gaps (b) limiting greenhouse gas (GHG) emissions and water pollution, and (c) raising farm incomes by eliminating wasteful practices (Zhang et al., 2015). Dwindling freshwater supplies underscore the need
to develop more water use efficient cropping systems, particularly in South Asia’s irrigated environments, while the unreliability of precipitation in SSA has focused attention on enhancing rainwater use efficiency (De Fraiture and Wichelns, 2010; Rijsberman, 2006). Farm productivity in Latin America, South Asia, and SSA is limited by the availability of farm power, and increasingly high labor costs and scarcity, especially as rural out-migration increases (Baudron et al., 2015; Mottaleb and Krupnik, 2015). The resulting feminization of agriculture, particularly in population dense South Asia, is a concern for long-term farm productivity (Justice and Biggs, 2013). Research also increasingly focuses on the need for farmers to both harness and contribute to the flow of ecosystem services to maintain stable and resilient cropping systems, though serious efforts are needed to realize these goals in the context of smallholder, resource poor farming (cf. Pretty and Bharucha, 2014). CoA 4.3 builds on the extensive knowledge already generated by IITA, CIMMYT in systems agronomy, including integrated soil fertility management (ISFM), conservation and precision agriculture, appropriate mechanization, integrated weed management, soil ecology, and $G \times E \times M$ analysis.

CoA 4.3’s goal is the development, evaluation, adaptation, and refinement of promising cropping systems, crop management methods, and technologies that can be readily and easily implemented by smallholders. The CoA also aims to provide actionable recommendations for smallholders with different investment capacities and levels of risk aversion as collaboratively identified with CoA 4.1 and 4.2. Research focuses on multi-criteria evaluation of cropping systems and technologies, and farmer participatory adaptation of systems management options that improve productivity, resource use efficiency, profitability, and yield stability and/or resilience, with a focus on harnessing ecosystem services while limiting environmental externalities.

CoA 4.3 will deliver the following outputs:

1. Multi-criteria agronomic and environmental assessments and participatory adaptation of cropping systems, with emphasis on assuring that resulting data are discoverable and accessible for partners and other researchers. This research theme uses long-term trials and networks of on-farm observational studies that assess trade-offs and synergies between agronomic, socioeconomic, and environmental criteria. Such multi-criteria approaches and are important for targeting SI interventions (Gathala et al., 2016), while minimum dataset standards are increasingly called for when assessing SI (Brouder and Gomez-Macpherson, 2014). Life cycle analysis (LCA) can contribute to these goals, with particular relevance for work with CCAFS in South Asia to reduce GHGs. Key research products will therefore include tools and minimum data guides for multi-criteria and LCA assessments developed cooperatively with NARES and CCAFS, decision support tools that provide input on trade-offs between production and environmental goals while generating recommendations for sound alternatives. Additional products will be the supply of comprehensive and publically available datasets for additional research and interpretation, using systems such as DataVerse (http://data.cimmyt.org/dvn/) that are currently under refinement.

2. Innovative tools, methods, and multi-media extension materials appropriate for smallholder farmers to enhance soil quality, nutrient, and water use efficiency using integrated soil fertility management, biologically diverse rotations, and tillage practices that enhance nutrient cycling. Additional science outputs will include cost-effective methods for monitoring and conserving critical soil ecosystem service providing indicator species.

3. Feedback to FP3 regarding the performance of, and farmers’ preferences for, new stress tolerant maize genotypes when placed in the context of smallholders’ diverse production environments and
management practices, with emphasis on the use of germplasm and management to improve both rain and irrigation water use efficiency.

(4) Decision support tools for precise maize nutrient management, and irrigation scheduling and targeting, using remote sensing and geospatial frameworks. Research products to support this goal include studies into the scientific basis of attainable yield targets, water and nutrient requirements under different production systems, management practices and ecologies, and how this informs decision support tool and precision sensor development under different rotational and tillage practices.

(5) With NARES, the deployment of recommendations and extension materials for best-bet biologically diverse and intensive crop rotations and intercropping practices, the latter emphasizing nutritious leafy vegetable and dual-purpose legume relay and intercrops, using methods adapted with smallholders and to their resource constrained circumstances.

(4) Advanced knowledge products regarding the ways in which crop management and environmental factors interact to structure weed species community diversity and competition in maize-based systems. Such knowledge will aid in developing improved integrated weed management (IWM) practices that decrease farmers’ drudgery, particularly for women. IWM methods are likely to include dust, live, and dead mulching with CA practices, weed suppressive inter-cropping and rotational systems, and low-environmental impact herbicides.

(5) Improved planting, intercultural operation, and irrigation machineries for maize that are appropriate for the smallholders’ small and fragmented fields. In Phase-I, significant advances in two-wheel tractor (2WT) based CA and irrigation equipment were made, with the development viable zero-till maize planters, and the private sector uptake and commercial deployment of fuel-efficient axial flow pumps (which can be hitched to 2WT engines) in South Asia, from which farmers on over 40,000 ha now benefit. Such machinery will be refined to suit farmers in marginal and environments, including those with stony soils, high-residue conditions, and where water availability and access is temporally dynamic.

CoA 4.4: Partnership and collaborations models for scaling

Systematic research in the areas of evaluating alternative dissemination and scaling up models, and designing institutional innovations that achieve equitable outcomes is virtually non-existent. While this represents an enormous opportunity for the work of CRP Maize, it also creates the challenge of developing new research methodologies to support this work. Inherent in this type of work there will be the need to combine quantitative approaches with qualitative methods and more process-oriented, action research approaches where systematic monitoring is key to evaluating performance and outcomes. MAIZE will draw upon existing collaborations with KIT and with the expertise gained from Humid Systems. This CoA focusses on research questions relating to enabling the scaling-up and out of technologies and crop management practices to support SI: 1) how to strengthen and improve business models for small and medium enterprises (SMEs), especially for seed and scale-appropriate mechanization servicers, 2) how to increase the effectiveness of partnerships needed to scale up and out, and (iii) how to assess the ways in which institutions and actors decide to pursue innovation, while using research results to build capacity in this key area. Feedback and integration of research results to CoA 4.2 through collaborative learning processes will contribute towards a deeper understanding of how to develop and seed and sustainable intensification technologies by MAIZE.
The main goal of this CoA is to develop and validate scaling models that will facilitate the uptake of SI interventions, including the creation of enabling conditions. Research on how to incentivize and improve the effectiveness of SMEs is limited, despite the increasing emphasis placed on this sector by R4D. Research will provide new insights into the role of SMEs at local level in supporting and scaling-out SI technologies. Business model development through SME’s will focus on the relationship between upstream stakeholders in the value chain and smallholder farmers. Partnerships and collaboration will be developed with downstream value chain actors - private sector companies involved in the provision of seeds, appropriate inputs, and machinery and implements, and public sector extension services. For scaling-up to be successful, the different actors and institutions that contribute to innovation need to possess the capacity to effectively do so. The capacity to innovate can be developed through (i) upgrading the skills, expertise, competencies and confidence of individual actors, with emphasis on leveraging women and youth, (ii) improving the structure, processes and incentives within organizations, businesses and stakeholder groups, and (iii) creating an environment in which actors actively interact, exchange new ideas and expertise, and collaborate.

This CoA will deliver the following outputs:

(1) Business model development for the provision of goods and services in support of smallholder intensification, including conducting business model appraisals of small and medium scale local enterprises, strengthening the relations between appropriate scale mechanization supply chain actors, developing linkages with financial service providers and extension services (public/private) to de-risk and enable smallholders to invest in the above options, organization of farmers with emphasis on youth and women, and evaluating the performance and impact of different business models in providing goods and services.

(2) Partnership and collaboration in support of scaling sustainable intensification technologies and practices, including developing public-private partnerships with corporate level seed companies, agro-dealers and mechanization, conducting negotiations and developing partnership agreements with agro-input companies and importers and manufacturers of machinery and implements, facilitating linkages between farmer organizations and input and output market actors and financial institutions, developing collaborative arrangements with public and private sector advisory service providers, developing new ICT tools for the scaling of technologies, and utilizing mass media to facilitate the adoption process.

(3) Developing the capacity to innovate among multiple stakeholders, including establishing and strengthening innovation platforms/hubs for the horizontal scaling-out of technologies and feedback mechanism to research, establishment of meso- and central level platforms for advocacy among policy makers and development organizations, strengthening the capacity of farmer organizations to link with value chain stakeholders, awareness raising and technical support to extension services, national research organizations and NGOs, training and mentoring of trainers, farmer organizations, private sector actors and service providers, and formulation and advocacy of policy options to address institutional constraints on the adoption/adaptation of SI based technologies.

2.7 Partnerships

In addition to the long history of fruitful collaboration with NARS in all the countries where we work, under MAIZE Phase-I, a large number of strategic partnerships were initiated with world leading universities and advanced research institutions worldwide to help the CRP to tackle the most challenging methodological and research issues related to SI. For example, in CoA 4.1, a close collaboration has evolved with Wageningen UR in the domain of systems analysis, especially in the area of synergies,
trade-off analysis, and targeting of SI interventions. In the case of CoA 4.2, MAIZE has teamed up with the Royal Tropical Institute (KIT) to expand expertise in Agricultural Innovation Systems and gender and development research capacity. KIT is working closely with MAIZE to improve the efficiency and effectiveness of our Innovation Platforms and as a sounding board for our investments in gender. In CoA 4.3, MAIZE works with a number of world leading partners to take technology break-through innovations in remote sensing (University of Twente, Holland, and University of Cordoba, Spain), geospatial science [Oak Ridge National Laboratory (ORNL), USA; University of Nebraska, USA], and mechanization (Georgia Tech University, USA; Charles Sturt University, Australia). MAIZE also has a large number of inter-CRP and inter-CG center collaborations through various W3/bilateral projects, as well as private sector collaborations that have proven crucial for scaling-up and -out research results.

Scaling-out partnerships in ESA have to date been project-orientated rather than strategic. For technology and knowledge transfer we have worked with and through NARES for scaling, most commonly using Innovation Platforms (e.g. the SIMLESA model with NARS throughout ESA) or directly with NGOs on specific technologies (e.g. TLC in Malawi, Mozambique and Zambia; SG2000 in Ethiopia). We also work with the private sector on seeds and small mechanization, and scaling focuses on direct partnerships with many SMEs (e.g. Alliance Ginneries in Zimbabwe, Meru Seeds in Tanzania) and some parastatals (e.g. METEC in Ethiopia, CARMARTEC in Tanzania) to develop business models and improve the enabling environment. We also work with NARS and regional organizations such as ASARECA in ESA to influence policy, resulting for example in the recent Entebbe declaration on sustainable intensification, and participate in national CA-task forces (e.g. in Ethiopia and Zimbabwe). In Phase 2 our strategy in ESA will be to more purposefully engage with the bigger development organizations (e.g. Norwegian Government CA programs in Ethiopia and Zambia), NGOs (e.g. CARE in Zimbabwe, One Acre Fund in Kenya, Tanzania and Rwanda), and national farmer organizations (e.g. NASFAM in Malawi) to credibly demonstrate the technologies we have available and to support their scaling through knowledge products and capacity development of users.

2.8 Climate change

MAIZE FP4 with its focus on systems approaches to developing socially equitable SI-based best practices provides a natural home for climate smart agriculture (CSA) and will generate the scientific evidence needed to inform decisions regarding which CSA practices in maize systems are suitable, for who and where? Working closely with MAIZE FP1 and CCAFS, the evidence produced by this flagship will be used to model future climate effects on production, together with synergies and trade-offs, to identify target adaptation domains with potential mitigation co-benefits that will inform how CSA is integrated into strategies and plans at the regional, national and local levels. More specifically, MAIZE FP4 will work closely with CCAFS around research activities related to: a) participatory evaluation of MAIZE technologies and practices in climate smart villages (CSVs) and other sites where appropriate, b) improved resource use efficiency, particularly nitrogen and water, and impacts of GHG emissions, c) evaluation of the C sequestration potential of SI interventions (Dendooven et al., 2014; Govaerts et al., 2009; Powlson et al., 2016, 2014), d) creation of minimum datasets for climate-smart technologies, all aligned with CoA 4.3.

This work will leverage MAIZE and CCAFS climate projections, farm typologies, and farming system models to support the evaluation of technologies in terms of enhanced resilience to climate variability and extremes (drought, floods, and high temperatures), mitigation of GHG emissions and associated costs at the landscape and regional scale, with support from CoA 4.1. Through CSVs and other CCAFS
research, MAIZE will gain access to important climate-related actors in both the public and private sectors, which will be evaluated for scaling leverage potential in CoA 4.2. MAIZE FP4 will also integrate with CCAFS in terms of data: (a) the generation of multi-criteria minimum datasets for maize-based systems and standardized methods and metrics to quantify climate smart agricultural technologies and practices over a range of scales and (b) to build a community of practice around climate resilient GxExM technologies and improved cropping system models that better characterize the effects of climate extremes on maize-based systems in terms of yield performance, resource use, GHG emissions, synergies and trade-offs (including costs). The GYGA spatial framework will provide a means to explicitly evaluate climate smart options in both current and future climates.

2.9 Gender
Lessons from Phase-I highlight the need to understand and address the socio-agro-ecological landscape in which maize based farming systems and sub-systems are embedded, especially its gender and youth dimensions within these, and the implications hereof for research and development interventions (Beuchelt and Badstue 2013; Badstue et al. 2015; Farnworth et al. 2015). Lack of opportunity and resources, rigid social norms and traditions, power relations, assumptions and domestic and caring responsibilities are factors that can limit especially women’s and youth’s abilities to engage with new opportunities for agricultural innovation (Eerdewijk et al 2015 Baudron et al 2015).

In Phase-II FP4 will integrate gender analysis into its agricultural innovation systems approaches and all applied R4D interventions will proactively engage women, men and youth of both sexes in technology development, evaluation, and validation, and systematically disaggregate their feedback by sex and age. Moreover, gender, age and other social characteristics will be integrated as key variables into the development of farmer typologies and related modelling. Important research and analysis questions related to sustainable intensification of maize-based farming systems include:

- How do gender and age differences in farmers’ access to and control over production means and resources influence technology choices?
- What are the factors underlying the differences in male and female maize farmers’ technology adoption and productivity; and how can this be characterized in ways that can enhance the targeting of maize R4D?
- What types of institutional arrangements and business models can enhance the ability of poor women farmers, youth and marginalized groups to access and benefit from more efficient and labor saving technologies?
- What are potential trade-offs of sustainable intensification technologies from a gender and social inclusion perspective? And what approaches can help mitigate these?
- How do social and gender norms constrain/enhance individuals’ ability to engage in agricultural innovation processes? And what are effective measures to address barriers to social inclusion in technology development and dissemination?
- How do social norms and values contribute to shaping the outcomes of agricultural innovation systems (AIS)? And vice-versa: how do AIS influence social norms and values?

2.10 Capacity development
With the wide range of actors from multiple sectors that the innovation systems approach encourages, the specific capacity development activities will cover leadership, coordination and facilitation expertise including negotiation, and conflict management and resolution skills, participatory approaches, collective action and extension methodologies. Capacities for advocacy will be required for policy dialogue and for building strong partnership and making linkages with policy decision makers to support
the required institutional change for further up-scaling. Effective skills and competencies will also be developed in communications, marketing and product promotion strategies to achieve enhanced adoption of and impacts from the improved maize seed. This will be accomplished by: a) improving small-scale farmers’ knowledge of new maize varieties along with complementary crop and land management practices; b) building capacities in seed business management and marketing strategies (business planning, demand forecasting, branding, market segmentation, product mapping, etc.); and c) developing linkages among seed companies, farmers/community-based organizations, financial institutions and end-user markets.

A key element in FP4 is the capacity strengthening of multi-stakeholder innovation platforms for scaling-up and scaling-out. Key components will be the inclusion of farmer based organizations, extension services and NGOs in the research so to strengthen their capacity to scale-out appropriate technologies to support sustainable intensification.

Training and mentoring of trainers, farmers, farmer organizations, private sector actors and service providers in aspects of scaling up technologies will be organized. Formulation and advocacy of policy options to address institutional constraints for sustainable intensification based technologies will support the policy advocacy. Promotional materials to create awareness of market opportunities for goods and services for value chain actors will also contributed to partners’ capacity development. Training (on the job, workshops, short and long term training) will be organized on gender and social inclusion. Other methods include exchange visits, dissemination) of knowledge to all partners, development of decision support materials, models such business model development.

2.11 Intellectual asset and open access management

The FP will comply with the overall CGIAR policy and W3/bilateral donor requirements on IP and open access.

2.12 FP management

FP4 management will be constituted of co-leaders from the two leading centers at FP level and CoA level (Bernard Vanlauwe/IITA and Bruno Gerard/CIMMYT for overall FP4 management, Bernard Vanlauwe/IITA and Santiago Lopez-Ridaura for CoA4.1, Alpha Kamara/IITA and Jens Anderssson/CIMMYT for CoA4.2, Stephen Bohen/IITA and Tim Krupnik/CIMMYT for CoA4.3, and Alpha Kamara/IITA and David Kahan for CoA 4.4). We recognize that the management structure is not following the CO guidelines but our experience is that it is very difficult to get firm commitment and understanding of CRP complexity from non CGIAR partners. In addition having the lead centers managing the FP will ensure proper complementarity/synergies between meager W1/2 allocated to FP4 and the large W3/bilateral portfolio being mapped under this FP.

Guidance for FP science quality and relevance will be provided by a group of scientists recognized in the field for their tremendous expertise and experience (mentoring committee). The committee will be constituted of Ken Giller (WUR), Ken Cassman (ULN), .... , reps form NARS where we have major investments in South Asia, Africa, LAC, high level rep. from 1 or international NGOs.

FP4 management and mentoring committee will meet once year to plan and review. Additional virtual meetings will be organized on a need base.

2.13 Budget summary (To be completed)
FP5: Adding Value for Maize Producers, Processors and Consumers

2.1 Rationale, scope

Maize is one of the three leading global cereals, but in contrast to wheat and rice, it has multiple uses, particularly as food and feed, both of which offer various opportunities to add value in agri-food systems. Maize is of paramount importance as a staple in the diets of many in developing countries, particularly in Africa and Latin America (Nuss and Tanumiharjo, 2010). Maize food products are really diverse especially in the Americas, with Mexico alone having more than 600 food products derived from maize. With the CGIAR’s commitment to move from commodity-based systems to agri-food systems (AFS), optimization of value chains and integration of nutritional dimensions will provide opportunities to improve incomes, employment, and better diets of poor and vulnerable people. Maize AFS are well placed to help feed Africa, the only continent that has seen an increase in the number of undernourished over the last decades and yet has an additional billion mouths to feed by 2050 – double the current population. The maize revolution will provide much of the needed food calories to do so.

Consumer preferences for maize products may change with time and economic development, with for instance urban consumers in some countries moving away from maize meal to wheat and rice that are prepared faster (Louw et al., 2010). In other countries, cheaper and more productive maize flour is mixed into more expensive rice or wheat flour to provide less expensive food for the urban poor. At the same time there is an increase in obesity and related diseases; and obesity and undernutrition now co-exist in a large number of countries (FAO, IFAD and WFP, 2015). There is a need to develop new nutritious and affordable maize-based products. In rural areas, we know very little about how sustainable intensification affects diet diversity, the nutritional intake of farm household members, and the underlying rationales and incentives, or how the greater competitiveness of local value chains would stimulate local production, processing and employment of the poor (Dogliotti et al., 2014). For example, analysis of the competitiveness of small- and medium-scale maize millers indicates that on average, 59% and 30% of the costs incurred by small- and medium-scale maize mills, respectively, could be avoided without reducing maize meal output (Abu and Kirsten, 2009).

Post-harvest losses in maize AFS are a serious problem in the developing world: they reduce the quantity and the quality of maize grain available to the household, for either consumption or marketing (Hodges 2012). Moreover, the expected losses during storage encourage farmers to sell soon after harvest at low prices. This loss in income reduces incentives to farmers to intensify their maize production and use maize AFS to improve their livelihoods. Post-harvest losses are linked to various activities and practices from farm-to-fork, and include both quantity and quality losses; but quality data are scanty and spotty across regions, commodities, and along the value chain (Affognon et al. 2015). Poor post-harvest practices such as insufficient drying and poor storage conditions also increase the probability of aflatoxins (Kaaya et al. 2006), and the adverse impact of aflatoxins on human and livestock health is well established (Wu 2004). Reducing food losses offers an important way of increasing food availability: More than 15% of grain may be lost in the post-harvest system (Partiff et al., 2010; Hodges et al 2012). In Africa, poor post-harvest management leads to between 14 to 36% loss of maize grains and aggravate hunger (Tefera, 2012). Reducing losses in maize AFS offers an important way of increasing food availability and could contribute to rural development and poverty reduction by improving agribusiness opportunities and livelihoods. More effective AFS that provide sufficient financial incentives at the producer level can contribute to this.
The uses of maize for feed and industries is expected to continue grow rapidly. As feed, maize is a multi-purpose crop, as both grain and by-products are used as livestock feed. Maize is one of the most important ingredients in poultry feed, and this demand will continue to grow in developing countries, as demand for poultry is expected to rise rapidly, driven by population and income growth (Hellin et al 2015). The use of by-products offers particular opportunities for maize as a dual-purpose food-feed crop (Grings et al., 2013). Industrial uses currently are mostly in food processing, including maize flour, porridge, baby food and so forth.

MAIZE Flagship Project 5 (FP5) assesses value addition opportunities for maize producers, processors and consumers and has numerous implications for the societal grand challenges (Table FP5.1). It will variously contribute to several SDGs including ending poverty, zero hunger, good health and well-being, gender equality and responsible consumption and production. In FP5 CIMMYT and IITA, with significant expertise in maize processing, product development and postharvest (storage), will join forces with Wageningen UR which has vast experience in developing and adapting processing technologies. MAIZE FP5 will seek to create a wider range of synergies and strategically partner with leading worldwide research institutions and the private sector in nutrition, food product development, postharvest storage, and consumer preferences to truly move to a maize agri-food systems focus to enhance impacts from farm-to-fork for producers, processors and consumers. FP5 will work in specific countries in sub-Saharan Africa (SSA), Latin America (LA) and Asia. Prioritization is based on the farming systems, current uses and trends of maize, nutritional status and alignment with efforts by FP1, FP3, FP4, A4NH and PIM and site integration. FP5 will focus on developing diverse novel and nutritious maize-based products (CoA 5.1); improving technology and knowledge for small-to medium scale processors (CoA 5.2); and reducing post-harvest losses (CoA 5.3). As part of the uplift scenario, and subject to the mobilization of additional funding and strategic partnerships, we envisage pursuing livelihood opportunities through maize and maize by-products for animal feed (CoA 5.4).

### Table FP5.1  MAIZE FP5 and the societal grand challenges

<table>
<thead>
<tr>
<th>Grand challenge</th>
<th>MAIZE FP5 contributions</th>
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<tbody>
<tr>
<td>GC1 - Competition for land from multiple sources</td>
<td>Better maize storage and processing technologies improve access to quality food and reduce food insecurity.</td>
</tr>
<tr>
<td>GC7 - Nutritious and diverse agri-food systems and diets</td>
<td>Better storability of maize grains through hermetic storage leads to food security, higher prices/income, and possibility of diet diversification. Better storability and stability of biofortified crops will ensure larger nutritional benefits. Combined use of maize with other crops and protein-rich foods that supply complementary nutrients will improve the diets of vulnerable groups.</td>
</tr>
<tr>
<td>GC8 - Post-harvest losses</td>
<td>Developing low-cost and efficient storage structures can reduce post-harvest storage losses and enhance food safety. Grain processing is an efficient way to reduce cereal post-harvest losses and enhance food safety. Processing serves to extend the availability of foods beyond the area and season of production, thus contributing to reducing losses</td>
</tr>
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</table>
of raw materials, stabilizing supplies and increasing food and nutrition security at the household level.

| GC9 - Employment and income opportunities created for men, women and youth | Value adding options provide new entrepreneurial and job opportunities, including for input supply, production and processing. |

1 Summary titles of grand challenges listed in CGIAR Strategy & Results Framework 2016–30 (SRF, 2015)

### 2.2 Objectives and targets

Today more than 795 million people are suffering from chronic undernourishment (UNF, 2015). That means one in nine people do not get enough food to be healthy and lead an active life. Most of the hungry people, 780 million, live in developing countries, representing 12.9%, or one in eight, of the population of developing counties (FAO, 2014). Hunger and malnutrition are the number one risk to health worldwide. Maize provides more than 25% of total calories in human diets in Africa and Latin America and therefore maize and maize-based diets can contribute to reduce malnutrition.

Global trends that influence food consumption and AFS like urbanization, dietary transitions and increased globalization, demand new interventions and focus on the consumer side to complement agricultural development programs. The CGIAR’s commitment to move from commodity-based systems to agri-food systems (AFS), will provide opportunities to improve incomes, employment, and better diets for poor and vulnerable people. FP5 is a new flagship in MAIZE phase 2 that seeks to improve food and nutrition security in maize AFS through value addition opportunities for maize producers, processors and consumers. Depending on the funding available, we envisage four objectives – each with an associated cluster of activities:

- To develop diverse novel and nutritious maize-based products for maize AFS;
- To improve the technology and knowledge for small-to medium scale processors in maize AFS;
- To reduce post-harvest losses in maize AFS; and
- To enhance livelihoods through maize and maize by-products for animal feed in maize AFS.

FP5 will variously contribute to 6 sub-IDOs: diversified enterprise opportunities; increased livelihood opportunities; reduced pre- and post-harvest losses, including those caused by climate change; increased availability of diverse nutrient rich foods; enhanced capacity to deal with climatic risks and extremes; and development and dissemination of technologies that reduce women’s labor and energy expenditure (Table FP5.2). FP5 expects to generate: a) a wide range of nutritious maize-based food products; b) widely accepted and efficient methods to produce nutritious maize-based foods; c) new tools and methodologies to reduce post-harvest losses in maize AFS; and possibly as part of the uplift, d) new animal feed formulations based on dual-purpose maize.

Progress towards the sub-IDOs will be variously measured and documented (Table FP5.2). The investment made in FP5 will generate multiple outcomes (Error! Reference source not found. to be completed) and contributions to sub-IDO (Error! Reference source not found. to be completed). The target countries of FP5 are selected based on malnutrition prevalence, maize uses and maize...
consumption in maize-based AFS, with target intervention areas aligned with FP3 and FP4. First users of FP5 are NARES and NGOs that promote consumption of nutritious food products and improved processing technology, small and medium-scale processors, policy- and decision-makers, and extension agencies. The ultimate beneficiaries of FP5 are consumers, especially women and preschool children, through the consumption of nutritious food products; women’s groups for best practices for the production of novel nutritious food products; men and women farmers through access to storage and feed solutions; specialty maize producers and sellers; and the young for new employment opportunities.

Table FP5.2 MAIZE FP5 contributions, indicators and targets

<table>
<thead>
<tr>
<th>Target Sub-IDOs</th>
<th>Nature of FP5 contributions</th>
<th>Indicators and targets</th>
</tr>
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<tbody>
<tr>
<td>Diversified enterprise opportunities</td>
<td>• Mapping consumer preferences and characterize germplasm for quality and processing traits&lt;br&gt;• Labor and cost saving devices for maize processing&lt;br&gt;• Value chain analysis for maize and maize-based products in the target regions</td>
<td>• Number of maize germplasm characterized for quality and processing traits&lt;br&gt;• Number of improved/developed maize processing equipment, especially labor saving devices&lt;br&gt;• Number of value chains analyzed and concise actions proposed</td>
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<tr>
<td>Increased livelihood opportunities</td>
<td>• Identification of end-use quality germplasm&lt;br&gt;• Labor and cost saving devices for maize processing&lt;br&gt;• Development of maize and maize-based food products</td>
<td>• Number of maize germplasm characterized for quality and processing traits&lt;br&gt;• Number of improved/developed maize processing equipment, especially labor saving devices&lt;br&gt;• Number of food standards established</td>
</tr>
<tr>
<td>Reduced pre- and post-harvest losses, including those caused by climate change</td>
<td>• Development and deployment of effective grain storage technologies&lt;br&gt;• Recommendation to reduce grain losses at critical stages like harvesting, drying, shelling and milling</td>
<td>• Number of households using improved postharvest storage technologies&lt;br&gt;• Number of farmers adopting better crop management practices to reduce post-harvest losses</td>
</tr>
<tr>
<td>Increased availability of diverse nutrient-rich foods</td>
<td>• Nutritious maize hybrids/varieties with superior agronomic performance and desirable gender-informed traits (processing properties, palatability and storability) developed and deployed in targeted geographies in SSA, Asia and LA.&lt;br&gt;• Availability of improved maize-based food products nutrient enriched&lt;br&gt;• New/modified food processing methods that contributes to enriched micronutrient retention&lt;br&gt;• Value chain studies for nutritionally enhanced maize</td>
<td>• Number of nutritious maize-based food products available&lt;br&gt;• Number of households consuming nutritious maize-based food products&lt;br&gt;• Number of value chains analyzed and nutritionally enhanced</td>
</tr>
<tr>
<td>Enhanced capacity to deal with climatic risks and extremes</td>
<td>• Development and deployment of effective grain storage technologies&lt;br&gt;• Recommendation to reduce grain losses at critical stages like harvesting, drying, shelling and milling</td>
<td>• Number of households using improved postharvest storage technologies&lt;br&gt;• Number of farmers adopting better crop management practices to reduce post-harvest losses</td>
</tr>
</tbody>
</table>
Development and dissemination of technologies that reduce women’s labor and energy expenditure

- Identification of maize varieties with end-use qualities
- Development and deployment of effective grain storage technologies
- Development and deployment of maize processing equipment, labor and cost saving.

- Number of households using improved postharvest storage technologies
- Number of improved/developed maize processing equipment, especially labor saving devices

2.3 Impact pathway and theory of change

The FP5 Adding Value for Maize Producers, Processors and Consumers’ theory of change was developed during a workshop with the MAIZE Flagship Program team. A participatory approach was used to capture all views, experiences and known evidence into the theory of change. The workshop participants were able to increase their understanding of the CGIAR Strategy and Results Framework and awareness of results-based management concepts. The workshop was also structured to encourage sharing and learning on a variety of topics.

Using the CGIAR Results Framework’s sub-intermediate development outcomes (IDO) the team agreed to focus on four sub-IDOs and two cross-cutting sub-IDOs:

- 1.3.1 Diversified enterprise opportunities;
- 1.3.2 increased livelihood opportunities;
- 1.4.1 Reduced pre- and post-harvest losses, including those caused by climate change;
- 2.1.1 Increased availability of diverse nutrient-rich foods;
- B.1.2 Technologies that reduce women’s labor and energy expenditure developed and disseminated; and
- D.1.1 Enhanced institutional capacity of partner research organizations.

Other sub-IDOs were noted by the team as important to programming given that they overlap with the above sub-IDOs of focus.

Based on these areas of focus, the team agreed that this Flagship Program contributes to reducing poverty (SLO 1) and improving food and nutrition security for health (SLO 2) by the mean of increasing incomes and employment (IDO 1.3), increasing productivity (IDO 1.4), improving diets for poor and vulnerable people (IDO 2.1), and enhancing the cross-cutting issues of gender and youth (B), and capacity development (D).

A number of research and development outcomes were identified and a pathway of change was created demonstrating the causal relationship between outcomes and sub-IDOs. During this process, partners involved in the pathway of change were identified. Current and proposed interventions and associated outputs to support the achievements of the outcomes were mapped. Assumptions describing the contextual underpinnings of the theory as well as the risks that may have the potential to undermine success were documented.

This theory of change will be the foundation for the monitoring, evaluation and learning plan. The monitoring plan will consist of a continuous process of collection and analysis of data based on a set of indicators directly related to the performance of the CRP at the output and outcome levels; the key assumptions of the theories of change; and the critical risks. The theory of change will also be the basis for evaluating the FP as well as reflecting on lessons and program improvements.
Figure 10: Theory of Change for MAIZE FP5: Adding Value for MAIZE Producers, Processors and Consumers

SLOs
1. Reduced Poverty
   - 1.3 Increased incomes and employment
   - 1.4 Increased productivity
   - 2.1 Improved diets for poor and vulnerable people

IDOs
1.3 Increased enterprise opportunities
   - 1.3.1 Diversified enterprise opportunities
   - 1.3.2 Increased livelihood opportunities

Sub-IDOs
1.4.1 Reduced pre- & post-harvest losses, including those caused by climate change
   - 2.1.1 Increased availability of diverse nutrient-rich foods

Cross-Cutting Issue:
Gender & Youth, and Capacity Development
- B.1.2 Technologies that reduce women’s labor & energy expenditure developed & disseminated
- D.1.1 Enhanced institutional capacity of partner research organizations

R&D Outcomes
5.10 Consumers increased consumption of maize diverse novel and nutritious food products
   - 5.6 Processors, marketers and traders increased demand for maize diverse novel and nutritious food products
   - 5.7 Fabricators improved efficiency and labor saving of equipment maize processing and storage
   - 5.4 Producers (farmers) increased continual supply of maize grain and stover
   - 5.5 Producers (farmers) increased continual supply in quantity and quality of maize grain, and adopt improved storage techniques
   - 5.2 NARS increased development and testing of novel and locally appropriate maize-based-products
   - 5.3 NARS increased improved storage techniques testing and release

5.1 Advanced Research Institutions and universities better aligned research and teaching programs to complement the FP’s agenda

FP1, FP4 Theories of Change
### Assumptions and Risks

| A | Maize diverse novel and nutritious food products are responsive to consumers  
   | Consumers have access to and accept these novel products  
| B | Existence of enabling policy environment and government support to establish food processing and quality standards and ensured compliance  
   | CGIAR influence national decision-makers  
   | Risk: Lack of financial and human capacity of national regulators and national nutritional programs  
| C | Existence of an enabling policy environment and government support to extension services  
   | Existence of financial and human capacity in extension services  
   | Development agents see value and are willing to promote new technologies and products  
| D | Fabricators see value and are willing to improve efficiency of labor saving devices and maize processing equipment and storage structures  
   | Existence of an enabling policy environment and government support for fabricators  
   | Risks:  
   | Lack of financial incentive for fabricators to make these improvements  
   | Lack of adoption by the communities of new processing methods  
| E | Available maize diverse novel and nutritious food products  
   | Existence of an enabling policy environment and government support for processors, marketers and traders in novel and nutritious food products  
   | Partners are willing to share and exchange data and information  
   | Risk:  
   | Uncompetitive prices for novel and nutritious food products  
   | Non-organized and stable market chain  
| F | Producers’ grain are responsive to consumer quality needs  
   | Storage techniques are responsive to producer  

### Interventions and Outputs

| 1 | Seek feedback from consumers on product quality needs:  
   | Outputs: Communication materials, documented consumer needs and acceptability of products  
   | Promote novel products using demos and field days to increase awareness  
   | Outputs: Dissemination and marketing information, training documentation, training sessions  
| 2 | Advocate for harmonization of quality standards systems across regions  
   | Outputs: Technical advice, dissemination information, recommendation for standards  
| 3 | Exchange of data, information and market intelligence  
   | Outputs: Data, information, marketing intelligence, dissemination documentation  
   | Advocate for improvements  
   | Outputs: Technical advice, dissemination documentation  
| 4 | Advocate for improvements  
   | Outputs: Technical advice, dissemination documentation  
| 5 | Exchange of data, information and market intelligence  
   | Outputs: Data, information, marketing intelligence, dissemination documentation  
   | Demonstrate maize-based products  
   | Outputs: Dissemination and marketing product information  
| 6 | Promote improved grain and storage techniques using demos and field days to increase awareness  
   | Outputs: Dissemination and marketing information, training documentation, training sessions  

2.4 Science quality

FP5 is a new flagship project for MAIZE-2 building on a body of published work from MAIZE-1. FP5 will use several new and innovative multidisciplinary and inter-institutional approaches and tools.

**Co 5.1:** In collaboration with A4NH, MAIZE-1, through Harvest+ project, provided an excellent platform and learning experience on using agriculture as a human nutrition delivery pathway by developing agronomically superior and nutritionally enriched maize varieties (Pixley et al., 2013; Babu et al., 2012; Menkir et al., 2014, 2015; Dhlawayo et al., 2014; Suwargo et al., 2014). Retention of nutrients, stability in storage and food products were investigated and challenges identified especially for provitamin A (Alamu et al., 2014a; Rosales et al., 2015). A nutrient database for analyzing nutrient intakes, and quantity and types of foods consumed was established; this could be systematically expanded to MAIZE target areas for sustainable intensification. Strategies are needed that add value for producers, processors, and consumers with synergistic impacts on nutrition, health and income, and considering the diversity of options in maize AFS (Charles et al., 2010). Other MAIZE-1 relevant work includes: Alamu...
et al., 2015; Akinola et al., 2014; Alamu et al. 2014b; Awoyale et al., 2011, 2013; De Groote and Kimenju, 2012; Galicia et al., 2012; Miranda et al., 2013; Keleman et al., 2013. MAIZE-2 envisions:

- Use of robust, high-throughput methodologies and tools for rapidly assessing the nutritional and end-use quality of raw materials and linking them to sensory and consumer preferences.
- Development of a database on the nutrient content of maize products consumed in different regions and linking it to processing methods.
- Integrating farming systems and dietary knowledge in maize-based food product development.
- Guidelines for using new maize varieties, making a clear link with FP3 and A4NH.
- Use of consumer-driven food/diet design and product development approach; South-South exchange of best practices and uses of maize among different countries.
- In collaboration with FP1 and CCAFS, development of models that predict the impact of climate change on likely diet changes.
- In collaboration with A4NH and dependent on resources, coordinate efforts for nutrition studies.

CoA 5.2: The proposed CoA is new for MAIZE but builds on a body of published work (Arinloye et al. 2015a; 2015b; Fogliano, 2014). An important prerequisite of any attempt to improve food technological practices in favor of improved nutritional quality, is that the sensory characteristics of the newly processed food should not be altered to the extent that the intended consumers do not like to eat the food anymore (Sijtsema et al., 2002; Linnemann et al., 2006). In the Western world there are numerous examples, of new product introductions that failed because they were technology-driven rather than based on insights regarding consumer needs and wishes (Fogliano, 2014). When two different foods of a known nutritional quality are mixed, the nutritional quality of the mixture is not the sum of the constituting ingredients; the resources impact each other, making it necessary to assess the nutritional quality of the mixed food separately and thus adding a hurdle to defining the optimal combination of ingredients. Another challenge in food product development is the bioavailability of the nutrients present in the food product. Thus, there are many options for technological interventions along a food production chain and it is important to make the proper choice (INREF, 2010). MAIZE-2 envisions:

- The creation of value and product diversification along the entire production chain, from producers to processors to (street) vendors.
- Designing locally-adapted and cost-efficient processing equipment.
- Evaluation of existing traditional processing methods to develop more nutritious maize-based food products adapted to consumers preferences.
- Use of robust methodologies and tools for assessing nutrient retention in newly developed products.
- In collaboration with A4NH and depending on resources, coordinate efforts for nutrition studies.

CoA 5.3: Previous research in MAIZE-1 has shown the technical and economic feasibility of improved storage methods, and the interest of consumers in the quality increase that improved storage, especially hermetic storage, brings (Tefera, 2012; De Groote et al., 2013b). Access to improved storage technologies not only reduces postharvest losses, in quantity and quality, it also helps farmers to keep their harvest longer and take advantage of increased prices in the future (De Groote et al., 2013b; Bokar et al., 2014; Bartisbuta et al., 2014; Gitonga et al., 2013; Moussa et al., 2014). MAIZE-1 focused mostly on hermetic storage technologies, in particular metal silos and hermetic bags. Metal silos in SSA were shown to be effective in controlling maize weevils and the larger grain borer without the use of pesticides such as Actellic Super and Phostoxin. The major outcome of metal silos was a change in marketing behavior: farmers sell later, at 5 months after harvest, increasing their income (Gitonga et al.}

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Training of metal silo artisans was key for technology adoption (Ndegwa et al. 2015a). Randomized Controlled Trials (RCTs) in Kenya showed that hermetic bags are effective in controlling insect pests on-farm (Ndegwa et al. 2015b). Farmers also appreciate the improved quality of the grain stored in hermetic bags or silos. Results in West Africa, have shown that farmers are interested in the technology as it offers them a low-cost method, especially for short term storage for family consumption (Baoua et al., 2014). Economic analysis indicates that hermetic containers are cost efficient if losses are sufficiently high and maize is stored long enough. For smaller quantities, hermetic bags are economically feasible, while metal silos become interesting from quantities over one ton (Kimenju and De Groote 2010). Uptake of the products developed and tested can be increased by greater consideration of sensory attributes, consumer preferences and availability of competing products and market potential (Tefera, 2011). MAIZE-2 envisages:

- Use of improved experimental design to test livelihood outcomes of the adoption of storage technologies.
- Use of robust, high-throughput methodologies and tools for rapidly assessing the nutritional and end-use quality of raw materials and linking them to sensory and consumer preferences.
- In collaboration with FP3, FP4 and A4NH develop recommendations for best agronomic practices to reduce post-harvest losses; In collaboration with FP1 develop recommendation on enabling policies to ensure adoption of effective post-harvest management practices.

CoA 5.4: MAIZE-1 has conducted extensive research for the use of maize for food and feed, including the potential and the economics of the use of maize grain and maize stover in animal feed. Livestock in mixed cropping systems is increasingly important for income and nutrition. Improving livestock value chains can be of particular interest to women, who are often in charge of feeding and milking, as in Ethiopia (De Groote et al. 2014). As feed, maize grain is missing some essential amino acids for monogastric animals. MAIZE-1 showed the potential of using maize as a dual-purpose food-feed crop (Grings et al. 2013, a special issue), albeit there can be significant trade-offs in residual biomass use (Erenstein et al. 2015). Positive correlations between grain yield and stover yield in maize have been demonstrated in India (Zaidi et al. 2013) and East Africa (Ertiro et al. 2013). Farmers in East Africa use stover for feed, and are interested in dual purpose varieties that do not compromise other important field and consumer qualities (De Groote et al. 2013a). Such varieties would have the potential to increase the productivity of maize-livestock systems and the income of these farmers, while reducing the pressure on the environment. Other MAIZE-1 feed work includes: Hellin et al 2015; Krishna et al., 2014; Muttoni et al., 2013.

- Use of robust, high-throughput methodologies like near-infra-red spectroscopy (NIRS) for rapidly assessing the stover and feed grain quality.
- In collaboration with FP3 identified cultivars with higher potential as dual-purpose maize.
- Development of maize-based feed formulations.
- In collaboration with FP1 and FP4 recommend the best practices to use dual purpose maize with less impact on biomass use.

2.5 Lessons learnt and unintended consequences

Compared to MAIZE-1, FP5 is a new FP built on the R4D and lessons from MAIZE-1 and a significant body of MAIZE-1 scientific work (see previous section). FP5 pulls these together in a coherent FP and expands it in terms of scope towards a more comprehensive coverage of maize AFS. Some generic lessons learnt follow.
Diverse novel and nutritious maize-based products required to improve nutrition and generate income:
The pattern of maize consumption within countries usually varies along a continuum from rich to poor. Amongst the affluent, the direct use per capita of maize as human food is small, while among the poor, high consumption patterns prevail, especially in rural areas. In developing countries, maize flour serves as the raw material for fermented or boiled beverages, thick porridge, and weaning gruel. In highly maize-based diets, there are opportunities to enhance maize-based products nutritionally in order to supply essential nutrients for a healthy and productive life. Nutritious maize like Quality Protein Maize (QPM) and provitamin A maize is already available, however studies have demonstrated that acceptability of this maize improves with strong public awareness campaigns adequate to the target public. Building capacity of the nutrition and health partners to talk the same language is essential to impact consumers. Equally important is to ensure biofortified maize fulfill the end user and sensory preferences.

Stability of nutrients during processing and storage: Maize is often stored for 6-12 months between harvests but can deteriorate in quality (e.g. 42% carotenoid loss after 6 months, Weber et al., 1987). β-carotene is also lost during soaking and milling; spontaneous fermentation and during cooking. Research will focus on further evaluating the effect of different traditional processing and storage methods on micronutrient content (provitamin A carotenoids, iron, and zinc) and anti-nutritional factors such as phytates.

End-use quality of maize grain, sensory preferences and consumer acceptability of maize food products are key for industries and consumers: Variety and harvesting time had significant effects on most of the physical properties, except porosity. The optimum harvest maturity stage to consume boiled maize hybrids was found to be 20DAP. There was negative but significant correlation between the physical characteristics and the sensory properties except color that showed positive correlation. Differences in kernel characteristics caused by genetic inheritance and harvesting time can influence the processing, utilization and consumer appreciation of maize. Therefore, FPS will evaluate the end-use quality and functional properties and determine the relationship among the quality characteristics, sensory profile and consumer acceptability of the food products to enhance acceptability and consumption of novel products and target varieties for the different industries. Ensuring food supply and reducing post-harvest losses are equally important to increase consumption and improve nutrition.

Better links between agriculture and consumers through appropriate food systems (storage, transport, processing and marketing): Efficiency of grain processing can be increased by ensuring the quality of the raw material. Processing losses are less noted at small and medium scale food industries. Inappropriate raw material may add time, energy, additives and cost to food processing. Research will focus on developing tools and methods which will be used in assessing post-harvest losses. In addition, research will be undertaken in collaboration with the Post-harvest Losses Innovation Laboratory, which will provide expertise in entomology, facilitate pilot-testing of a low-cost moisture meter, monitoring aflatoxin levels and research in drying technologies.

2.6 Clusters of activity (CoA)

CoA 5.1: Develop diverse novel and nutritious maize-based products

Strategic interventions through CoA 5.1 will include:
1. **Link consumer preferences to sensory and physicochemical properties of maize grain:** Quality, stability and storability of maize grain is a key factor for adoption of varieties by processors and consumers (De Groote and Kimenju, 2011; Sahai et al., 2001). These traits are determined by the genotype, environment and management (crop development and post-harvest) (Cirilo et al 2011). Interaction of physical and chemical characteristics of kernels are crucial as well as processing methods and final products, which in turn will affect the sensory preferences (Flint-Garcia et al., 2009; Blandino et al., 2013). This intervention will map end-use quality for maize to enable targeted breeding (FP3 and A4NH) for consumer-preferred traits and the development of new nutritious food products. Research will include profiling sensory quality traits for commonly consumed traditional maize products.

2. **Develop nutritious and novel maize-based food products and increase diet diversification:** Maize AFS can provide a more nutritious diet when maize is nutritionally enhanced (with micro- and macro-nutrients) through bio-fortification, by combining with nutrient-dense crops (e.g., legumes), by improving processing methods and/or developing new nutritious food products. This key intervention will map the quantity and quality of women’s and children’s diets in selected agri-food systems, understand local and traditional food processing and storage, and the potential for using biofortified maize or combining maize with nutrient-dense crops derived from common farming systems in target countries (FP4) for improving the nutrition of the poorest. Also, when maize spread from Central America, food preparation processes (nixtamalization) that have been found to improve nutritional quality, by enhancing calcium uptake and availability of some amino acids (Serna-Saldívar et al., 1990), did not spread to Africa or Asia. Co-development of alternatives with local communities will hence assess acceptability and ability to make sustainable nutrition shifts among the poorest and most malnourished who continue to rely mostly on plant-based diets.

**Explore use of specialty maize for income generation:** There are untapped market opportunities for specialty maize landraces and their improved versions (e.g., maize with colored grain, vegetable maize, or grain types with special food characteristics), especially in (peri-)urban areas (Keleman et al., 2009; Keleman and Hellin, 2009; Bellon and Hellin, 2011). With support from FP1, participatory value chain action research and development of maize land races aims to develop such opportunities with key actors in the informal sector and relying on poor women. There is limited knowledge of the size of these informal markets, the mechanisms through which they operate and potential interventions. Different options for gender-transformative and gender-inclusive specialty maize product value-chains will be explored, directed both at higher value specialty markets and street food chains. This will be coordinated with efforts in FP3. Selected improved maize varieties are commonly harvested as “green maize”. Green maize is valued as a basic component of the diet during the hungry period and also as an important cash crop and source of income (Keleman et al., 2013). As a perishable commodity, price fluctuations and marketing risks are high. In spite of its importance in the diet and as a source of income, there is lack of information on various aspects of green maize quality, shelf life extension, processing and utilization in informal markets. Areas to be researched include defining what constitutes green maize quality, varietal characterization for organoleptic quality, and developing green maize value chains.

**CoA 5.2: Improved technology and knowledge for small-to-medium-scale maize processors**

Cultural differences and consumer preferences are key drivers for food acceptance. New technologies must be introduced considering the needs and preferences of the target group (Mestres et al., 2009) as well as considering the local processing methods in a holistic way. By improving the processing technologies and knowledge of small-to-medium processors in maize AFS, new commercialization
opportunities are open for producers and better quality foods become available to consumers. Moreover, we often also observe positive spillover effects, like, for instance, the stimulation of other economic activities like urban agriculture (Zezza and Tasciotti, 2010). The continued existence of small and medium-scale maize enterprises producing maize based products in a very competitive market dominated by large capital-intensive food companies depends to a large extent upon the competitiveness of these local enterprises which are able to keep production costs lower than their competitors and cater for specific markets knowing the consumers’ needs (Arinloye et al., 2015). Maize processing into primary and secondary products is dominated by small and medium-scale processors whose challenges include poor market access for their products, inadequate packaging, inefficient processing equipment and poor product quality.

This CoA will work on two strategic interventions:

1. **Optimization of small and medium-scale (SME) processing systems in maize AFS:** There are many industrial options for high-grade maize products (plywood, paper board, textiles, sugar syrup, industrial alcohol, bakery products, glue, etc.), which are currently imported by developing regions. The projected high population growth and increased urbanization will require a greater supply of easily accessible maize-based food products as well as feed for the peri-urban livestock production systems that will support urban demand in years to come. However, current processing practices by small and medium-scale processors are not sufficient to sustain such trends. Research will focus on analyzing the efficiency of processing equipment and technology requirements to meet end-users’ demand for product development (traditional and new products) by small- and medium-scale businesses; designing/adapting and disseminating improved and profitable processing equipment developed in each region or available elsewhere for the production of maize products for defined markets; in collaboration with regulatory agencies, evaluating different packaging materials and storage for identified food products produced by SMEs; formulating product quality standards through low-cost quality assurance systems; enhancing the capacity of small and medium-scale processors within the public and private sectors to promote entrepreneurship, strengthen managerial skills and enhance food product standards and grades.

2. **Optimization of processing methods in maize AFS for enhanced product nutritional and storage quality, greater labor productivity and income generation:** Processing is one of the key drivers of increased production in developing countries. To cope with the demand for labor, there is a need to introduce simple and efficient labor-saving devices and procedures. At the same time, there is a need for introducing/evaluating new or improved traditional processing methods that could result in products with higher micronutrient content (e.g. using fortification, see Seleka et al., 2011), enhanced nutritional and storage quality, and greater market potential. This will require involvement of consumers and local processors in order to add value to the various actors in the food chain. Street food is becoming very popular in rapidly growing cities, where it constitutes a significant part of the diet. Street food vendors can be a very effective target to promote the use of new processing practices. Building on the lessons learned from MAIZE Phase-I, this activity will focus on adapting milling fractionation technologies, fermentation and lime cooking to meet the needs of processors and consumers, conducting limited market studies for identified products, identifying appropriate packaging materials, empowering rural communities with knowledge of sustainable maize processing technologies to improve nutritional quality and reduce food losses, and small-scale maize flour extrusion technologies for development of value-added products.
CoA 5.3: Reduce post-harvest losses

Building on the post-harvest storage work of MAIZE-1, MAIZE-2 will expand to include other upcoming technologies developed by private partners. Public-private partnerships will be key to developing this CoA, which will work on a number of strategic interventions:

1. **Tools and methods for assessing postharvest losses:** Although a methodology for assessing post-harvest grain losses will not in itself reduce those losses, it is essential to post-harvest operations so that priorities for loss reduction can be determined. The enormous variability of local post-harvest situations means that no complete or definitive loss assessment methodology for all situations is available. Thus tools and methods will be developed that can provide post-harvest grain loss assessment and yield standardized and reproducible results so that effective grain loss reduction efforts can be undertaken.

2. **Storage technologies to reduce post-harvest losses and improve grain quality of stored grain:** Research will be undertaken in collaboration with the Post-harvest Losses Innovation Laboratory, which will provide expertise in entomology, facilitate pilot-testing of a low-cost moisture meter, monitoring aflatoxin levels and research in drying technologies (also with the Food Processing Lab - Purdue University). Tools and methods mentioned above will be used in assessing post-harvest losses.

3. **Effectiveness and impacts of on-farm storage using randomized control trials (RCTs):** RCTs will be used to assess the on-farm effectiveness and impacts of hermetic storage assessed on health (nutritional status, exposure to aflatoxins), livelihoods (Income, food security) and behavioral change (increased consumption and marketing). In another experiment, system of testing and labeling maize products for aflatoxins will be piloted.

4. **Scaling storage technologies:** In partnership with the private sector and development agencies, dissemination methods and supply chain development for promotion of improved post-harvest technologies will be explored and scaled in maize AFS.

CoA 5.4: Use of maize and maize by-products for animal feed (uplift)

Maize is a multi-purpose feed crop (both maize grain and by-products are used as livestock feed) that offers opportunities to add value in agri-food systems. Maize grain has the highest meat, milk and egg conversion ratio compared to other grains used as livestock feed, due to its high starch and low fiber content which make it a very concentrated source of energy for livestock production. As feed, maize grain is missing some essential amino acids for poultry, which thus far has been challenging to address in a cost-effective manner through purposive quality maize (Krishna et al., 2014). More promising to date in MAIZE Phase-I was the use of maize as a dual-purpose food-feed crop (Grings et al., 2013), albeit there can be significant trade-offs in residual biomass use (Erenstein et al., 2015). Building on recent research, this CoA will work on two strategic interventions:

1. **Enhancing dual-purpose use of maize:** Low-cost feeding systems that utilize maize crop residues and processing waste can provide promising opportunities for gender-equitable livelihoods. Building on and complementing recent research, this intervention will review the state of men’s and women’s knowledge of the use of maize residues as animal feed; assess the potential for incorporating greater value maize by-products as feed input into selected livestock value chains for greater incomes as well as potential differences in market access and shifts in gender labor burden.
2. Developing innovative and affordable animal feed formulations that can generate income and impacts: Popular released and advanced pipeline cultivars of maize used as animal feed in maize-based systems will be investigated for exploitable variations in food, feed and fodder quality traits at regional or national near-infra-red spectroscopy (NIRS) hubs in close collaboration with fodder traders and feed processors. Trait relationships will be investigated to explore possible trade-off effects. Research will be conducted on the development and adoption of suitable processing technologies; formulation of compound feeds based on maize by-products (including cassava leaves, groundnut and cowpea hay) for feeding ruminants; determination of nutritional composition using NIRS and monitoring of anti-nutritional components; and refinement of maize stover for inclusion in feed for monogastric species such as poultry. Information and findings from CoA 3.2 will be synthesized and, in combination with food, feed and fodder market surveys, used to build scenarios for context-specific feed optimization and appropriate information and delivery systems.

2.7 Partnerships

FP5 is largely the result of reflective analysis of feedback from clients, partners and stakeholders to assess the value-chain and nutrition nexus in maize AFS in selected geographic areas where MAIZE engages in sustainable intensification approaches (FP4) and where strong contextual knowledge already exists. Internally FP5 will draw on methodological strengths that exist within FP1 (identification of market opportunities, technology and gender targeting, impact assessment), FP2 (germplasm characterization), FP3 (variety options; high-throughput analytical knowhow; and seed scaling) and FP4 (intervention areas, livelihood approaches and scaling). Externally, FP5 has and will form stronger or new strategic partnerships with advanced research institutions (Wageningen UR, Purdue University) and the private sector. Wageningen UR will lead one of the CoAs (improve technology and knowledge for small-to medium scale processors); Purdue University and Tecnologico de Monterrey will contribute to research on reducing post-harvest losses; and EMBRAPA will be involved in product development, small- and medium-scale processing (Table FP5.3). Subject to the mobilization of additional funding, FP5 expects to further its strategic partnerships with both research and private sector partners.

Table FP5.3 Partners by CoA for MAIZE FP5

<table>
<thead>
<tr>
<th>CoA</th>
<th>Type</th>
<th>Partner name</th>
<th>Key contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>CGIAR</td>
<td>A4NH</td>
<td>Food systems, nutrition</td>
</tr>
<tr>
<td></td>
<td>Research</td>
<td>Purdue University, EMBRAPA</td>
<td>Product formulation and scale out</td>
</tr>
<tr>
<td></td>
<td>Private sector</td>
<td>Kellogg’s, Nestle</td>
<td></td>
</tr>
<tr>
<td>5.3</td>
<td>ARI</td>
<td>ICIPE (Tadele Tefera)</td>
<td>Entomology; storage pests</td>
</tr>
<tr>
<td></td>
<td>ARI</td>
<td>Feed the Future (FtF) Innovation Lab for the Reduction of Post-Harvest Loss, Kansas State Uni</td>
<td>Post-Harvest Loss</td>
</tr>
<tr>
<td></td>
<td>FtF Food Processing Lab at Purdue Uni</td>
<td></td>
<td>drying methods, storage and aflatoxins testing</td>
</tr>
<tr>
<td></td>
<td>Harvard School of Public Health</td>
<td></td>
<td>Impact of storage technologies on human health,</td>
</tr>
</tbody>
</table>
Docking with other Agri-Food Systems CRPs

FP5 will preferentially work within a sub-selection of agri-food systems where partnerships with other agri-food systems CRPs have already been established by FP4, and especially with DCL, and Livestock CRPs, given that the combination of maize, grain legumes and livestock is the backbone of several traditional farming systems and within the context of site integration. Docking of activities with Livestock/ILRI and RTB will be essential for using maize and its by-products as animal feed. Other opportunities exist in the shared approaches to processing and storage options (e.g. with DCL or RTB).

Docking with Integrating Programs

Nutrition is a multi-level, multi-cultural and multi-sectorial challenge. Collaborative work with A4NH in MAIZE Phase-I has been focused on developing biofortified crops and advocating for research products that decrease consumption of aflatoxin-contaminated maize, especially in Africa. During Phase-II, FP5 will develop stronger collaboration with A4NH and PIM for the adoption and dissemination of biofortified products, approaches and lessons to be learned on diet shifts, advocacy for better data capture and integration of value chain research into agri-food systems research.

Several areas of iteration and complementarity have been identified with A4NH including food systems and understanding the dynamics of consumption and the differential roles in food systems for people by socio-economic status, age and gender, particularly among adolescent girls and women of reproductive age. There is a need for effective innovations with food suppliers to improve diets through maize AFS – requiring an enabling environment from regulators and policymakers.

2.8 Climate change

Climate change is one of the societal grand challenges and a cross-cutting theme for the CRP MAIZE overall. Post-harvest losses are aggravated by climatic variability (Hodges, 2012; Stathers et al., 2013) and a better understanding of the consequences of climate change from farm-to-fork is needed, including its effect on the nutritional characteristics of food. When food prices rise, healthier foods may become too expensive and consumers may choose less healthy food (Cummins and Macintyre, 2006). Of particular concern is that food with a high energy density (usually more processed foods with high sugar and fat contents) is often cheaper than its less energy dense counterparts and less affected by price rises. This may reduce the nutritional quality of dietary intakes, lower the nutritional status of some groups and increase the risk of obesity. Changes in how foods are grown, processed, stored, prepared and cooked (all of which could alter with climate change) may affect the nutritional content of food. Higher fuel costs may reduce cooking options for poorer groups (Lake et al, 2010).

Strategies focusing on better integration at the AFS level, increased biomass production and improving diet diversity are likely to offer opportunities for climate mitigation whilst also having the potential to improve food and nutritional security and incomes (the elusive win-win scenario). FP5 will monitor and collect data on types and amounts of foods consumed by vulnerable groups (women and children);
monitor trends in diet changes essential in highlighting changes in nutritional intake and status resulting from climate change. This may ensure that any problems that arise can be addressed. Some post-harvest technologies may result in increased fossil fuel consumption. Where possible, renewable energy sources will be examined for their potential to support processing related interventions and where necessary, basic life cycle analyses will be used to ensure climate neutral impacts across the flagship.

2.9 Gender

Women often play a key role in post-harvest management and processing, including food preparation. This makes them important actors from whom to seek input when addressing issues related to maize quality traits, as well as improved processing and storage technologies, or new and nutritious maize food products. However, women’s decision making and bargaining power, including around grain storage and processing technologies as well as food preparation and distribution, is often influenced by local gender dynamics and household power relations. To fully understand these dimensions and take them into account in R&D interventions, it is therefore often necessary to involve both men and women.

FP5’s work to link consumer preferences to sensory and processing characteristics of diverse maize materials will involve participatory trials with both women and men, and nutrition education initiatives will include both women and men as well as youth of both sexes. Furthermore, additional efforts to address and enhance the nutrient content of maize-based diets, whether through biofortification or diet diversification combining maize with other nutrient dense crops, will assess and take into account the quantity and quality of women’s and children’s as well as men’s diets.

Significant work on the gender dimensions of improved maize storage technologies was carried out in MAIZE phase-I (Kandiwa et al. 2015) revealing the complexities hereof and the importance of paying close attention to this. This work lays the ground for further development, testing and introduction of improved post-harvest technologies in Phase-II.

New market opportunities can, in principle, benefit women and youth as well as men through new openings for income generation, as producers, processors and market participants. However, women and youth often face a number of gender related challenges which can limit their ability to take advantage of and benefit from new opportunities. Therefore, thorough gender analysis of the specific value chains targeted will be undertaken to inform the research interventions, and efforts will be made to prioritize a focus on small- and medium-scale female and youth processors and their specific technology needs and preferences, supported by business skills-, and entrepreneurship strengthening. Relevant research questions include:

- What traits or combinations of traits related to quality do farmers and consumers in different contexts, or from different social groups, prioritize? For example, what are the post-harvest/processing/consumption/nutrition or fodder related traits that men and women demand?
- What factors that may influence men’s and women’s ability to access, use and benefit from these technologies? And do these factors affect men and women small scale farmers in the same or different ways?
- From a gender and social perspective, what are the potential trade-offs of the technology or value-chain intervention in question?
2.10 Capacity development

FP5 will align with the CRP MAIZE overall Capacity Development plan and CGIAR CapDev Framework. In FP5, activities will focus on developing stakeholders capacity to support enhanced adoption of improved processing methods and labor-saving technologies, increased adoption of improved storage and drying technologies and optimized feed processing options using maize and its byproducts. Women and young people will be empowered by new market opportunities, as producers, processors and market participants. Efforts will be made to focus on upgrading of the capability of small- and medium-scale female processors to conduct research on gender-friendly processing equipment. Special attention will be paid to the improvement of the skills of women and youth in relevant technologies to increase the efficiency and profitability of agribusiness ventures, as producers, processors and market participants.

Other activities that will contribute to the strengthening of capacity are the production and sharing of knowledge and communication materials, promotion of novel products and field days to increase awareness. Capacity development of technology dissemination partners (NGOs, private sector, extension) will be done through training of trainers’ workshops. Capacity development will be undertaken through hands-on training; mentoring; graduate student supervision; postdoctoral and visiting-scientist placements; on-the-job training; and short courses.

In all FP5, strengthening the capacity of R&D partners will be an important component for the development and transfer of knowledge. This will help build a core of competent and experienced individuals who are prepared to assume scientific and leadership roles in advancing research and scale-out linkages on maize value addition for farmers, processors, and consumers. These individuals will work together in an organized fashion to create a stronger base for effective, well-functioning interventions, research planning, resource mobilization and scientific writing.

2.11 Intellectual asset and open access management

FP5 will align with the CRP MAIZE intellectual asset and open access management, and as such adhere to the associated CGIAR and institutional principles.

Co-location of FP5 activities within selected FP4 focal areas provides a unique opportunity to integrate nutritional and value chain data with the wealth of available data and to characterize production systems, their opportunities, links to market realities, climate change challenges and other external shocks (failed harvests, price fluctuations) at farm landscape and country levels. Such integration will overcome disconnects between agricultural and nutrition research in an agro-food system perspective, and arrive at economically sustainable interventions and recommendations for policy- and decision-makers. More accurate and relevant data on post-harvest losses and the types and amounts of foods consumed by populations in maize agro-food systems will be generated for combination with other data sets, including nutrition studies.

2.12 FP management

FP5 is managed jointly between CIMMYT-IITA – with both joint FP coordination and co-CoA leads and Wageningen UR co-leading 5.2 (Table FP5.4). The co-leadership allows centers to have a clear co-leading role and provides clear focal points within each organization for each CoA and the FP as a whole. CIMMYT-IITA co-leadership is further warranted by the geographic complementarities between the two centers. The FPS leadership team has a long-term and successful partnership with a wide array of public
and private institutions that add value at different levels, including diagnostics, processing at household and SME levels, nutrition, postharvest storage, and community testing and scaling up of interventions.

Table FP5.4  MAIZE FP5 management

<table>
<thead>
<tr>
<th>FP/CoA Structure</th>
<th>CIMMYT</th>
<th>IITA</th>
<th>WUR</th>
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<tbody>
<tr>
<td>FP5</td>
<td>Natalia Palacios</td>
<td>Bussie Maziya Dixon</td>
<td></td>
</tr>
<tr>
<td>CoA 5.1</td>
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<td>Bussie Maziya Dixon</td>
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<tr>
<td>CoA 5.2</td>
<td></td>
<td>Bussie Maziya Dixon</td>
<td>Vicenzo Fogliano</td>
</tr>
<tr>
<td>CoA 5.3</td>
<td>Hugo De Groote</td>
<td>Tahirou Abdoulaye</td>
<td></td>
</tr>
<tr>
<td>CoA 5.4 [uplift]</td>
<td>Hugo De Groote</td>
<td></td>
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</tbody>
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2.13 Budget summary (To be completed)
Section 3: Annexes
3.1 Participating Partners Budgets (To be completed)

3.2 Partnership strategy

The global partners’ network of MAIZE is essential for addressing global, regional and sub-regional challenges through the co-generation, brokering, and pipeline stewardship of publicly accessible knowledge; often bound in new technologies and approaches. The MAIZE Partnership Strategy is based upon these assumptions:

1. MAIZE can achieve outcomes and impact only through partnerships outside and within the CGIAR
2. Different partnerships and partners are needed in the different phases along the non-linear continuum from knowledge discovery to systemic change (e.g. discovery to scaling out). Table xy visualizes this by way of examples.
3. The further MAIZE moves along this continuum, the less it can/should lead and influence (Circle of Influence principle).
4. As products, solutions and approaches developed under MAIZE move towards scaling-out/-up, partners-of-partners (e.g. boundary partners) become the key drivers of change.

Table 8: Different types of partnerships along the knowledge discovery to systemic change continuum

<table>
<thead>
<tr>
<th>Strategic**</th>
<th>Discovery</th>
<th>Validation</th>
<th>Scaling-out</th>
</tr>
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<tbody>
<tr>
<td>Regional / Global</td>
<td>PIM and the University of Minnesota for MAIZE foresight. Wageningen UR and the former Humid Tropics CRP for systems characterization and systems trajectories, synergies and trade-off analysis. Oak Ridge National Laboratory (ORNL) and the University of Minnesota on Big Data. Cornell University on high-density genotyping-by-sequencing (GBS), genomic selection and GOBII.</td>
<td>KIT: Gender and development work. University of Hohenheim: R4D on haploid inducers and DH technology. The University of Barcelona and the private sector on field-based phenotyping. Multinational companies (Monsanto, Pioneer) and partners in SSA (e.g., KALRO, ARC and NARO) on maize transgenic testing under CFTs and stewardship implementation.</td>
<td>GIZ: Build Scaling Out networks. SFSA: Business models and commercialisation of scale appropriate mechanisation. CIMMYT-IITA-KIT: Building a functional innovation platform “infrastructure”, while simultaneously building on-the-job capacity to facilitate maize system innovation in SSA, Asia and Latin America. KALRO and the private sector seed companies on the MLN trait pipeline.</td>
</tr>
</tbody>
</table>
### National

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<tr>
<th></th>
<th>A wide array of NARES, seed companies and NGOs are partners in germplasm development and multi-location testing in SSA, LA and Asia. Introggression of other institutional germplasm and technologies (e.g., Monsanto under WEMA; Pioneer under IMAS).</th>
<th>NGO collaboration on mechanization business development. Public sector – NARES in Mexico; Guatemala, Haiti, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Nigeria, Rwanda, Zambia, Zimbabwe; Bangladesh, India and Nepal for adaptive research for maize varieties.</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGO collaboration on mechanization business development.</td>
<td>MasAgro Take It To The Farmer: Innovation Systems Approach</td>
<td></td>
</tr>
</tbody>
</table>

#### Program-/Project-based

<table>
<thead>
<tr>
<th></th>
<th>Genomic Selection: The next frontier for rapid gains</th>
<th>Cereal Systems Initiative in South Asia <em>Complex agri impact challenges</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated Breeding Platform (IBP), DArT and James Hutton Institute (JHI) on database management, medium-density GBS, and breeding informatics.</td>
<td>SARD-SC/MAIZE in 4 SSA countries (AfDB)</td>
<td></td>
</tr>
<tr>
<td>GENNOVATE (11-CRP multi-case studies)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>National</th>
<th>MasAgro <em>Complex agri impact challenges</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sustainable Intensification of Maize-Legumes Systems in Eastern and Southern Africa (SIMLESA) <em>Complex agri impact challenges</em></td>
</tr>
</tbody>
</table>

As defined in ‘Good Practice in AR4D Partnership’, ISPC Guidance Paper, Sept 2015 (draft). ILRI’s Partnership Strategy (2011) distinguishes between institutional (e.g. with FARA; at Center Mgmt level), strategic and project-driven partnerships.

This strategy aims to

1. Make clear to our existing and future partners how we want to go about partnership and why it is so important to MAIZE, based on their feedback;
2. Support program and project leads, as well as MAIZE-MC, to better plan ahead, set up, manage and close well-functioning partnerships at the strategic and operational level; be they lead, co-lead or participating partner (ILRI Partnership Strategy refers to contractor, equal partner and service provider categories);
3. Develop new kinds of partnerships, for specific purposes and in specific contexts: Work with new kinds of partners (e.g. ORNL, USA), participate in new types of partnership (e.g. GIZ and SFSA scaling out multi-CRP partnership).

How will this strategy be implemented? By

A. Giving partnership as such more attention:
   a. Integrating methods and tools along the partnership life cycle into the MAIZE project management cycle;

B. Improving upon screening partners:
   a. In many cases, MAIZE cannot choose its partners (e.g. there is only one, donors stipulate partners). Therefore, a better SWOT analysis at the outset is needed, as well as explicit mutual expectations management (e.g. agree on ‘how to partner’)

C. Staying close to partners and fostering partnership management practices (sustaining, partnering capacity) in three critical areas:
   a. Approaches, methods and tools, such as stakeholder and network analysis, mutual self-assessments and targeted capacity development activities
   b. Relationship management: Roles and Competencies
   c. Building and maintaining Partnership Knowledge Base

D. Exchange of experiences and know-how with other CRPs in the context of country coordination.

Just as important is committing resources to developing and maintaining partnerships:

MAIZE uses a mix of (co)-funding approaches and modalities to accommodate different partnership purposes and partner co-funding ability.

**Table 10: MAIZE (co)-funding approaches and modalities**

<table>
<thead>
<tr>
<th>Funding source</th>
<th>Decision-maker</th>
<th>Funding timeframe</th>
<th>Partner co-funding</th>
<th>W1&amp;2 bilateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAIZE Competitive Grants</td>
<td>Research; MAIZE = contractor (to non-CGIAR R&amp;D partner sub-grantees)</td>
<td>MAIZE-MC</td>
<td>1-3 yrs; 1 yr contracts</td>
<td>Sometimes; in-kind (salaries, infrastructure use)</td>
</tr>
<tr>
<td>MAIZE Commissioned Grants</td>
<td>See above</td>
<td>MAIZE-MC</td>
<td>1-3 yrs; 1 yr contracts</td>
<td>Sometimes; in-kind</td>
</tr>
<tr>
<td>Global or regional consortium</td>
<td>Equal partners CRP NARS, other / International Maize Improvement Consortium</td>
<td>Consortium mgmt. body, Sci advisory body guides. CIMMYT and private sector seed companies</td>
<td>Multi-year</td>
<td>Yes, in-kind &amp; financial</td>
</tr>
<tr>
<td>Mode of Engagement</td>
<td>Examples</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>----------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National, regional or global coordination of R4D</td>
<td>African SROs (e.g. ASARECA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Members, by consensus</td>
<td>Varies, for coord. only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilateral program or project</td>
<td>Research, development; national implementation partner sub-grantees / CSISA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program or Project Mgr, steering committee, donor</td>
<td>1-3 yrs depends on bilateral contract</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEW: Joint CRP project</td>
<td>CRPs = equal partners</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRP-MCs</td>
<td>1-3 yrs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What kind of partners does MAIZE work with? Overall, MAIZE combines more than 350 partners that together have a tremendous track record. Instead of providing a generic categorization of partners, we provide some examples of collaboration:

1. MAIZE works extensively with both public and private sector partners. In recent years, work with the private sector has expanded considerably. Currently, MAIZE works directly with DuPont, Monsanto, and Syngenta multi-national seed corporations, more than 180 Small to Medium Sized (SME) Seed companies and 226 Community-Based Seed producers across Asia, sub-Saharan Africa and Latin America. These partnerships vary from exchange of promising germplasm between CIMMYT/IITA and the multi-national seed corporations through to development of varieties, along with technical support, to many of the SME seed companies and Community-Based Seed Producers.

2. MAIZE works the University of Wageningen, CIRAD, SAIL (Sustainable Agriculture Innovation Laboratory), Earth Institute-Colombia University, ORNL, and IPNI to develop strategic, scalable approaches based on farming systems analytical frameworks at multiple spatial and temporal scales to support development partners (i.e., ‘last mile providers’), with knowledge products (including policy briefs and other advocacy materials), decision-support and information systems (including GIS and SMS); enabling them to take to scale targeted options that increase system performance and sustainability.

3. MAIZE works with development partners (such as SFSA, GIZ, Total Land Care, the One Acre Fund and machinery manufacturers etc.) for the scaling out of innovations.

4. MAIZE’s International Maize Improvement Consortium (IMIC) is the most important source of new genetic variation for maize yield increases, adaptation to climate change, resistance to pests and diseases and the basis for the rapid response to Maize Lethal Necrosis Disease.

5. MAIZE accesses, develops and transfers scientific innovations to NARS partners as an IPG, through germplasm and data exchange, joint research and capacity development. It uses its convening power to involve ARIs and the private sector in research within pre-competitive domains, e.g. for hybrid research, genomic selection, Big Data, mechanization, and nutrition research.

6. MAIZE is co-leading an 11-CRP research study on gender norms and women and men’s decision-making within households related to farm planning and management. The study develops synergies between the scarce gender research capacities in ARIs and NARS to empirically analyze gender roles and social norms in maize growing environments. It also examines the way these factors affect
production and productivity of maize. The study will develop strategies to address gender-based constraints in maize farming systems and the wider environment.

7. MAIZE partners are an important source for the capacity building of students, scientists, technicians and professionals from NARS with X to Y students finishing their degree training every year. In 2015, over X applied training courses and field days reached out to X farmers and research and development collaborators.

8. The deployment of CGIAR maize staff in regional offices allows close collaboration, understanding of farmer needs, opportunities for engaging local partners in collaborative research and scaling-out, which has led to the successful development of sustainable intensification approaches in Asia, Africa and Latin America, as well as south-south collaboration on mechanization.

9. MAIZE shapes the international R&D agenda to address cross-border challenges and foster collaboration among NARS based on delivery of IPG. It engages with sub-regional and regional agricultural research organizations (e.g. ASARECA and APAARI) and launches new international consortia (e.g. IMIC) with partners.

What are MAIZE partners looking for? Surveys underline key elements of Centers’ and their R&D partners’ comparative advantage

1. In the first CGIAR Stakeholder Perceptions Survey, research partners rated MAIZE highest among all CRPs on: Sector-specific knowledge; Working effectively with partners, and; Insightful external communications.

2. According to the IEA Review of 2014, “MAIZE has strong research and boundary partners engaged throughout the MAIZE target geographies” and that “NARS are appreciative of the collaborations”.

3. Indeed, MAIZE’s “success rests on strong partnerships and good quality science” (IEA, 2014). For example, “strong partnerships with National Research Programs, and increasingly with the private sector, have enabled rapid effective reaction to MLN in Africa” (IEA, 2014).

Major MAIZE partner planning/consultation events between 2012 and 2016 (outside the significant partner consultations held as part of annual planning meetings for the big bilateral projects):

- 2012, Dublin II meeting on the CGIAR and CAADP in Dublin 17th to 20th of June.
- 2012, BISA Work Planning Meeting in Delhi, 15th to 19th September.
- 2012, GCARD2 Meeting in Uruguay 27th October to 1st of November.
- 2013, Consortium Office and ISPC Intermediate Development Outcomes (IDO) meeting in Cali, Columbia, 23rd to 26th of March.
- 2013, FARA Science Week, in Accra, Ghana, 15th to 18th July.
- 2013, CGIAR ISPC 8th Meeting, IWMI, Colombo, Sri Lanka, 8th to 13th of September.
- 2013, Innovation Transfer into Agriculture / Adoption to Climate Change (ITAACC) and Advisory Service on Agricultural Research for Development (BEAF), Feldafing, Germany, 18th to 22nd of November.
- 2013-14: MAIZE Partner Priorities Survey, with 67 responses from 23 countries regarding priorities for IAR4D versus national research.
- 2014, KIT Innovation Systems Workshop, Amsterdam, Holland, 29th September to 3rd of October.
- 2014, 12th Asian Maize Conference at Hanoi, Vietnam, 27th to 29th of October.
- 2014, ASARECA multi-CRP coordination meetings (Nairobi, June, and Burundi, December)
2015, IITA-CIMMYT 'summit' on CGIAR Maize research, 16th of February.
2015, CRP Leaders meeting in Montpellier, 1st to 5th of June.
2015, High Level Policy Dialogue on Investment in Agricultural Research for Sustainable Development in Asia and the Pacific, at Bangkok on 8th and 9th of December.
2015, MAIZE & WHEAT Sustainable Intensification write-shop with CRPs HT, DS 15th to 17th December.
2016 Selected R&D partners participate in Full Proposal development.
(Feb): Online partner feedback to Full Proposal.
(Apr): Participation GCARD3 Conference.

3.3 Capacity development strategy

The strategy takes into consideration multiple elements including the status quo, the strengths and weaknesses, opportunities highlighted in the evaluation of the CRP and the Maize Proposal. Main gaps identified in the evaluation of Maize CRP⁶ can be clustered into the following areas:

a) Research program management - The Evaluation of the CRP recommends actions to further improve and maintain science quality through the development of protocols, processes and working instructions for research operations and delivery. These impacts negatively on the effectiveness of MAIZE. Substantial improvements in data sharing and analysis are required. At present there is no formal, structured process to leverage and exchange data globally and among projects. The Evaluation highlighted scientists’ frustration about the lack of a mechanism for sharing results and experiences across projects.

b) Strengthening Maize science capacity – a major constraint to AR4D in many developing countries is the insufficient number of skilled scientists and technicians. According to the evaluation, the quality of MAIZE science is good, but greater efforts are needed to enhance opportunities for skill development of MAIZE scientists. Another weakness is the lack of key skills needed in some key areas such as biotechnology and new techniques and practices. Also, there is a low representation of women among research staff who work on MAIZE. Another challenge facing the research institutions in SSA is the lack of maintenance and decay of the research infrastructure, including the equipment and laboratories due to lack of funding.

c) Gender analytical competencies - As pointed out in the ISPC commentary on the 2015–2016 Extension Proposal and the Evaluation regarding gender mainstreaming performance, this is seen as a high priority to support improved policy, management and decision-making.

d) Knowledge and technology dissemination, uptake and out-scaling - Over the years, MAIZE has collaborated with different organizations and applied various research and dissemination approaches to improve the generation and uptake of technologies. Although the CRP has yielded and disseminated successful research outputs including technologies, approaches and policy outcomes, more efforts are needed in this area.

Key Strategic Actions

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⁶ Evaluation of the CGIAR Research Program on MAIZE. April 2015.
The objective of the strategy is to support the development effectiveness of the MAIZE Program. The strategic actions identify high priorities for potential capacity-development activities across clusters, FP and technical areas. A set of four strategic priorities have been developed for consideration. These priorities are aligned with the CGIAR CapDev Framework and address all key elements.

a) **Improving MAIZE science capacity** - enhancing global maize science capacity is critical for a continual influx of high quality people into careers in maize research. In developing the science capacity, the CRP will work closely together with leading universities, the NARES, the private sector, and advanced research institutes in building a new cadre of maize scientists. This will be developed through PhD and MSc training. CapDev efforts will link closely with other initiatives such as the AWARD program for African women. Particular attention will be given to the training of female scientists who are currently under-represented in MAIZE.

Research capacity will also be built in specific areas such as genetics, genomics, experimental design and data curation to enable staff harnessing the potential of these technologies. It is also planned to increase capacity in more fully understanding of impacts of innovations through foresight, targeting and modeling approaches, impact assessment, adoption pathways and factors such as markets, institutions, policies and farmers’ risk and preferences. Different modes of short-term training will be used to develop and maintain up-to-date knowledge and skills, including coaching and mentoring, workshops, short-term courses and visiting scientists' schemes, delivery of innovative learning materials, guidelines, tools and protocols.

A major challenge in the NARS is the lack of maintenance and decay of the research infrastructure, a modest support would continue to be provided for the improvement of the infrastructure to enable them to carry out successfully their assigned research responsibilities.

b) **Enhancing gender in research design and impact pathways** – CapDev activities will aim at increasing the capacity in analyzing the implications of gender for technology adoption and ensuring feedback from analysis to research, conducting strategic gender research for better research prioritization, and developing quality standards for gender analysis, mainstreaming of strategic thinking, theories of change and gender sensitive approaches. In particular, the capacity of young women and men to participate in decision-making and to facilitating their access to markets and value chain opportunities and job opportunities.

Different modes of short-term training will be used in order to develop and maintain up-to-date knowledge and skills of staff in these areas including, coaching and mentoring, workshops, technical short-term courses and visiting scientists’ schemes, design and delivery of innovative learning materials, sharing of good practices, guidelines, common tools and protocols.

c) **Improving research-based management, governance, learning and knowledge sharing** – MAIZE recognizes that tools and guidance can make a significant contribution in building the capacity of AR4D practitioners. Therefore, a set of tools, protocols and support materials will be developed to support the development of competency based approaches and collaboration. Capability should also be enhanced in data and information management in compliance with the CGIAR policies on open- data access. This activity should take root and becomes an integral part of maize improvement program and contribute to the sub-IDOs: Enhanced genetic gains through tools and
methods and the efficient management of databases and informatics tools that enhance accessibility of genotypic, phenotypic and enhanced use of genetic resources.

Rules and procedures should be developed to guide researchers. All researchers should be required to develop a Research Data Management Plan to formalize decisions relating to ownership, retention, storage and disposal of data. This will ensure that researchers continue to understand data in the long term and that re-users of data are able to interpret them.

Capacity for learning and knowledge sharing will be increased in line with the Learning Strategy to provide opportunities for all partners to update themselves and discuss findings, strengthen their competencies and skills, and hone their research and analytical capabilities. MAIZE relevant resources will be easily discoverable and in accessible formats (appropriate to audience) and useful for stakeholders. This will be implemented in collaboration with the various learning functions, which include communications, partnerships, research, information technology to develop a range of knowledge products and dissemination approaches. The learning program is also concerned with the packaging of practices, protocols for improving research capacity, and insights/lessons for knowledge sharing, training and policy advocacy.

The strategic actions to implement this priority include graduate training, short-term training courses, theme-based workshops, visiting scientists, internship, and a mentoring and coaching scheme targeting mainly young and mid-career scientists, development and dissemination of relevant learning resources through the MAIZE Platform and other medium. Specific short-term training and workshops on data curation and stewardship, software tools for breeding program management, statistical analysis methods and tools and genomic data analysis will be organized.

d) **Strengthening capacity in technology dissemination and upscaling** - much of the CapDev in this area will be through ‘learning-by-doing’ in the innovation platforms for upscaling and through exchange and sharing of practical experiences at different learning workshops and other experience sharing fora. Syntheses of successful approaches with illustrative case studies and other insights drawn from the action research projects and other sources will provide complementary learning materials to be shared through platforms and other channels.

Additionally, MAIZE will organize and facilitate focused short theme-based training and learning events to achieve enhanced adoption and impacts from the improved maize seed in the following areas: improving small-scale farmers’ knowledge of new maize varieties along with complementary crop and land management practices, seed production, business management skills, sustainable intensification, processing and value-addition; and strengthening institutions to influence policy. Other actions in CapDev that will be used include cross-projects exchange visits, mentoring for young scientists and practitioners. Lessons and practices for upscaling will be packaged in various forms and in appropriate languages and disseminated.

**Implementation, management and delivery**

Implementation will build upon the experiences of the MAIZE phase 1 and other initiatives. The CapDev will operate in a matrix that cuts across clusters and includes input from the broader scientific and development communities on needs and priorities. The CapDev will support activities where MAIZE has high potential impact; high quality results promote inclusiveness and contribute to the CGIAR research outcomes in terms of human welfare benefits. The guiding principles for the operationalization are
“participation and alignment, understanding the context, building on strength, interlinking priorities and continuous learning.” In the implementation of the Plan the following are needed: (a) a schedule of activities, identification of results and indicators, clarification of roles and responsibilities; (b) integrating the plan with existing plans of other partners; (c) clarifying financial and human resource levels required; (c) establish a CapDev function to coordinate, monitor, and evaluate activities within the overall framework of Maize M&E; and (d) adjust the plan as necessary to achieve results. While, setting priorities is the rational process of allocating limited resources, in practice, the priority of setting involves a combination of supply- and demand-oriented methods, consultation with stakeholders, and a resource mobilization program. NARS with weak capacity should be given high priority.

Measure of success

Results will be assessed against predefined targets and indicators following the MAIZE M&E framework and in alignment with the CapDev Indicators for the second phase of the CGIAR Research. In selecting the indicators during the planning process, MAIZE should take into account: the purpose – what will be and how it will indicate required change; the availability – how straightforward is it to collect the relevant data; and the cost – how much will it cost in terms of time and money to collect the data. For each activity the desired output and outcome should be determined as well as the baseline and target for each indicator. The proposed indicators indicated below are specific to each priority. They should be combined with more generic of indicators such as “Number of workshops or trainings provided on each strategic priority, number of people trained”, etc.

<table>
<thead>
<tr>
<th>Strategic priority</th>
<th>Proposed performance indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving MAIZE science capacity</td>
<td>▪ Amount of funding for fellowship programs</td>
</tr>
<tr>
<td></td>
<td>▪ Number of fellowship places provided (disaggregated by level, gender, department)</td>
</tr>
<tr>
<td></td>
<td>▪ Number of participants from NARS and research partner organizations attending</td>
</tr>
<tr>
<td></td>
<td>▪ Number of knowledge products produced on innovative research approaches and research process management tools and practices</td>
</tr>
<tr>
<td></td>
<td>▪ Increase in peer reviewed publications led by NARS students and faculty</td>
</tr>
<tr>
<td></td>
<td>▪ Availability of funding from CRPs for institutional strengthening</td>
</tr>
<tr>
<td>Enhancing gender in research design and impact pathways</td>
<td>▪ Funding made available for design/review of gender sensitive approaches in partner projects /programs/policies (disaggregated by type of organization)</td>
</tr>
<tr>
<td></td>
<td>▪ Number of new policies that support gender transformative measures (disaggregated by country)</td>
</tr>
<tr>
<td></td>
<td>▪ Number of CapDev activities in gender approaches/toolkits initiated (disaggregated by type)</td>
</tr>
</tbody>
</table>
| Improving research-based management, governance, learning and knowledge sharing | ▪ Number of knowledge products produced on innovative research approaches and research process management tools and practices  
▪ Increase in engagement activities between NARS and brokers and end users of research (identifying research needs and subjects; sharing research results)  
▪ Proportion of learning materials using media formats accessible to intended audience  
▪ Efficiency of MAIZE internal processes, e.g. % of tools, guidelines developed and used  
▪ Number of best practices identified, documented and packaged  
▪ Increase in learning and MAIZE intellectual assets |
| Strengthening capacity in technology dissemination and upscaling | ▪ No. of collaborations (e.g. joint research, training/workshops conducted jointly, shared funding arrangements, common membership of multi-stakeholder platforms) with partner organizations  
▪ Number of groups and multi-stakeholder (innovation) platforms facilitated by CRP (disaggregated by gender, socio-economic status, organizational affiliation)  
▪ Adaptation, adoption and spread of innovation associated with participating groups, platforms, households, etc  
▪ Number of NARs researched and field-tested technologies, patents or practices in valorisation (through commercialization or public programs)  
▪ Number of technologies/tools adopted across partnering organizations. |

### 3.4 Gender strategy

**Introduction**

Gender relations are a key aspect of the real-life contexts that agricultural technologies are deployed within. They affect what results can be achieved, how, and for whom.

Key constraint to smallholder maize production include labor shortage, low soil fertility, land degradation, drought, insufficient institutional support, lack of knowledge, access to fertilizer and other inputs, micro-finance etc. Depending on the context, these constraints can all have significant gender dimensions (Doss & Morris 2001; Fisher and Kandiwa 2014; Hampton et al 2009; IFAD 1999; Kassie et al. 2014; Morris et al 1999; Ndiritu et al. 2014; World Bank, FAO and IFAD 2008).

Gender stereotypes and social restrictions often exclude certain groups from research and extension programs, and from participation in farmer participatory experiments, demonstrations and field days. When men migrate and women are left in charge of the farm labor production relations are affected. Women sometimes face several constraints in addressing these challenges, for instance because of lack of access to technical knowledge and technologies, which can reduce their drudgery and provide additional income (Bellon et al. 2002, Beuchelt and Badstue 2013; Mehra and Hill Rojas 2008). Moreover, women’s “triple roles” are well acknowledged in the literature (Momsen 2010, Moser 1993). To the extent that domestic and caring responsibilities may limit their mobility, women often lose out on crucial opportunities for learning and interactions that could stimulate agency and innovation.
Gender and other social inequalities are an important factor in low production levels, inefficient marketing, and limited uptake of innovations. Empowerment, - or at least adequately considering the needs, preferences and constraints of women and men of different age and social groups, is key to sustainable productivity and food security gains. To ensure that interventions are gender-responsive and socially inclusive – and avoid situations in which apparently technically superior innovations exacerbate existing gender inequalities, research and analysis is needed on how gender and other social inequalities interact with technological change and development.

**MAIZE Gender Strategy**

The CRP MAIZE gender strategy outlines the process and approaches that MAIZE continues to adopt and adapt in order to contribute to and promote gender equality in agricultural R4D related to maize-based systems. The **objective** of the strategy is: *To promote equality of opportunity and outcomes for resource-poor farmers in maize-based systems, including women and men, youth and other social groupings.*

The integration of gender in MAIZE is conceived as a process of continual improvement, in which research design and practice, and research management frameworks and procedures complement and reinforce each other. The scope of the strategy includes: **I) Integration of gender analysis and gender research in maize R4D; and II) Mainstreaming of gender in key maize R4D management frameworks and procedures.**

**I) Gender research and analysis:**

In the process of integrating gender research and analysis in MAIZE, the concept of gender is used as an analytical tool to strengthen the relevance and targeting of maize R4D and enhance development impacts. On one hand, gender analysis is applied as part of other technical research, e.g. socio-economic surveys, maize breeding or crop management, to capture differences in the perspectives and assets of male and female farmers from different social groups, and feed this into the technology or policy development process. On the other hand, this is complemented by gender research on strategic issues to further expand the knowledge base concerning gender in relation to maize-based farming and livelihoods to inform and deepen the relevance of other research themes, as well as overall priority setting and targeting, in order to better address gender constraints related to maize-based systems development.

Five general *categories of research questions* or themes set the overall stage for gender research in CRP MAIZE:

a) How do women and men farmers’ roles, resources, constraints and priorities differ in maize-based production systems? What are the implications of this, e.g. for technology development and diffusion?

b) How do gender relations and access to resources influence men’s and women’s adoption of new maize technologies? And how does the introduction of new technologies influence gender relations?

c) How can we ensure that the introduction of improved maize technologies benefits both men and women?
d) What is the capacity for gender responsive technology generation and dissemination of R&D partners, including advisory services, input- and service providers, and seed enterprises?

e) What gendered impacts of maize R4D, who benefits, and how?

Further information on the prioritization and way of addressing these aspects in relation to particular Flagship Projects, including FP specific gender research questions, is offered in the full version of MAIZE gender strategy. Table X lists the gender responsive objective for each of the five FPs:

Table X:

<table>
<thead>
<tr>
<th>FP:</th>
<th>Gender responsive objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP 1</td>
<td>To strengthen the evidence base on gender in maize-based systems and livelihoods; and ensure that foresight and targeting, adoption- and impact studies, as well as maize related value chain development interventions, are informed by a gender and social inclusion perspective.</td>
</tr>
<tr>
<td>FP2</td>
<td>To ensure that perspectives of male and female end users are taken into account in up-stream targeting and decision making.</td>
</tr>
<tr>
<td>FP3</td>
<td>To document and understand gender differentiated preferences for specific traits in maize germplasm, and the factors that influence them, as well as the implications hereof in relation to priority setting and targeting of maize breeding strategies.</td>
</tr>
<tr>
<td>FP4</td>
<td>To ensure that sustainable intensification of maize-based systems and livelihoods take gender- and social disparities into account and delivers positive benefits to both men and women of different social groups.</td>
</tr>
<tr>
<td>FP5</td>
<td>To improve men and women small-scale farmers’ access to and benefit from quality seed of improved maize varieties with combinations of traits that meet their needs and preferences.</td>
</tr>
</tbody>
</table>

II) Mainstreaming gender in the MAIZE Research Management Framework

Operational frameworks and procedures have important roles in clarifying, streamlining and guiding the research management process throughout the project cycle. Mainstreaming gender into key frameworks and procedures can help actively promote the consideration of gender issues in relation to the research in question, and ensure that such issues are addressed, whenever it is relevant and appropriate. This involves the integration of gender in research management policies and procedures, including in relation to e.g.:

- R4D project design, -budgeting
- Research implementation, including targeting, data collection and analysis, participatory technology testing or evaluation, demonstrations and trainings
- Monitoring and evaluation
- Gender analysis capacity and awareness strengthening
- Gender accountability

Linking gender research and analysis to operational frameworks

As gender analysis capacity, and frameworks and procedures that support and encourage gender responsive R4D are strengthened, this will influence research practice and further catalyze integration of gender analysis in MAIZE research projects and FP portfolios. As a result, the proportion of gender

7 [http://maize.org/?page_id=1654](http://maize.org/?page_id=1654)
responsive and gender transformative projects in the MAIZE R4D portfolio is expected to increase. Eventually, the main emphasis will be on gender research and analysis in MAIZE research projects and FP implementation, while a moderate emphasis on enabling frameworks will continue to be required in order to run and maintain the institutional structures and resources for gender integration and related technical backstopping. This shift in focus is illustrated in figure 2.

As results and lessons learnt are generated in gender analysis and research implementation, these will provide feedback to the FP and CRP learning processes and contribute to further development and adjustment of the programmatic and institutional frameworks, which, in turn, will inform the next generation of research projects and adjustments in the diverse FP implementations. As these dynamics progress and gain traction, the integration of gender in MAIZE continues to expand and improve. The complementarity of this overall approach in MAIZE is illustrated in figure 3 below.

The MAIZE gender strategy sets an ambitious agenda – particularly in terms of the potential integration of gender analysis and gender research perspectives in each of the MAIZE Flagship Projects. Such potential integration will be prioritized and rolled out in a phased manner – starting with a focus on the more downstream and operational R4D particularly under FP1, FP4 and FP5. As we continue to
strengthen our gender expertise within the network of implementing partners this will be expanded to encompass the full R4D portfolio. In the end we envision that gender, social inclusion and poverty lenses are systematically applied to all MAIZE’s major innovation pipelines and assessments. In addition, we envision that the gender and poverty differentiated knowledge base will support differentiated recommendations on choice of interventions and scale-out strategies that support social inclusion and greater empowerment of women and youth within the maize value chains.

3.5 Youth strategy

Introduction

90% of the world’s young people live in Africa, Asia and Latin America and the Caribbean. Up to 70% of youth in SSA and South Asia live in rural areas (Bennell 2010), and 47% of rural youth in Africa work in agriculture (Kokanova 2013).

The combined challenges of continued population growth, declining agricultural productivity growth and environmental depletion put pressure on agricultural research and development to work on all fronts to further enhance agricultural productivity and food security. Youth, or young women and men, represent a tremendous human resource and development potential, but has often been neglected in agricultural research and development. In recognition of the need to leverage the potential of youth, CRP MAIZE phase II will include special attention on exploring avenues for harnessing the capacities, opportunities and empowerment of young women and men as agents of change in maize agri-food systems.

The rationale for a focus on youth in CRP MAIZE

The agricultural sector’s declining ability to attract youth causes concern in the face of continued population growth, rising food demands and natural resources challenges (Sumberg et al. 2012). Young people today are generally better educated than their parents. However, with higher levels of education typically come greater expectations – both of young people themselves but also parents’ expectations for their children. But many rural contexts do not offer options that match youth aspirations (Leavy and Hossain 2014; Chinsinga and Chasukwa 2012). According to Kokanova (2013) youth working in agriculture represent the poorest group of working rural youth compared to rural youth engaged in other sectors, often earning significantly less than the common poverty threshold of $1.25 per day. Across the globe, more and more people do not see the farming sector as offering attractive livelihood options (Leavy and Hossain 2014). Increasingly, traditional small-scale farming, which in many parts continues to involve high levels of drudgery and hardship, is no longer enough to make ends meet and raise a family.

In 2013, global youth unemployment reached 12.6%, with young people almost three times more likely than adults to be unemployed (DS Youth Strategy, table 1) and the situation is particularly critical in developing regions where 90% of the global youth population lives. Moreover, high levels of unemployment and disllusion can lead to social and political instability with the ‘Arab spring’ in 2010-11 as a recent example, see also ILO (2012). Bezu and Holden (2014) put these and other factors into a migration and push-pull perspective in a study from Ethiopia.

The world needs farmers, as well as professionals and entrepreneurs engaged in dynamic, inclusive agri-food systems, to ensure the food and nutrition security of future generations. However, while hopes for developing the agricultural sector are often pinned to the alleged energy and innovativeness of youth and their willingness to take risks (e.g. IFAD 2013; Adedugbe 2013), interventions focusing on youth
should appeal and make sense to young women and men from their own perspectives and an instrumental approach to youth should be avoided (White 2012).

**Defining youth as a social category**

The concept of ‘youth’ as a distinguishable demographic group is socially defined and varies across different contexts. Formal, legal definitions of youth typically apply an age-related definition that is linked to rights or special protective measures and policies, e.g., the right to vote or the uptake of hazardous work, and in many countries the age of 18 marks the boundary to adulthood in the legal sense. The UN system defines youth as persons between the ages of 15 to 24, and children as persons up to the age of 14 years.

‘Youth’ is often viewed as a stage in life of transition from childhood to adulthood, associated with physiological and psychological changes and increasing social and economic autonomy (World Bank 2006; Bennell 2007; White 2012). In many contexts the concept of ‘youth’ does not exist as such or is delimited by entirely different parameters for entry into adulthood, e.g. age-sets, initiation or rites of passage marking transition from one stage in life to another, the onset of menstruation or childbearing, marriage, death of a parent, working for pay (Keesing 1981; Potash 1981 in Quisumbing et al. 2014). However, defining ‘youth’ as being in transition to adulthood, conceals the fact that they are living in the here and now with their own needs, rights and interests (White 2012; Sumberg in CGIAR Consortium Office 2015).

Though in principle the term ‘youth’ covers both genders, in practice it often refers primarily to young males, thus rendering invisible the gender-based constraints and opportunities young rural women face (Farnworth and Sillah 2013; Levine et al. 2008; Bertini 2011). Overall, the social heterogeneity of youth and their embeddedness in different social relations and institutions needs to be understood and taken into account in research and development interventions.

**MAIZE youth strategy**

Informed by the commitment to promote equality of opportunity and outcomes, the objective of the CRP MAIZE youth strategy is: *To harness the opportunities and capacities to innovate of resource-poor young women and men in maize-based agri-food systems.*

The expected impacts are: Improved livelihoods due to improved opportunities for young women and men to engage in maize-based agri-food systems.

The expected outcomes include:
- Reduced vulnerability of young women and men due to increased livelihood opportunities directly or indirectly linked to maize based agri-food systems.
- Increased research focus on local opportunity structures and their linkages to sustainable agri-food system development.

**Overall approach to youth in CRP MAIZE**

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8 This is reflected in national policies; for example, Ethiopia’s national youth policy (2004) defines youth as those aged between 15-29, while the National Youth Policy of Nepal (2010) defines youth as “women, men and third gender” persons aged 16-40 years old (http://www.youthpolicy.org/).

9 See MAIZE gender strategy: [http://maize.org/?page_id=1654](http://maize.org/?page_id=1654)
Agriculture is a viable choice only for those who can access (enough) land and inputs. However, land fragmentation linked to rising populations as well as gerontocratic and very often patriarchal social systems is a key constraint to the development of small-scale agriculture (White 2012; for Ethiopia, see also Bezu and Holden 2014). Still, as Leavy and Hossain (2014) note, agriculture, and related fields, could acquire status among young people to the extent that it was modern and cash-based rather than subsistence oriented.

MAIZE’s overall approach to youth focuses on understanding and harnessing rural opportunity structures. Limited research has been conducted specifically on the roles of young women and men in agriculture (Farnworth and Sillah 2013; Proctor and Lucchesi 2012; Paroda et al. 2014) including maize-based systems, and statistics are rarely disaggregated by age (FAO 2014, p. xvii). Integrating a perspective on youth in the MAIZE phase-II agenda therefore has to begin with strengthening the evidence base and the establishment of a research agenda. Borrowing from Sumberg et al. (2012), key research questions include:

- How are opportunities for engagement with maize farming and maize agri-food system development more broadly structured for young women and men in different places?
- What are the implications of this structuring for consequent patterns of young women and men’s engagement with maize farming and maize agri-food systems, as well as for livelihood, poverty, social justice and sustainability outcomes?
- How might particular policy options affect or modify these outcomes?
- What are the politics around these policy options and associated processes?

Building on current experience

Current examples under CRP MAIZE of research with specific attention to the perspectives of rural youth include the cross-CRP comparative research initiative, GENNOVATE, informed by an agency – opportunity structure conceptual framework, and in which MAIZE plays a lead role. As part of this initiative, through sex-specific focus group discussions in rural communities across Latin America, Asia and Africa, MAIZE is capturing the views of young women and men regarding gender norms and practices in relation to their aspirations, livelihoods, capacities for innovation, physical mobility, access to economic opportunities and family formation.

While collection and cleaning of the GENNOVATE case-study data is still to be completed, initial findings from Zimbabwe, Mexico, Malawi, Nigeria, Ethiopia and Nepal seem to support the literature, and indicate that aspirations of young, rural men and women are mostly found outside agriculture or NRM activities (See Fig. XX below). For many of these young respondents owning a business, holding a degree, or migrating is fundamental for moving out of poverty. As many relate farming activities with economic stagnation and backwardness, they hope for other opportunities. An example of concern by youth respondents is labour drudgery, as expressed by a young woman from Zimbabwe: “I wish someone could invent tools that dig basins in conservation agriculture so that we do not do it manually since as women we already have the burden of doing all household chores.”

Both young women and men express interest in agriculture-related business activities, see Fig XXX. Yet, limited access to knowledge and resources are common constraints for youth respondents across these

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10 GENNOVATE involves 11 CRPs and more than 135 community case studies in 26 countries. Of these, 27 are carried out by CRP MAIZE. For more information on GENNOVATE, see: http://gender.cgiar.org/wp-content/uploads/2015/12/GENNOVATE-Flyer_WEB.pdf
countries. As a young woman from Zimbabwe points out: “If young women can get land, one can start potato planting projects. I also think that girls should be trained in a number of income generating activities like poultry, piggery, and mushroom production so that they are equipped in how to earn some cash.” Likewise, a young Zimbabwean man asserts that, “availability of inputs, such as fertilizers, [are prerequisite] to successfully venture into agriculture.” On the same token, youth speak critically about the current mechanisms used to inform about new agricultural technologies and ask for a more inclusive and far-reaching approach, as one young man from Nepal points out: “Information is not reaching up to the grass root level. Like trainings, and other programs.”

**Figure XX**. Aspirations of rural youth, 2015 data from 23 communities in Zimbabwe, Mexico, Malawi, Nigeria, Ethiopia and Nepal

### Aspirations of rural youth by gender (frequency)

*43 FGs (21 men and 22 women)*

<table>
<thead>
<tr>
<th></th>
<th>Young women</th>
<th>Young men</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non agri livelihoods</td>
<td>114</td>
<td>95</td>
<td>209</td>
</tr>
<tr>
<td>Agri and NRM livelihoods</td>
<td>35</td>
<td>44</td>
<td>79</td>
</tr>
</tbody>
</table>

**Figure XXX**. Entrepreneurship by gender, agri and non-agri 2015 data from 23 communities in Zimbabwe, Mexico, Malawi, Nigeria, Ethiopia and Nepal

### Entrepreneurship agri and non-agri by gender (frequency)

*43 FGs (21 men and 22 women)*

<table>
<thead>
<tr>
<th></th>
<th>Agri entrepreneurship</th>
<th>Non-agri entrepreneurship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>203</td>
<td>151</td>
</tr>
<tr>
<td>Other work, MAIZE can include, youth-responsive that CRP phase-II build on for</td>
<td>youth-responsive that CRP phase-II build on for</td>
<td>youth-responsive that CRP phase-II build on for</td>
</tr>
<tr>
<td>Young men</td>
<td>89</td>
<td>49</td>
</tr>
<tr>
<td>Young women</td>
<td>114</td>
<td>102</td>
</tr>
</tbody>
</table>

instance, the project MasAgro Productor, which involves the establishment of a farmers’ typology,
considering age and gender to promote innovations that are more inclusive. Similarly, one of the priority
groups targeted in the Buena Milpa Project in Guatemala is children and youth as key actors in the
future feasibility and sustainability of traditional maize systems. Likewise, the IITA Youth Agriprenuer
Program targets youth via trainings, business development, strategic alliances and the facilitating of
market access to establish and improve their own agri-business along different value chains.

**Integrating youth in MAIZE phase-II R4D agenda**

In phase II, MAIZE will take a two-pronged approach: i) develop and implement a strategic framework
for the systematic integration of youth-related issues in maize agri-food systems research; ii) develop
and apply key principles and practices for inclusion of youth-related concerns in research.

i) **Strategic framework**

In order to take stock, and achieve a rigorous input to the process of strengthening the systematic
integration of youth into the MAIZE research agenda, in 2016 MAIZE is partnering with IDS to develop a
strategic framework for its engagement with young people and youth-related issues.

The framework will include a detailed exploration of the distinction between, on the one hand,
structural issues and interventions (i.e. that affect or have the potential to affect multiple social groups),
and on the other hand, what might be considered “youth-specific” issues and interventions. Structural
issues within the agricultural sector include those affecting productivity, and access to land, credit,
technology and markets. A working hypothesis is that much current policy and development
programming that purports to address the youth and agriculture problem is “youth-specific” and
therefore fails to address – or even acknowledge – the core structural issues.

The development of the strategic framework will draw on findings from GENNOVATE, and on relevant
research literatures, including: literature on the structural transformation of agriculture in the
developing world; literature on youth transition, youth employment and young people’s imagined
futures; and literature on the “new entrant problem” in developed country agriculture and the use of
social protection programs to facilitate the inter-generational transfer of key assets like land. The
strategic framework will guide the subsequent steps to integrate youth-related issues in the MAIZE
research agenda.

ii) Integrating a youth-lens in MAIZE research practice and procedures

Where relevant, youth will be targeted purposefully in the design of MAIZE research projects and
increased emphasis will be put on gathering feedback on the research and technology development
process from young men and women. In addition to sex-disaggregation, people level data collection and
analysis will also be disaggregated systematically by age and other relevant socio-economic variables.
Where possible and relevant, mixed methods will be applied, combining qualitative and quantitative
data collection and analysis. To take into account the social heterogeneity of youth, representation of
diverse groups will be ensured to the extent possible.

For projects with a youth focus or component, this dimension will be incorporated in the monitoring and
evaluation frameworks. Similarly, adoption studies and impact assessments as well as foresight and
targeting and value chain analyses will seek to incorporate consideration of youth issues.

The integration of youth-related issues in CRP MAIZE is based on the principle of continuous
improvement. As integration of youth in MAIZE research practice and procedures progresses, it is
expected that increased awareness and capacity will lead to an increase of research projects paying
special attention to youth.
References


The Chicago Council on Global Affairs, Chicago.


3.6 Results based management

Purpose
For phase 2, the CRP will be implementing a results-based management (RBM) framework. This framework will act as a strategic management system that integrates strategy, results, people, resources, processes and measurements. It will also consist of a set of tools for strategic planning, monitoring and evaluating performance, reporting, improvement and learning. RBM seeks to support greater accountability, transparency, informed decision making, swift corrective actions, learning from experience and better management of risks and opportunities.

Principles
This framework will be implemented based on a set of globally recognized RBM principles: a culture focused on outcomes; strong leadership in RBM to model results orientation across the system; participatory approaches at all levels including partners and stakeholders; learning and adaptation through the use of performance information; accountability and transparency where program staff are held accountable for appropriate levels of results that are acquired and reported in a transparent manner; and utilization-focused and flexible operational system where RBM tools, procedures and practices can be adapted based on contexts and needs.

Steps in Managing for Results
Given that RBM is a management strategy, the framework will be part of the overall ongoing CRP cycle of planning, budget allocation, risk management, and performance reporting and evaluation, including value for money.

Key steps that will be used throughout this cycle include: defining and revising based on lessons the impact pathways at CRP level and theories of change at the Flagship level; budget allocation based on performance; planning for monitoring and evaluation; establishing responsibilities and accountabilities; monitoring and analyzing performance and risks information; using performance and risks information; and reporting performance results.

Implementation within CRP
CRP Impact Pathway and Flagship Theories of Change
The CRP impact pathway and Flagship Programs’ theories of change as presented in the proposal above were developed during workshops with Flagship teams. A participatory approach was used to capture all views, experiences and known evidence into these theories of change. They serve as the CRP’s

13 Ibid.
hypotheses of the way by which change is expected to occur from output to outcome and impact. They are meant to be dynamic document and adapted as evidence is further collected. Assumptions explaining the causality underlying the relationships between the outcomes and impacts were also identified. Key assumptions will be tested to validate the theories of change. Furthermore, critical risks were included and will be monitored to support effective management of the CRP.

In terms of high-level outcomes, the CRP will be contributing to the following elements from the CGIAR Strategy and Results Framework:

- **System-level Outcomes:**
  - 1. Reduced Poverty
  - 2. Improved food and nutrition security for health
  - 3. Improved natural resource systems and ecosystem services

- **Intermediate Development Outcomes**
  - 1.1 Increased resilience of the poor to climate change and other shocks
  - 1.3 Increased income and employment
  - 1.4 Increased productivity
  - 2.1 Improved diets for poor and vulnerable people
  - 3.2 Enhanced benefits from ecosystem goods and services

- **Cross-cutting Intermediate Development Outcomes**
  - Climate change – A.1 Mitigation and adaptation achieved
  - Gender and youth – B.1 Equity and inclusion achieved
  - Policies and institutions – C.1 Enabling environment improved
  - Capacity development – D.1 National partners and beneficiaries enabled

**Interoperable Tools to Support RBM Implementation**

The CRP’s RBM framework will be supported by a user-friendly Information Communication Technology (ICT) online platform that will cover the whole program and project management cycles, including pre-and planning, monitoring, reporting, adaptive management (i.e., support decision making and program/project improvements) and learning as part of the operationalization of the CRP’s MELIA plan. Given that projects will align to Flagship Projects’ theories of change (ToCs), the platform will be structure on the basis of these ToCs. The CRP will ensure that the platform will comply with CGIAR policies (e.g., Open Access and Data Management Policy); is interoperable with other systems, including those of the other lead center; and can produce reports necessary for the CRP. To the extent possible, interoperability with other CRPs’ systems will also be sought to support reporting at the portfolio level.

To ensure effective implementation of this ICT online platform, capacity building at various levels will be needed.

**3.1.1 Monitoring, Evaluation, Learning and Impact Assessment (MELIA)**

**Purpose**

In order to effectively implement the RBM framework, strengthening monitoring, evaluation, learning and impact assessment (MELIA) will be necessary at both project and program levels. A robust and
strategic plan is proposed and will support CRP cycle of planning, budget allocation and reporting steps. Operationalization of the plan will take place following submission of the proposal under the guidance of the CGIAR MEL Communication of Practice (CoP). To the extent possible, the MEL CoP will strive to establish minimal standardization and consistency across the CRPs to contribute to an coherent reporting at the portfolio level.

In addition to the above RBM principles, the MELIA strategy will focus on adding value and creating opportunities for adaptive management and learning. The CRP will use a modular approach for the implementation of the strategy, which will include a suite of tools, guidelines and best practices. Furthermore, plans will be put in place to systematically review the strategy and make necessary adjustments, where required, to better assist staff and management in delivering and improving the performance of the CRP. It is expected that the strategy and its modules will improve over time as more information is gathered and experience is gained in implementing such a framework.

**MELIA Strategy Modules**

**Monitoring**

A monitoring plan consisting of a continuous process of collection and analysis of data is proposed on: the performance of the CRP at the output, outcome and impact levels; the key assumptions of the theories of change; and the critical risks.

The definition of indicators to assess these above elements will be conducted by using a two-pronged approach. First, the CRP will seek indicators already in existence that are credible, well-recognized, accessible, and being monitored by other better positioned organizations (e.g., FAO, WB) and/or in national statistics. Second, in cases where there are no suitable indicators, the CRP will develop new indicators with a cost-effective monitoring system in close collaboration with the Flagship teams. Furthermore, the CRP will support and seek to use, where possible, standardized indicators established by the MEL CoP and other communities of practice.

A set of proposed indicators for intermediate development outcomes to which the CRP will be contributing is proposed in the below table. Indicators at other levels will be developed during the operational phase after proposal submission.

<table>
<thead>
<tr>
<th>IDOs</th>
<th>Proposed Indicators</th>
<th>Proposed Monitoring Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Increased resilience of the poor to climate change and other shocks</td>
<td>To be included shortly</td>
<td>To be included shortly</td>
</tr>
<tr>
<td>1.3 Increased income and employment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4 Increased productivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Improved diets for poor and vulnerable people</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2 Enhanced benefits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In addition to the targets identified for SLOs, the CRP will identify targets to indicators, to the extent possible and where appropriate, drawing from existing baselines, studies, and thematic and regional context expertise. The methodology used to identify the targets and to measure progress, as well as key assumptions, will be detailed to ensure transparency.

To complete the monitoring plan, data collection sources and methodologies, responsibilities and timelines will be identified for each of the indicators. A variety of methodologies are expected to be used dependent on the indicators, including document reviews, surveys, case studies, meta-analyses, meta-syntheses, impact assessments, adoption studies and contribution analysis.

**Evaluation**

Under the CGIAR Policy for Independent External Evaluation, several types of evaluations have been identified to support the system, including IEA commissioned External Evaluation, CRP-Commissioned External Evaluations (CCEEs), and Impact Assessments.

The IEA conducts a cycle of **Independent External Evaluations** of CRPs to provide accountability, support to decision making, and lessons for improving quality and effectiveness of research programs. It is expected that IEA will use CRP monitoring and evaluation information as its primary source of evidence, including CCEEs, impact assessments, and annual monitoring reports.

The CRP will operationalize a rolling evaluation plan to build credible evaluative evidence to support decision-making and lessons for improved and more cost-effective programming. This rolling plan will include CCEEs, impact assessments and other studies identified by CRP management.

The **CCEEs** will most likely be at the Flagship level but could also include other programming elements to evaluation. The conduct of these CCEEs will be spread over the cycle to minimize the burden on management and researchers. The CCEEs will cover at least half of the budgeted activities of a Flagship in a cycle in line with the CGIAR Independent Evaluation Arrangement’s Guidance for CRP-Commissioned External Evaluations (January 2015). A maximum budget of $300,000 per year will be identified in the CRP budget for the conduct of these CCEEs. Joint CCEEs will be sought to leverage the resources of multiple CRPs and to assess performance within a geographic focus (likely in line with the site integration plans) or thematic area (e.g., seed systems, nutrition, and gender). They will be conducted in line with the CGIAR Evaluation Standards.

These CCEEs will consist of a systematic and objective assessment of the program based on evaluation criteria related to relevance, efficiency, quality of science, effectiveness, impact and sustainability. They are considered the building blocks to the external evaluations conducted by the IEA.

The CRP proposed rolling plan for CCEEs are presented in **annex X**. The CRP management will annually review this plan to ensure it meets its needs for accountability and learning purposes. Planned impact assessments can be found in the FP1 section of the proposal.

**Impact Assessment**
Globally, impacts are defined as the positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended. Within the CGIAR, impacts are described as the consequences of the CRPs on the state of selected development variables concerning the SLOs, which are themselves related to Sustainable Development Goals. There is increasing recognition that interventions that contribute to complex, indirect causal chains, with multiple partnerships, and with data limitations require a broad range of methods to evaluate effectively, especially at the impact level.

Therefore, the CRP will adopt a mixed methods approach to evaluate its performance, including ex-ante and ex-post impact assessments. Specific needs of the CPR for the conduct of impact assessments will be identified as part of the monitoring plan as well as by the programming needs for prioritization of research and improved performance.

Impact assessments aim to understand impact (attributable change) and how that impact has been brought about. In order to do so in a way that yields unambiguous results, it is helpful to analyze interventions with a theory-based evaluation (TBE) methodology (Ton, 2012). The basis of this approach is the use of theories of change and the determination of critical nodes where the development process may need to be validated. These critical nodes are the focal points of impact assessment. Depending on the nature of the critical node, (i) whether it is a state or a process, (ii) whether data related to the critical node can be gathered easily or not, and (iii) whether the data is quantitative or qualitative, will determine the type of method that can be employed for the impact assessment, hence the mixed methods. The rigorous application of impact logic for conducting meaningful ex-ante impact assessment allows for determining the key issues that need to be monitored in order to do ex-post impact assessment.

For each step in the intervention logic framework there are a number of questions that need to be answered:

- What are the key assumptions and do they need to be tested?
- What outside factors that are not under control of the programme play a key role? How do they form a counterfactual to the intervention logic?
- To what extent are idiosyncratic circumstances at play? Is there scope for generalisations?

**Reporting**

The annual reporting process will be the key method for the CRP to describe its progress and results achieved as established in the Flagship theories of change. Reporting of results will be conducted at the output and outcomes levels, and when possible, at the impact level. A review of data collected on indicators, assumptions and risks will serve as guides for reporting on results. As part of this process, the CRP will also document any lessons and changes to the implementation of the program, including to the theories of change and monitoring plan.

**Learning**

In line with the RBM principles, the CRP will be operationalizing a variety of measures to support learning from the information collected from monitoring and evaluation. The CRP will integrate these measures as part of its planning and reporting cycle with clear roles and responsibilities. The measures include:
● annually reviewing and revising the ToCs based on evidence collected, and to the extent possible, conducting contribution analysis to reflect and strengthen the CRP performance story;
● annually conducting reflection sessions on performance and risk information collected;
● adjusting and prioritizing the implementation of the Program in line with the evidence collected;
● implementing and adjusting mitigation measures to manage risks;
● documenting lessons learned and best practices (e.g., meta-synthesis of lessons from evaluations);
● conducting evaluation workshops to reflect on and adjust to the evaluation findings and lessons;
● knowledge management and information sharing; and
● following up on learning decisions, including actions plans in response to evaluation recommendations.

3.1.2 Budget Allocation to MELIA

Resources required to implement a robust and credible MELIA strategy have been included accordingly in the CRP’s budget.

For the MEL elements of the strategy, a budget of 2% of CRP budget should be allocated. This allocation would cover:

● development and implementation of a stronger monitoring and reporting interoperable platform
● management of data collection measures in various geographies to implement the monitoring plan effectively
● annual conduct of a CCEE, which is estimated at USD 300,000 of consulting fees per evaluation
● MEL specialists to provide MEL expertise to CRP and project leads, build capacity across the lead centers and partners, and coordinate the implementation of the MEL modules

As for impact assessments, detailed information of the budget and coverage can be found under the FP1 section of the proposal.
### 3.1.3 MAIZE Phase-II Key Outcomes, Targets and Beneficiaries

<table>
<thead>
<tr>
<th>Most important result or outcome</th>
<th>Year of delivery of the result or outcome</th>
<th>Direct beneficiaries type and targets</th>
<th>Target geographies</th>
<th>Key targets/deliverables and estimated direct/first users</th>
<th>Ultimate beneficiaries</th>
<th>Type of benefit to ultimate beneficiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flagship 1: Enhancing MAIZE R4D strategy for impact</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Increased capacity of partner organizations (investment in agricultural research) through MAIZE R4D strategy (foresight and ex-ante analysis) | 2017 onwards | CRP team and management, NARS researchers, policymakers, donors, private sector and other last mile providers | SSA: Ethiopia, Kenya, Malawi, Nigeria, Tanzania, Uganda, Zambia, Zimbabwe Asia: India, Bangladesh, Pakistan, Nepal LA: Mexico | • By 2018, MAIZE investments in 3 innovation pipelines guided by ex-ante studies (including discovery, validation, scaling out)  
• By 2020, MAIZE investments in innovation pipelines guided by further ex-ante studies (including updates and 3 new ones)  
• By 2022, MAIZE investments in all innovation pipelines guided by systematic ex-ante studies  
• At least 1 peer-reviewed paper p.a. focusing on ex-ante analysis | Resource poor farmers and consumers, with a focus women and youth | MAIZE innovations appropriate to future needs |
| Increased capacity of partner organizations (investment in agricultural research) through: MAIZE value chain opportunities prioritized for their livelihoods enhancing potential | | | | | | |
| Increased capacity of beneficiaries to adopt research outputs (based on MAIZE’s targeting strategy) | 2017 onwards | CRP team and management, NARS researchers, policymakers, donors, private sector and other last mile providers | SSA: Ethiopia, Kenya, Malawi, Nigeria, Tanzania, Uganda, Zambia, Zimbabwe  
Asia: India, Bangladesh, Pakistan, Nepal  
LA: Mexico |  
MAIZE investments guided by MAIZE value chain opportunities in target geographies  
• At least 1 peer-reviewed papers p.a. focusing on value chain opportunities  
• Spatial innovation targeting applied in at least 3 MAIZE target countries by 2017; in 3 MAIZE target regions and at least 6 more target countries in 2019  
• By 2012, beneficiaries in MAIZE target regions and countries systematically exposed to more appropriate innovations through better spatial targeting  
• At least 1 peer-reviewed paper p.a. focusing on targeting  
• Investments in validation stage guided by documented impact pathways: at least 1 by 2017; at least 3 by 2019; and by 2021, all investments in validation stage guided by systematic impact pathways  
• By 2017, at least 1 innovation pipeline realigns/increases investment due to M&E learning; by 2019, at least 3; and by 2021, innovation pipelines systematically realign/increase investment due to M&E learning  
• Beneficiaries’ increased innovation adoption and associated factors credibly documented in 3 MAIZE target countries by 2018; in 6 more target countries by 2020; and  
Resource-poor farmers and consumers, with a focus women and youth  
Exposure to more appropriate MAIZE innovations |
| Increased value capture by producers (MAIZE’s interventions enhanced through learning from impact assessment) | 2017 onwards | CRP team and management, NARS researchers, policy-makers, donors, private sector and other last mile providers | SSA: Ethiopia, Kenya, Malawi, Nigeria, Tanzania, Uganda, Zambia, Zimbabwe  
Asia: India, Bangladesh, Pakistan, Nepal  
LA: Mexico | systematically in main MAIZE target countries by 2022  
- At least 2 peer-reviewed papers p.a. focusing on adoption | Increased value capture by producers |
| Improved capacity of women and young people to participate in decision-making (based on MAIZE’s gender and social inclusiveness strategy) | 2017 onwards | Gender lens being applied in major MAIZE innovation pipelines - at least 1 pipeline by 2017; at least 3 by 2019; and by 2021, systematic application of gender lenses across major MAIZE innovation pipelines and assessments  
- Gender differentiated intervention and scale-out strategies in at least 1 major MAIZE project by 2018; at least 3 by 2020; and systematically gender differentiated intervention and scale-out strategies in MAIZE by 2022  
- At least 2 peer-reviewed papers p.a. focusing on impacts | Resource-poor farmers and consumers, with a focus women and youth | Improved capacity of women and young people to participate in decision-making; Exposure to more appropriate MAIZE innovations |
<p>| focusing on gender |   |   |   |   |</p>
<table>
<thead>
<tr>
<th>Flagship 2: Novel diversity and tools for increasing genetic gains</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency and effectiveness of MAIZE partners and global</strong></td>
</tr>
<tr>
<td><strong>research community enhanced by use of new data capture,</strong></td>
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<tr>
<td><strong>storage and analysis tools</strong></td>
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<tr>
<td>2017 and ongoing</td>
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<tr>
<td>MAIZE researchers and global research community</td>
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<tr>
<td>Global</td>
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<tr>
<td>• At least 100 MAIZE scientists and technicians using the tools;</td>
</tr>
<tr>
<td>• Adoption by wider research community increasing by at least</td>
</tr>
<tr>
<td>30 annually</td>
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<tr>
<td>Farmers and their families; consumers and society, dependent</td>
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<tr>
<td>on maize as food or feed</td>
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<tr>
<td>Better and faster availability of needed/useful varieties</td>
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<tr>
<td>enhances livelihoods of farm families and food security for</td>
</tr>
<tr>
<td>society</td>
</tr>
</tbody>
</table>

| Efficiency and effectiveness of MAIZE partners and global      |
| research community enhanced by use of a suite of breeding      |
| program management and pipelined decision support tools        |
| 2018 and ongoing                                               |
| MAIZE researchers and global research community                |
| Global                                                        |
| • At least 40 MAIZE scientists using the decision support tools |
| • Adoption by wider research community increasing by at least  |
| 20 annually                                                   |
| Farmers and their families; consumers and society, dependent  |
| on maize as food or feed                                       |
| Better and faster availability of needed/useful varieties     |
| enhances livelihoods of farm families and food security for   |
| society                                                      |

<p>| Increased use of doubled haploids by MAIZE partners,           |
| accelerating genetic gains                                     |
| 2018 to 2021                                                  |
| MAIZE breeders and global community                           |
| Global, through hubs in Mexico, Kenya and India               |
| • Second-generation haploid inducers with higher haploid      |
| induction rate                                                |
| • Novel haploid selection systems that enable a reduction in  |
| land and labor requirements for haploid identification        |
| • Protocol optimization to improve chromosome doubling        |
| efficiency and reduce haploid seedling mortality              |
| • Reduce the cost of DH line development by more than 30%     |
| compared to 2015 costs                                         |
| Farmers and their families; consumers and society, dependent  |
| on maize as food or feed                                       |
| Better and faster availability of needed/useful varieties     |
| enhances livelihoods of farm families and food security for   |
| society                                                      |</p>
<table>
<thead>
<tr>
<th>Description</th>
<th>Year</th>
<th>MAIZE Breeders and Global Research Community</th>
<th>Global</th>
<th>Benefits for Farmers and Their Families; Consumers and Society, Dependent on Maize as Food or Feed</th>
</tr>
</thead>
</table>
| Rates of genetic gain in adopting breeding programs increased through the use of pipelined genomic selection tools/methods | 2021 | MAIZE breeders and global research community | Global | - Statistical models incorporated into software tools  
- GS pipeline interoperable with BMS software  
- Genomic prediction sufficiently accurate to replace up to 50% of the stage 1 testing effort by 2021 |
| New germplasm sources of genetic variation and molecular markers for prioritized traits used by MAIZE partners | 2018 and ongoing | MAIZE researchers and global research community | Global | - Sources of tar spot resistance available and used by >50 researchers  
- Sources of MLN resistance available and used by >100 researchers  
- Molecular markers for alleles or haplotypes available and used by >50 researchers |
| Increased capacity to identify and use allelic diversity to accelerate breeding progress | 2018 | MAIZE researchers and global research community | Global | Tropical maize reference genome available and used by >300 researchers |

Farmers and their families; consumers and society, dependent on maize as food or feed
Better and faster availability of needed/useful varieties enhances livelihoods of farm families and food security for society
| New genetic diversity available from editing of native genes for breeders to address key traits (e.g., herbicide tolerance, disease resistance and possibly heat tolerance) | 2021 | MAIZE breeders and global research community | Global | • The function and potential value of allelic variants identified through mapping and candidate gene analysis  
• Capacity for gene editing will be established in-house and through partnerships  
• First products of gene editing work validated | Farmers and their families; consumers and society, dependent on maize as food or feed | Better and faster availability of needed/useful varieties enhances livelihoods of farm families and food security for society |
| MAIZE partners and global research community use novel sources of useful genetic variance for drought, MLN, tar spot and other key traits | 2017 onwards (annual roll-out of lines for different traits) | MAIZE breeders and global community | Mostly global tropics and subtropics, except tar spot (Meso-America) and certain traits which may be of regional rather than global importance | • Tar spot lines for Latin America with associated haplotype info accessed by >15 breeders in Latin America  
• Drought tolerant and MLN lines with associated haplotype info accessed by >30 breeders worldwide | Farmers and their families; consumers and society, dependent on maize as food or feed | Improved livelihoods due to reduced production risks and/or increased productivity; contribution to achievement of global demand for maize |

### Flagship 3: Stress Tolerant and Nutritious Maize

| New MLN resistant maize hybrids developed and deployed in SSA | 2018 onwards | Breeders in NARES and private sector, especially in the MLN-endemic countries of SSA | Tier 1: Kenya, Uganda, Tanzania, Ethiopia, Rwanda (MLN-endemic countries of SSA as of July 2015); Tier 2: Presently MLN non-endemic countries in southern and West Africa | • At least 10 NARES and 30 seed companies in SSA annually access 25% more MLN-resistant lines  
• At least 20 new MLN resistant hybrids (with a minimum 1.0-1.5 point improvement on a 1-5 MLN disease severity scale) commercialized by seed company partners in MLN-endemic countries, replacing the existing susceptible varieties | Farmers using improved crop varieties | No more major crop failures due to MLN, and reduced impact of MLN on commercial maize seed sector in SSA; stabilization of regional maize supply buffering low-income maize consumers from... |
Effective pest/disease surveillance, monitoring and diagnosis of MLN and other exotic / emerging threats, established in SSA

| 2017 onwards | NPPOs, commercial seed sector, seed trade organizations in SSA | MLN-endemic countries: Kenya, Tanzania, Uganda, Ethiopia, Rwanda, D.R. Congo
MLN non-endemic, but major commercial seed producing/importing countries: Zambia, Malawi, Zimbabwe, South Africa, Nigeria, Ghana, Mali |
| • At least 13 NPPOs and 6 relevant national/regional seed trade organizations in SSA become part of a vibrant community of practice (CoP), implementing harmonized phytosanitary protocols to curb further spread and impact of MLN and other potential threats in SSA
• At least 50 commercial seed companies in MLN-endemic countries implement SOPs to produce and commercialize MCMV-free maize seed |
| Farmers get access to clean, MLN/MCMV-free, commercial seed |
| No more major crop failures due to MLN or other threats, and reduced impact of pests/pathogens on commercial maize seed sector in SSA |

Increase in the rate of genetic gain for grain yield in rainfed, climate-vulnerable environments from 0.6% to 1.5% annually in SSA, and from ≤1% to at least 1.75% in Asia and LA (linked to FP2)

LA: Mexico (West mid-altitude, Central Highlands and Southeast lowlands), and lowlands of Guatemala, Nicaragua, Honduras, El Salvador, Panama, Haiti, Colombia, Bolivia, Ecuador, Peru, Venezuela
Asia: Bangladesh, Bhutan, South China, |
| At least 45-50 kg/ha/year improvement in mean yield of improved MAIZE hybrids relative to baseline checks |
| Farmers using improved crop varieties |
| Increased genetic gain; better varieties replacing the existing less-productive ones |
| New stress-resilient and nutrient-use efficient maize hybrids developed, for targeted deployment in rainfed, stress-prone agro-ecologies of SSA, Asia and LA (linked with FP6 CoA 6.1; complements CCAFS CRP) | 2017 onwards | Breeders in NARES and the private sector; NGOs promoting climate-resilient and nutrient-use efficient crop varieties in remote rural areas | SSA: Angola, Benin Republic, Burkina Faso, DRC, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Nigeria, Rwanda, South Africa, Tanzania, Uganda, Zambia, Zimbabwe  
LA: Mexico, Guatemala, Haiti, Colombia, Bolivia, Ecuador, Peru, Venezuela  
Asia: Bangladesh, South China, India, Indonesia, Nepal, Pakistan, Philippines, Thailand, Vietnam | • At least 100 NARES institutions and 150 seed companies annually access 25% more stress tolerant donors and inbred lines for use in their breeding programs  
• At least 100 new stress-resilient (with tolerance to drought, heat, waterlogging, acidity; resistant to major diseases, insect-pests, and parasitic weeds) and nutrient use efficient hybrids/varieties commercialized by seed company partners in target geographies, replacing the existing less-productive and >15-year old varieties | Farmers using improved crop varieties | Reduced production risk and greater input use efficiency (land, labor, purchased inputs, water) |
| --- | --- | --- | --- | --- | --- | --- |
| New maize hybrids/varieties with *Striga* resistance combined with NUE developed for targeted deployment in *Striga*-affected in SSA countries (linked to FP6 CoA 6.1) | 2017 onwards | Breeders in NARES and the private sector; NGOs promoting nutrient-rich maize varieties in remote rural areas | **Tier 1**: Kenya, Uganda, Nigeria  
**Tier 2**: Southern African countries with *Striga* incidence | • At least 10 NARS and 10 seed companies annually access 25% more *Striga*-resistant and drought tolerant lines  
• At least 10 new maize hybrids/varieties combining *Striga* resistance with drought tolerance (with at least 1 t/ha yield improvement over commercial checks) commercialized by partners in *Striga*-affected countries in SSA | Farmers using improved crop varieties | Reduced production risk and greater input use efficiency (land, labor, purchased inputs, water) |
| Nutritious maize hybrids/varieties with superior agronomic performance and desirable gender-informed traits (processing properties, palatability and storability) developed and deployed in targeted geographies in SSA, Asia and LA (linked to FP5 and A4NH and complementing A4NH) | 2017 onwards | Breeders in NARES and the private sector in SSA | **Tier 1:**  
**Asia:** Nepal  
**Africa:** Ethiopia, Kenya  
**LA:** Haiti, Bolivia  
**Tier 2:**  
**Asia:** India, Bangladesh, China (southern), Pakistan, Indonesia, Vietnam  
**Africa:** Uganda, Ghana and all countries where A4NH activities are focused (Zambia, Zimbabwe, Tanzania, Nigeria, Benin, DRC)  
**LA:** Honduras, El Salvador, Panama, Peru, Ecuador and all countries where A4NH activities are focused (southern Mexico, Guatemala, Nicaragua, Colombia) | • At least 30 NARS and 25 seed companies annually access 25% more nutritious maize donors and inbred lines for use in their breeding programs  
• At least 20 new nutritious maize varieties with high and stable concentration of micronutrients (provitamin A, kernel Zn) and macronutrients (essential amino acids, protein or oil) commercialized by partners in SSA, Asia and LA | Farmers and their families, and consumers, dependent on maize as staple food; Poultry sector that depends on maize for feed | Improved varieties and maize-based food/feed products with better nutritional quality |
| Improved maize varieties with specific end-use traits (e.g., dual purpose maize with stover/fodder quality; high kernel methionine, high oil, high carotenoids for poultry sector; specialty corn; blue maize) coupled with agronomic performance, developed for meeting stakeholder requirements | 2019 onwards | Breeders in NARES and the private sector | **Tier 1:**  
**Asia:** India, Bangladesh, Nepal  
**Africa:** Ethiopia, Kenya, Nigeria  
**LA:** Mexico  
**Tier 2:**  
**Asia:** China (southern), Pakistan, Indonesia, Philippines, Vietnam  
**Africa:** Tanzania, Mali, Malawi  
**LA:** Guatemala, Honduras, El Salvador, Nicaragua, Colombia | • At least 25 NARES institutions and 40 seed companies annually access 25% more inbred lines with end-use quality attributes for use in their breeding programs  
• At least 25 new hybrids with gender-preferred end-use quality traits commercialized by seed company partners in target geographies, catering to the requirements of maize processors and consumers | Farmers dependent on maize for food and fodder; poultry/livestock sector demanding improved maize for feed; rural and urban consumers seeking quality food products | Improved varieties and maize-based food/feed products with better nutritional and end-use quality; increased market opportunities for specialty maize |
<p>| Requirements (linked to FP5 and Livestock CRP) | Peru, Ecuador, Bolivia | Reduction in product development and elite line recycling time | 2017 onwards | MAIZE-supported public and private sector breeding programs | SSA: Ethiopia, Kenya, Uganda, Zambia, Zimbabwe, Nigeria, Ghana, Mali Asia: Bangladesh, India, China, Thailand, Vietnam LA: Mexico, Colombia | Maize breeding programs of at least 15 NARES and 30 seed companies increase genetic gains and reduce product development time by deploying DH technology, marker-assisted breeding and appropriate cost-effective and precision phenotyping assays developed through MAIZE, coupled with improved data capture and decision support tools | Farmers using improved crop varieties | Quality of varieties or seed technology reaching the farmers, in terms of input use efficiency, nutritional quality, and production risk mitigation |
| Enhanced breeding capacity of NARES and SMEs to develop and make available improved stress tolerant and nutritious maize varieties | 2017 onwards | Maize breeders, technicians and graduate students in public and private sector institutions | SSA, LA and Asia, with particular focus on MAIZE FP3 target countries | At least 250 scientists, technical staff and graduate students trained annually on advanced phenotyping and maize breeding methodologies, with at least 30% female trainees, and at least 50% of trainees below 25 years of age | Farmers using improved crop varieties |
| Commercial seed of first-generation MLN resistant maize hybrids adopted by farmers in MLN-affected SSA countries as a stop-gap solution to MLN | 2017 and 2018 | Farmers in MLN-affected countries | Ethiopia, Kenya, Uganda, Tanzania, Rwanda | • At least 100,000 farmers in 2017 and 150,000 in 2018 | Farmers in MLN-affected countries purchasing MLN tolerant seed |</p>
<table>
<thead>
<tr>
<th>Commercial seed of second-generation MLN-resistant maize hybrids adopted by farmers, replacing the existing susceptible varieties, in MLN-affected countries</th>
<th>2019 onwards</th>
<th>Farmers in MLN affected countries</th>
<th>Ethiopia, Kenya, Uganda, Tanzania, Rwanda</th>
<th>• At least 150,000 farmers in 2018, increasing by 15% every year</th>
<th>Farmers in MLN-affected countries purchasing MLN-resistant seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smallholder farmers in stress-prone rainfed environments adopt improved multiple stress-tolerant maize varieties with better yields and stability (linking with CCAFS CRP)</td>
<td>2017 onwards</td>
<td>Farmers in stress-prone rainfed agro-ecologies in SSA, LA and Asia</td>
<td>SSA: Ethiopia, Kenya, Tanzania, Uganda, Malawi, Mozambique, Zambia, Zimbabwe, Nigeria Asia: Bangladesh, South China, India, Indonesia, Nepal, Pakistan, Philippines, Thailand, Vietnam LA: Mexico, Guatemala, Haiti, Colombia, Bolivia, Ecuador, Peru, Venezuela</td>
<td>• At least 7 million farmers in 2017, reaching at least 12 million farmers by 2021, across SSA, LA and Asia</td>
<td>Farmers in stress-prone (sub)tropical agro-ecologies</td>
</tr>
<tr>
<td>Farmers grow and use improved maize varieties with enhanced gender-preferred nutritional/end-use quality, thereby improving nutritional well-being of families/income opportunities and fodder/feed value chains (linked with A4NH, Livestock, DCLAS and PIM CRPs)</td>
<td>2017 onwards</td>
<td>Farmers in the maize-based agri-food systems</td>
<td>SSA: Ethiopia, Kenya, Tanzania, Uganda, Malawi, Mozambique, Zambia, Zimbabwe, Nigeria Asia: Bangladesh, South China, India, Indonesia, Nepal, Pakistan, Philippines, Thailand, Vietnam LA: Mexico, Guatemala, Haiti, Colombia, Bolivia, Ecuador, Peru, Venezuela</td>
<td>• At least 1.5 million farmers in 2017, reaching at least 5 million farmers by 2021, across SSA, LA and Asia</td>
<td>Farmers in maize-based systems</td>
</tr>
</tbody>
</table>
| More competitive and vibrant local, national and regional maize seed systems | 2017 onwards | Small- and medium-size seed enterprises and community-based seed suppliers | SSA: Angola, Benin Republic, Burkina Faso, DRC, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Nigeria, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe
LA: Mexico, Guatemala, Haiti, Colombia, Bolivia, Ecuador
Asia: Afghanistan, Bangladesh, Bhutan, South China, India, Indonesia, Nepal, Pakistan, Philippines | • At least 200 SME seed companies and community-based seed suppliers (with at least 30% owned/managed by women and youth) across target countries in SSA, Asia and LA trained and technically supported by MAIZE to strengthen quality seed production, seed business management, and product promotion | Farmers in maize-based agri-food systems |

| Reduced cost of seed production (= reduced "cost of goods sold or COGS") of newly developed and released maize varieties (linked to FP6 CoA 6.1) | 2017 onwards | Private sector, especially SMEs, in SSA, LA and Asia | SSA: Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Uganda, Zambia, Zimbabwe, Nigeria
LA: Mexico, Colombia, Bolivia, Ecuador, Peru, Venezuela
Asia: Bangladesh, India, Indonesia, Pakistan, Philippines, Thailand, Vietnam | At least 100 NARES and private seed sector institutions in target geographies access information on improved maize hybrids with at least 20-25% improvement in mean seed producibility index score | Farmers using improved crop varieties | Availability of suitable and affordable seed of improved varieties |

**Flagship 4: Sustainable intensification of maize-based systems for better livelihoods of smallholders**
| Improved understanding of farmers’ livelihood strategies and their diversity, allowing NARES and extension partners to target and implement institutional and technical interventions (in collaboration with other CRPs with a systems Flagship) | 2017 onwards | MAIZE researchers, global and national research and development community; policy makers; private sector partners | SSA: Cameroon, DRC, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe  
LA: Dominican Republic, Guatemala, Haiti, Mexico, Nicaragua  
Asia: Bangladesh, Cambodia, India, Laos, Pakistan, Nepal, Vietnam | By 2018, a robust and harmonized livelihood operational framework is designed and implemented in pilot sites (site integration with other CRPs) and at least 300 NARES scientists and other stakeholder representatives are trained to implement the methods  
By 2021, the framework is implemented in all FP4 sites/geographies | Smallholder farmers, with specific attention given to typologies, equity, and gender  
Resource poor farmers and development community  
Community of practice, cross-learning on SI metrics and indicators reinforced across CRPs with direct engagement of Advanced Research Institutes engaged in monitoring SI | Improved agronomy practices by farmers leading to more productive, profitable and resilient farming enterprises |

| Sustainable intensification indicators and metrics at field, farm and landscape levels developed and used for monitoring systems’ trajectories of changes and efficiency of interventions | 2017 onwards | MAIZE researchers and global and national research and development community | SSA: Cameroon, DRC, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe  
LA: Dominican Republic, Guatemala, Haiti, Mexico, Nicaragua  
Asia: Bangladesh, Cambodia, India, Laos, Pakistan, Nepal, Vietnam | By 2018, methods and tools to systematically measure/collect SI metrics in MAIZE interventions developed and published  
By 2019, cost-benefit of multi-level SI indicators assessed through at least 6 pilot studies in South Asia, sub-Saharan Africa and Latin America  
By 2020, systematic implementation of key SI metrics and indicators in all MAIZE SI interventions and at least 60 NARES scientists are trained on the topic  
Community of practice, cross-learning on SI metrics and indicators reinforced across CRPs with direct engagement of Advanced Research Institutes engaged in monitoring SI | Sustainability of development interventions (economic, social and environmental) verified; providing feedback on the design, uptake, and validation of technical interventions | Resource poor farmers and development community | Improved agronomy practices by farmers leading to more productive, profitable and resilient farming enterprises |
<table>
<thead>
<tr>
<th>Area</th>
<th>Phase</th>
<th>Partners and Agencies</th>
<th>SSA:</th>
<th>Goals</th>
<th>Resource-poor Farmers, Private Sector Partners Operating within Agro-input Supply and Market Value Chains</th>
<th>Increased Yields and Productivity through Adoption of Technologies and Improved Farming Practices. Maintenance and/or Improvement of their Natural Resource Base</th>
</tr>
</thead>
</table>
| Adoption of productivity enhancing technologies by smallholder farming communities through participatory methods | 2017 onwards   | NARES partners, governmental and non-governmental development agencies                 | **SSA**: Cameroon, DRC, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe  
**LA**: Dominican Republic, Guatemala, Haiti, Mexico, Nicaragua  
**Asia**: Bangladesh, Cambodia, India, Laos, Pakistan, Nepal, Vietnam | By 2018, a set of proven productivity-enhancing technologies validated for MAIZE target sites  
By 2020, enhanced farmer knowledge on potential technologies fitted to their biophysical and socioeconomic environment in at least 50 sites/landscapes  
Feedback loop mechanisms to research community regarding the in-situ performance of technical innovations in a large range of environments established by 2020.  
By 2021, at least 400 NARES scientists and technicians trained on participatory methods by 2021 | Resource-poor farmers, private sector partners operating within agro-input supply and market value chains | Increased yields and productivity through adoption of technologies and improved farming practices. Maintenance and/or improvement of their natural resource base |
| Improved understanding of institutional/partnership arrangements to reach impact at scale | 2017 onwards   | NARES, development organizations, policy makers, and private sector                    | **SSA**: Cameroon, DRC, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe  
**LA**: Dominican Republic, Guatemala, Haiti, Mexico, Nicaragua  
**Asia**: Bangladesh, Cambodia, India, Laos, Pakistan, Nepal, Vietnam | By 2020, country and site specific collaborative models for increased adoption of SI innovations designed and tested in at least 20 sites and 8 countries | Resource-poor farmers, public and private sectors | Enhanced adoption of SI innovations by farmers and implementation of efficient institutional scaling models; creation of rural job opportunities through business models |
| Improved understanding of farmers’ livelihood strategies and their diversity allowing NARES and extension partners to target and implement institutional and technical interventions (in collaboration with other CRPs with a systems Flagship) | 2017 onwards | MAIZE researchers, global and national research and development community; policy makers; private sector partners | SSA: Cameroon, DRC, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe  
LA: Dominican Republic, Guatemala, Haiti, Mexico, Nicaragua  
Asia: Bangladesh, Cambodia, India, Laos, Pakistan, Nepal, Vietnam | ● Adoption by science and development partners of the framework through capacity building | Smallholder farmers, with specific attention given to farmer typologies, equity, and gender | Improved agronomy practices by farmers leading to more productive, profitable and resilient farming enterprises |
|---|---|---|---|---|---|---|
| Decision support systems for nutrient and water management used by development partners | 2017 onward | Development partners, NARES, private sector | SSA: Ethiopia, Kenya, Nigeria, Tanzania, Ghana  
LA: Mexico  
Asia: Bangladesh, India, Pakistan, Nepal | ● By 2018, recommendations generated by prototype decision support systems are evaluated in at least 50 MAIZE target sites | Resource-poor farmers, private sector | Increased profitability and more efficient use of inputs (reduced environmental footprint) |
| Improved understanding of institutional/partnership arrangements to reach impact at scale | 2017 onwards | NARES, development organizations, policy makers, and private sector | **SSA:** Cameroon, DRC, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe  
**LA:** Dominican Republic, Guatemala, Haiti, Mexico, Nicaragua  
**Asia:** Bangladesh, Cambodia, India, Laos, Pakistan, Nepal, Vietnam | • By 2021, capacity of at least 30 NARES collaborators further enhanced to build private partnerships through business models  
• At least 30 private companies (small and large) involved in scaling SI innovations by 2022 | Resource-poor farmers, public and private sectors  
Enhanced adoption of SI innovations by farmers and implementation of efficient institutional scaling models; creation of rural job opportunities through business models |
| Decision support systems for nutrient and water management used by development partners | 2017 onward | Development partners, NARES, private sector | **SSA:** Ethiopia, Kenya, Nigeria, Tanzania, Ghana  
**LA:** Mexico  
**Asia:** Bangladesh, India, Pakistan, Nepal | • By 2020, geospatial decision support for nutrient management implemented and used by development partners and fertilizer companies  
• By 2021, DSS adopted by private sector and implemented through cell phone and ICT in at least 4 countries  
• By 2021, at least 50 NARES and private sector partners trained in the use of DSS | Resource-poor farmers, private sector  
Increased profitability and more efficient use of inputs (reduced environmental footprint) |
| Resource-efficient technical innovations developed and tested in all maize agro-ecologies (in collaboration with CCAFS) | 2017 onwards | NARES | **SSA:** Cameroon, DRC, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe  
**LA:** Dominican Republic, Guatemala, Haiti, | Knowledge generated on climate smart technologies through field research and subsequent peer-reviewed publications. At least 50 peer-reviewed publications generated by 2022.  
At least 450 NARS scientists trained | Resource-poor farmers  
More productive, profitable and resilient farming enterprises; improved soil and water conservation; |
Flagship 5: Adding value for maize producers, processors and consumers

<table>
<thead>
<tr>
<th>SMEs, food and feed industries, NARES, farmers and NGOs adopt maize varieties with preferred end use quality traits and consumer preferences</th>
<th>2017 onwards</th>
<th>Farmers, SMEs, private sector, consumers</th>
<th>Tier 1: Mexico, Kenya, Nigeria, Ghana Tier 2: Nicaragua, Guatemala, Peru, Ecuador, Bolivia, Mali, Zambia, Benin</th>
<th>• At least 100 SMEs increase their income by 10%/year in 2019 through adoption of maize varieties with preferred end use traits, reaching 240 by 2021, across SSA and LA • At least 3 food and feed industries purchase maize with preferred end use quality traits in 2019, increasing by 10% every year across SSA and LA • At least 500 women increase their income by 10%/year through selling maize with preferred end use traits in 2019, increasing by 20% every year across SSA and LA</th>
<th>Consumers; small- and medium-scale processors, food and feed industries</th>
<th>Improved availability and access to maize varieties with better nutritional and end-use quality; increased market opportunities for maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased consumption of improved and novel maize-based nutritious food products by consumers, especially women and preschool children</td>
<td>2019 onwards</td>
<td>Consumers</td>
<td>Tier 1: Nigeria, Ghana, Kenya, Ethiopia, Mexico Tier 2: Uganda, Ghana, Malawi, Mali, Haiti, Bolivia, Ecuador, Peru, Brazil, and all countries where A4NH activities are focused (Zambia, Zimbabwe, Tanzania,</td>
<td>At least 120,000 farm families consume nutritious maize-based food products in 2019, reaching 1.5 million by 2021, across SSA and LA</td>
<td>Rural and urban consumers</td>
<td>Improved availability and access to maize-based nutritious food products</td>
</tr>
</tbody>
</table>
| Increased income to women and youth through engagement in established and profitable value chains for specialty maize | 2018 onwards | Farmers, processors, consumers, traders | **Tier 1**: Bangladesh, India, Nepal, Mexico, Nigeria, Ghana  
**Tier 2**: Vietnam, Pakistan, Bolivia, Ecuador, Peru, Guatemala, Mali, Zambia, Benin | At least 240 women traders (20% youth) increase their income by 20%/year selling specialty maize products by 2018, reaching 1000 by 2021 across Asia and LA | Rural and urban consumers | New market opportunities; access to nutritious food |
| Enhanced adoption of improved processing methods and labor saving technologies by NARES, NGOs and SMEs | 2019 onwards | Small- and medium-scale enterprises, women and consumers | **Tier 1**: Nigeria, Ghana, Kenya, Ethiopia  
**Tier 2**: Uganda, Malawi, Mali, Zambia, Zimbabwe, Tanzania, Burkina Faso, Senegal, Benin, DRC | • At least 120 SMEs increase their income by 20%/year in 2019 through adoption of improved processing methods, reaching 240 by 2021, across SSA  
• At least 100 traders increase their income by 15% by selling labor saving devices in 2019, increasing by 20% every year across SSA  
• At least 500 women increase their income by 10%/year through adoption of labor saving technologies in 2019, increasing by 20% every year across SSA | Consumers, traders, processors | Reduce food waste; open market opportunities; increase in grain demand |
| Increased adoption of improved storage and drying technologies by NARES, NGOs and SMEs | 2017 onwards | Farmers, processors, consumers, traders | Tier 1: Kenya, Ethiopia, Nigeria, Haiti  Tier 2: Malawi, Tanzania, Nigeria, Mali, Ghana, Benin, Senegal, Zambia | At least 50 extension staff trained on hermetic storage methods and 20 equipment manufacturers trained on making metal silos in each target country in SSA every year from 2017  At least 1000 demonstrations of hermetic storage each year across SSA and LA  At least 20 manufacturers and 10 traders increase their income by 10%/year in 2018 by selling metal silos and hermetic storage bags | Consumers, traders, processors, manufacturers | Improved availability of maize grain; reduced storage losses |
| Optimized feed processing options using maize and its by-products by feed industries and livestock owners adopt | 2018 onwards | Feed industries, farmers, traders and livestock owners | Tier 1: Bangladesh, India, Mexico, Ethiopia, Kenya, Nigeria  Tier 2: Nepal, Malawi, Tanzania, Mali, Nigeria, Ghana, Zambia, Benin | At least 12 feed producers increase their income by 10%/year in 2019 by selling feed with maize by-products, increasing by 15% every year across SSA, Asia and LA  At least 100 traders increase their income by 10%/year in 2018 by selling feed having maize-by-products; at least 500 livestock farmers use dual-purpose maize | Maize based processing industries; small scale farmers owning livestock in maize based production systems; livestock producers, consumers | New market opportunities; increased incomes |
3.7 Linkages with other CRPs and site integration

Background and the way forward

Significant cross-center and cross-CRP site integration took place during Phase-I. MAIZE Agr-Food Systems (AFS) CRP will start from a strong base in Phase-II. Most of the achievements in terms of site integration and existing cross-center collaborations are a direct consequence of multi-center large W3/bilateral projects, particularly in Africa and Asia (see Table below). Better integration and coordination of CRP interventions and stronger support from public and private sector national partners towards more enabling environments for development in target countries offer significant opportunities to respond to acute development challenges.

One of the key challenges AFS CRPs, such as MAIZE (and WHEAT) face, is defining appropriate ‘entry points’ at the site/system level that define research questions, and hence the necessary local, country and regional partnerships and frameworks that will drive integration (and scaling) on the ground (at multiple levels). One key ‘entry-point’ is livelihoods, primarily of farming households, but also including consumers, small-scale processors and other maize value chain actors; people ultimately make the decision on where to invest their human and capital resources within the context of their livelihood system.

Another key ‘entry-point’ for integration is the need to maintain and improve the environment and natural resource base. Sustainable intensification will require interventions and integration at multiple levels and with multiple partners and institutions. In Phase-II, we will invest in multi-scale system (biophysical, social and economic) analyses, diagnoses (see MAIZE FP1) and conceptual frameworks, based on well-defined research questions aimed at addressing critical bottlenecks to development.

MAIZE-AFS is involved in 14 of the 20 CGIAR Country Collaborations, which include all the six ++ countries (see Table below). MAIZE-AFS co-leads in three countries (Nepal, Tanzania and Zambia), of which Tanzania is a ++ country.

MAIZE-AFS will draw on experiences from the system CRPs, especially Humid Tropics, to generate the most meaningful, efficient and relevant site selection and integration plan. Discussions are underway towards incorporation of the ex-Humid Tropics Action Area in Western Kenya and Action Site in Nan, Thailand, into MAIZE-AFS in Phase-II. Good progress has also been made with CIAT in Central America towards stronger collaboration and coordination of R4D efforts in the region. A strong community of practice in the area of trade-off, synergies, characterization, and targeting and livelihoods analysis is evolving. This should subsequently assist the overall research design and the conduct of participatory research with stakeholders, as well as harmonizing data collection and improving curation, processing and exchange.

Proper attention to the design of CRP Phase-II, based on clear definition of the key ‘entry-points’ and R4D challenges, should further strengthen the existing collaborations, leading to more coherent, integrative and holistic approaches, and ultimately greater synergies and impact of CGIAR research.
## MAIZE Perspective on Site Integration in Phase-II

<table>
<thead>
<tr>
<th>Countries</th>
<th>Phase-I and Extension</th>
<th>Possible integration in Phase-II</th>
<th>Lead center</th>
<th>Topics/projects</th>
<th>Integration under FP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sub-Saharan Africa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Cameroon
- **Germplasm screening activity**
  - RTB, integration of CIRAD’s research
  - TBD (discussions among CRPs are ongoing)
  - Access to improved maize germplasm
  - **FP3**

### DRC
- **Germplasm screening activity in the maize-growing provinces (through MAIZE)**
  - RTB
  - TBD (discussions among CRPs are ongoing)
  - Access to improved maize germplasm
  - **FP3**

### Ethiopia
- **Large portfolio of projects from several CRPs with a significant contribution from MAIZE**
  - MAIZE, WHEAT, FTA, CCAFS, RTB, DCLAS, Livestock, PIM, WLE
  - MAIZE and/or CCAFS and/or Livestock
  - Adoption of improved maize varieties (see DTMA, NUME), Sustainable intensification (TAMASA, SIMLES, FACASI, Africa RISING), improved targeting of SI intervention and integrated research on crop, tree, livestock systems
  - **FP1, FP3, FP4, FP5**

### Ghana
- **Many IITA-led projects in relation to MAIZE, covering most Flagship Projects; includes Africa RISING, N2Africa**
  - TBD
  - TBD
  - Access to improved maize germplasm and sustainable intensification
  - **FP1, FP3, FP4, FP5**

### Kenya
- **Many CIMMYT-led projects in Kenya under FP3, 4, 5, 6**
  - WLE, Livestock, FTA, RTB, CCAFS
  - MAIZE, FTA
  - Adoption of improved maize varieties (see DTMA, NUME), Sustainable intensification (TAMASA, SIMLES, FACASI, Africa RISING), improved targeting of SI intervention and integrated research on crop, tree, livestock systems
  - **FP3, FP4, FP5**
<table>
<thead>
<tr>
<th>Country</th>
<th>Program/Initiative</th>
<th>Collaboration</th>
<th>Activities</th>
<th>FP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malawi</td>
<td>MAIZE (SIMLESA, DTMA, DTMASS)</td>
<td>DCLAS (ICRISAT), WLE MAIZE</td>
<td>Diversification, sustainable intensification (Africa RISING)</td>
<td>FP3, FP4, FP5</td>
</tr>
<tr>
<td>Mali</td>
<td>Africa RISING in southern Mali</td>
<td>DCLAS (ICRISAT), WLE, FTA, Livestock DCLAS</td>
<td>Diversification, intensification and risk in agro-ecologies where maize, sorghum co-exist</td>
<td>TBD</td>
</tr>
<tr>
<td>Mozambique</td>
<td>MAIZE (SIMLESA, USAID)</td>
<td>DCLAS (ICRISAT and CIAT), Livestock, RTB MAIZE, RTB</td>
<td>Access to improved maize germplasm and sustainable intensification of maize-bean-livestock systems</td>
<td>FP4</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Many IITA-led projects in relation to MAIZE, covering most flagship projects; good integration with DCLAS TBD TBD</td>
<td>TBD</td>
<td>Access to improved maize germplasm and sustainable intensification of maize-bean-livestock systems. Value-addition. Technology targeting.</td>
<td>FP1, FP3, FP4, FP5</td>
</tr>
<tr>
<td>Rwanda</td>
<td>FTA, RTB, MAIZE</td>
<td>WLE, Livestock, WHEAT, DCLAS RTB</td>
<td>Access to improved maize germplasm and sustainable intensification</td>
<td>FP3, FP4</td>
</tr>
<tr>
<td>Tanzania</td>
<td>MAIZE, RTB</td>
<td>WLE, Livestock, DCLAS MAIZE or RTB</td>
<td>Access to improved maize germplasm and sustainable intensification. Value-addition. Technology targeting.</td>
<td>FP1, FP3, FP4, FP5</td>
</tr>
<tr>
<td>Uganda</td>
<td>MAIZE, RTB</td>
<td>TBD</td>
<td>Access to improved maize germplasm and sustainable intensification</td>
<td>FP1, FP3, FP4</td>
</tr>
<tr>
<td>Zambia</td>
<td>MAIZE, RTB</td>
<td>CCAFS, DCLAS TBD (discussions among CRPs are ongoing)</td>
<td>Diversification and intensification (Africa RISING) and nutrient management (SIMLEZA)</td>
<td>FP1, FP3, FP4</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>MAIZE, DCLAS</td>
<td>CCAFS TBD (discussions among CRPs are ongoing)</td>
<td>Access to improved maize germplasm and sustainable intensification. Technology targeting.</td>
<td>FP1, FP3, FP4</td>
</tr>
<tr>
<td>Country</td>
<td>Organization</td>
<td>CRP</td>
<td>IGP</td>
<td>Objectives</td>
</tr>
<tr>
<td>-----------</td>
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<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>MAIZE, GRISP</td>
<td>WLE</td>
<td>GRISP</td>
<td>Nutrient and water management, salinity management, crop diversification and improved cropping systems linked to markets, Mechanization</td>
</tr>
<tr>
<td>Cambodia</td>
<td>CIRAD</td>
<td>CIRAD</td>
<td>TBD (discussions among CRPs are ongoing)</td>
<td>TBD</td>
</tr>
<tr>
<td>India</td>
<td>Large investment under MAIZE, WHEAT, GRISP through CSISA in the IGPs (Phase III under review -&gt; 2020. Good integration of CCAFS work in the IGPs with MAIZE and WHEAT. Livestock part of CSISA II but not in CSISA III</td>
<td>Develop further integration with WLE and DCLAS</td>
<td>MAIZE or GRISP. Site integration already exists</td>
<td>Resource conserving technologies (water and nutrients), PPP, scaling of SI practices. Reduction of production risks. Conservation Agriculture. Better targeting of technical innovations. Covering both irrigated and rainfed farming systems.</td>
</tr>
<tr>
<td>Laos</td>
<td>MAIZE and WHEAT, GRSP. Two distinct agro-ecologies. Rainfed hills and irrigated Terai (IGP)</td>
<td>WLE, FTA</td>
<td>GRSP</td>
<td>Access to improved maize germplasm and sustainable intensification</td>
</tr>
<tr>
<td>Nepal</td>
<td>MAIZE, WHEAT, GRSP, Livestock, WLE</td>
<td>Idem</td>
<td>WHEAT</td>
<td>Access to improved maize germplasm and sustainable intensification</td>
</tr>
<tr>
<td>Pakistan</td>
<td>MAIZE, WHEAT, GRSP, Livestock, WLE</td>
<td>Idem</td>
<td>WHEAT</td>
<td>Access to improved maize germplasm and sustainable intensification</td>
</tr>
<tr>
<td>Vietnam</td>
<td>FTA, GRSP</td>
<td>MAIZE, GRSP</td>
<td>TBD (discussions among CRPs are ongoing)</td>
<td>Access to improved maize</td>
</tr>
<tr>
<td>Country</td>
<td>Activity Status</td>
<td>Collaborators</td>
<td>Focus Areas</td>
<td>Targeting of Interactions</td>
</tr>
<tr>
<td>-------------------------</td>
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</tr>
<tr>
<td>Dominican Republic</td>
<td>No activity yet</td>
<td>CCAFS, DCLAS</td>
<td>Access to improved/adapted maize germplasm and sustainable intensification</td>
<td>FP3, FP4</td>
</tr>
<tr>
<td>Guatemala</td>
<td>USAID Buena Milpa project under MAIZE</td>
<td>WLE, DCLAS (CIAT)</td>
<td>Access to improved germplasm. Scaling of SI on-going work. Targeting of interventions</td>
<td>FP4</td>
</tr>
<tr>
<td>Haiti</td>
<td>On-going USAID project under MAIZE</td>
<td>DCLAS (CIAT), WLE</td>
<td>Access to improved germplasm. Resource conserving technologies (nutrient and soils). Production risk management. Development of viable seed systems</td>
<td>FP1, FP3, FP4</td>
</tr>
<tr>
<td>Mexico</td>
<td>MAIZE, WHEAT</td>
<td>DCLAS (CIAT), Livestock</td>
<td>Access to improved germplasm. SI of maize-bean-livestock systems</td>
<td>FP1, FP3, FP4</td>
</tr>
<tr>
<td>Nicaragua</td>
<td>DCLAS (CIAT)</td>
<td>MAIZE, Livestock, WLE</td>
<td>TBD (discussions among CRPs are ongoing)</td>
<td>FP4</td>
</tr>
</tbody>
</table>
3.8 Staffing of management team and flagship projects

MAIZE Director and Flagship Project Leaders

B.M. Prasanna, CIMMYT

MAIZE Director; Flagship Project 3

Biodata
B.M. Prasanna is the Director of CIMMYT’s Global Maize Program (since 2010) and of the CGIAR Research Program on MAIZE (since June 1, 2015). Based in Nairobi, Kenya, Prasanna leads a multi-disciplinary CIMMYT-Global Maize Program team of 45 scientists located in sub-Saharan Africa (SSA), Latin America and Asia, with a major focus on developing and delivering stress resilient and nutritious maize for the tropics, besides applying novel tools and technologies for enhancing genetic gains and breeding efficiency. Since 2012, Prasanna has provided strong leadership to intensive multi-institutional efforts to effectively tackle Maize Lethal Necrosis (MLN), a major disease that is affecting livelihoods of smallholder farmers in several eastern African countries. Under his leadership, a state-of-the-art Maize Doubled Haploid (DH) Facility was established in Kiboko, Kenya, in 2013, which now offers DH production service to NARS institutions and SME seed companies in Africa. Prasanna led the formulation and implementation of several successful public-private partnership projects on development and deployment of improved stress resilient maize germplasm in the tropics over the last five years. Prior to joining CIMMYT, Prasanna served as a faculty member and maize geneticist at the Division of Genetics, Indian Agricultural Research Institute (IARI), New Delhi, under ICAR, for nearly two decades. He led the Indian team under the Asian Maize Biotechnology Network (AMBIONET) (1998-2005), and served as ICAR National Fellow (2005-2010). During his tenure at ICAR and at CIMMYT, Prasanna has led the formulation and successful implementation of several multi-institutional projects on maize R4D. Prasanna guided 14 Ph.D. and 6 M.Sc. students. He has published more than 100 research/review papers in journals of repute, besides (co)authoring one book, 7 edited volumes, 45 book chapters, and 7 technical manuals. He was recognized with several awards and honors in India for his contributions to maize research, post-graduate teaching and human resource development.

Selected Recent Publications

Olaf Erenstein, CIMMYT

Flagship Projects 1 and 5

Scientific Career

- Director, CIMMYT Socioeconomics Program, 2013 to date, Mexico (Texcoco, Aug 2014 onwards); Ethiopia (Addis, 2013-14)
- Senior Agro-economist, Ethiopia (Addis Ababa) / eastern and southern Africa, 08/2009-2012 (3.5 yrs)
- CIMMYT, Agro-economist (IRS), India (New Delhi) / Indo-Gangetic Plains, South Asia, 08/2009-09/2004 (5 yrs)
- Africa Rice Centre (WARDA/ADRAO), Production economist, principal scientist (IRS), Côte d'Ivoire (Bouake) and Mali (Bamako) / West Africa, 08/2004-07/2000 (4 yrs)
- Dutch Government Development Co-operation (DGIS), Policy staff member ag commodities, The Netherlands (The Hague) / Global (developing countries), 06/2000-01/2000 (5 mos)
- CIMMYT (outposted, financed by DGIS), Associate expert Ag Economics for Natural Resources Group, Mexico (Texcoco) / Mexico, 04/1997 -03/1994 (3.1 yrs)
- Dutch Government Development Co-operation (DGIS), Associate expert agro-economy, PATA Integrated Ag Dvt/Irrigation Project, Pakistan (Saidu Sharif) / Malakand Division, NWFP, 02/1994 -11/1991 (2.3 yrs)

Education

- Ph.D. Agricultural/Natural Resource Economics, Wageningen University (NL), 09/1999
- M.Sc. Agricultural Economics, Wageningen Ag. University (NL), 08/1990
- M.Sc. Tropical Crop Science, Wageningen Ag. University (NL), 08/1990

Selected Recent Publications


Tahirou Abdoulaye, IITA

Flagship Project 1

Biodata
Tahirou Abdoulaye is from Niger. He is an Agricultural Economist based in Ibadan, Nigeria. His academic qualifications include a B.Sc. in economics (University of Niamey, Niger); and M.Sc. and Ph.D. in agricultural economics (Purdue University, USA). He has been involved in evaluating and doing impact assessment of several projects, mainly in West Africa. He has published papers on impact assessment of research activities in several African countries, including Niger, Ghana, Mali, Senegal, Nigeria and Benin. His research work covers a wide range of rural economic issues including seed systems, farm-level efficiency and also technology evaluation and transfer. His more recent research interest focuses on innovation systems and how they can help increase technology uptake by small farmers. Prior to joining IITA in 2007, he was a research fellow at JIRCAS (2005–2006), scientist at INRAN (2004–2005), graduate research assistant and postdoctoral research associate at Purdue University (1997–2003) and economist at INRAN (1989–1993, 1994–1996).

Selected Recent Publications
Kevin Pixley, CIMMYT

Flagship Project 2

Biodata
Kevin Pixley has a B.Sc. in agronomy from Purdue, an M.Sc. in crop physiology from the University of Florida, and a Ph.D. in plant breeding from Iowa State University (1990). Immediately afterwards, he began working at CIMMYT as a postdoctoral fellow and later as a maize breeder, moving to the Center’s Harare, Zimbabwe, research station in 1993 and serving as team leader there as of 1997. After 11 years in Africa, he returned to CIMMYT Headquarters in Mexico to serve in directing positions in the Global Maize Program. He currently is director of CIMMYT’s Genetic Resources Program and leads the Seeds of Discovery project, which is developing an open-access platform of genomic and phenotypic databases along with informatics tools to facilitate the use of maize and wheat biodiversity in applied research and breeding programs. His accomplishments include development of disease-resistant and nutritionally enhanced maize varieties.

Selected Recent Publications
Abebe Menkir, IITA

Flagship Projects 2 and 3

Biodata
Abebe Menkir holds a B.Sc. in plant science, an M.Sc. and a Ph.D. in plant breeding from Addis Ababa University (Ethiopia), University of Manitoba (Canada) and Kansas State University (USA), respectively. Prior to his assignment at IITA, he worked as a sorghum and finger millet breeder at the Alemaya College of Agriculture and the Institute of Agricultural Research in Ethiopia. He refined the varietal development procedures for sorghum, broadened the genetic base of breeding populations and released four varieties for production in the different agro-ecological zones of the country. He has been working at IITA as a maize breeder-geneticist since 1996, developing many OPVs, inbred lines, and hybrids for mid-altitude and savanna zones in West and Central Africa, making them available to NARS through regional trials and other means. His current breeding emphases include high yield potential, resistance to diseases and Striga, drought tolerance, and broadening the genetic base of adapted maize germplasm. He has also been involved in the development of maize with enhanced iron, zinc, and pro-vitamin A content, and in breeding for resistance to the fungus responsible for aflatoxins. Abebe has been the team leader for maize improvement research at IITA since 2001 and works with 4 scientists and supervises 30 support staff. He has maintained constant interactions with scientists in the national programs and served as elected member of the Research Committee of the regional maize network for West and Central Africa WECAMAN that reviews project proposals and progress reports and recommends funding to NARS through the network. He served as elected coordinator of the IITA multidisciplinary project on maize-grain legume production systems from 1999 to 2001. He has been one of the principal investigators of several special projects, which have attracted more than US$40 million from different donors. He has trained 14 Ph.D. and 11 M.Sc. students under his supervision and guidance and developed a large number of inbred lines, open-pollinated varieties and hybrids, making them available to NARS through regional trials. Twenty-five maize varieties and 35 hybrids with tolerance to drought, resistance to Striga hermonthica, high provitamin A content, and herbicide resistance developed in his breeding program were released for production in different countries. He has been an author or co-author of a book, 127 peer-reviewed journal articles, 10 book chapters, 16 abstracts, 3 monographs, 3 newsletter articles and 9 annual reports, and has made 82 workshop presentations. He also registered 20 inbred lines with resistance to gray leaf spot, 26 inbred lines with resistance to Striga hermonthica, and 6 inbred lines with resistance to aflatoxin in Crop Science.

Selected Recent Publications
Menkir A, Chikoye D, Lum F. 2009. Incorporating an herbicide resistance gene into tropical maize with inherent polynomic resistance to control Striga hermonthica (Del.) Benth. (Published online in Plant Breeding).
Bruno Gérard, CIMMYT

Flagship Project 4

Biodata
Bruno Gérard is the Director of CIMMYT’s Global Conservation Agriculture Program. He leads a team of 40 international scientists focusing on sustainable intensification of maize and wheat-based systems in Sub-Saharan Africa, South Asia and Latin America. Before joining CIMMYT, he worked for ICRISAT in Niger and ILRI in Ethiopia. He was trained as agricultural engineer and irrigation engineer, and holds M.Sc. degrees from the University Catholique de Louvain and Utah State University and a Ph.D. from the plant nutrition department at the University of Hohenheim. His research includes geo-spatial system analysis, research design, soil fertility management, and farm and landscape level crop-livestock integration in smallholder farming systems.

Scientific Career
• September 2011 – Present: Director, Global Conservation Agriculture Program, International Maize and Wheat Improvement Center (CIMMYT)
• September 2005 - August 2008: Visiting Scientist seconded from ICRISAT at Université Catholique de Louvain
• January 2000 - August 2005: Principal Scientist International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
• November 1998 - November 1999: University of Hohenheim (Sabbatical)
• September 1991 - October 1998: Farm and Engineering Services Manager International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
• September 1990 - June 1991: Research Assistant and project Engineer, Université Catholique de Louvain
• February 1987 - June 1990: Research Assistant, Utah State University
• Adjunct professor at Ganzu Agricultural University since August 2014

Selected Recent Publications
Bernard Vanlauwe, IITA

Flagship Project 4

Biodata
Bernard Vanlauwe joined IITA in Kenya in March 2012 to lead the Central Africa hub and the Natural Resource Management research area. In this capacity, he also has an oversight role in the Humid Tropics, Water, Land, Ecosystems and CCAFS CGIAR Research Programs. Prior to this recent appointment, he was the leader of the Integrated Soil Fertility Management (ISFM) program of the Tropical Soil Biology and Fertility research area of CIAT (TSBF-CIAT). He joined CIAT-TSBF in 2001 and led the development, adaptation and dissemination of best ISFM options in various agro-ecological zones in sub-Saharan Africa. In September 2010, he obtained a visiting professor position at Swedish Agricultural University in Uppsala in the Soils and Environment Department. Before, he worked at IITA in Nigeria (1991–2000) and Catholic University of Leuven, Belgium (1989-1991), focusing on unraveling the mechanisms underlying nutrient and soil organic matter dynamics in tropical agro-ecosystems. In that context, he obtained his Ph.D. in Applied Biological Sciences in 1996. He has published over 140 papers in scientific journals and over 160 in other forms and has (co-) supervised over 40 Ph.D. and over 60 M.Sc. students.

Scientific Career
- IITA, Nairobi, Kenya. 2012 – present: Director for Central Africa and Natural Resource Management
- Swedish Agricultural University (SLU), Uppsala, Sweden, 2010 – present: Guest Professor
- Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture (CIAT), Nairobi, Kenya. 2001 – 2012: Senior Scientist
- IITA, Ibadan, Nigeria. 1997 – 2000: Associate Scientist
- Laboratory of Soil Fertility and Soil Biology, K. U. Leuven, Belgium. 1990 – 1991: Research Assistant

Selected Recent Publications
Vincenzo Fogliano, Wageningen University

Flagship Project 5

Biodata
Vincenzo Fogliano is Full Professor and Chair of the Food Quality and Design Group at the University of Wageningen (The Netherlands). He has an M.Sc. in chemistry from the University of Rome “La Sapienza”, and a Ph.D. in food science, Corvinus University of Budapest. His fields of expertise include food design, thermal treatment, and food bioactives. During his professional career, Vincenzo has had the opportunity to investigate many aspects related to food processing, human nutrition and medical science related to bioactive food compounds. He has worked on the design of functional foods containing dietary fiber, proteins and phytochemicals from different sources in collaboration with many food industries. He has investigated chemical analytical and physiological aspects of the Maillard Reaction with the consequent formation of beneficial and detrimental bioactive products. He also developed an original research line connecting food science and phytochemicals, and their health effects, particularly inflammation and cancer. Vincenzo has acted as a consulting expert for some of the main Italian and international food companies. He was coordinator of FP7 EU projects, COST action and strategic national cluster Italian projects, and was a partner in several EU projects since 1998 (FP4). He was president of the International Maillard Reaction Society up to 2012, and member of the advisory board of ILSI Europe as well as of the editorial board of leading food science journals. He has guided 14 Ph.D. students, some of whom now occupy leading positions in academia and the food industry, and is presently supervising 18 Ph.D. students. Vincenzo has authored more than 250 papers published in peer-reviewed international journals with 6000 citations and an index of 46. He is cited in the ISI Thompson list of the World’s Highly Cited Scientists (www.highlycited.com).

Selected Recent Publications
Bussie Maziya-Dixon, IITA

Flagship Project 3, CoA 3.3 & Flagship Project 5

Biodata
After graduating with a B.Sc. in home economics, an M.Sc. in food science and a Ph.D. in food science from Kansas State University, Manhattan, Kansas, USA, Maziya-Dixon worked as Associate Lecturer, Department of Food Technology, University of Ibadan, Nigeria, before joining IITA as a Food Scientist/Crop Utilization Scientist. She is a citizen of Swaziland, conducts research on nutritional quality, processing, utilization, and product development and evaluation of maize aimed at providing a diversity of secondary food products for rural and urban poor or high value products for the richer consumers. She coordinates workshops to create awareness of innovative post-harvest technologies to enhance adoption of nutritious and safe food products, and also conducts research on nutritional assessment of children under 5 and women of childbearing age to guide in targeting of agricultural-based interventions thus promoting the agriculture-nutrition-health linkage. Together with national partners, she is involved in devising a mechanism for promoting strong linkages between agriculture and nutrition with a gender perspective in order to reduce food insecurity and malnutrition on a sustainable basis. Maziya-Dixon has experience in managing and coordinating projects that involve a variety of development partners, colleagues from national and international institutions with specialization in a range of disciplines, such as agriculture, public health, nutrition, economics, and biometrics. She has experience in administrative and management skills together with project design, implementation, and monitoring. In addition, she has led or participated in interdisciplinary teams in proposal writing, project design, implementation, and monitoring of research for development projects. She leads the IITA team for CRP on Agriculture for Nutrition and Health.

Selected Recent Publications
Natalia Palacios, CIMMYT

Flagship Project 3, CoA 3.3 & Flagship Project 5

Biodata
Natalia Palacios Rojas studied microbiology at Andes University in Bogotá, Colombia, and did her doctoral studies in plant biochemistry at the University of East Anglia and the John Innes Centre in Norwich, England. She did two postdocs at the University of Dublin and the Max Planck Institute for molecular plant physiology in Potsdam, Germany. She has been working as a nutritional quality specialist at CIMMYT since 2005. She is head of the Nutritional Quality Laboratory and nutritional maize activities. She has published more than 40 articles in refereed journals, 7 book chapters and more than 10 magazines and brochures of science. She has served as (co)supervisor for over 10 Ph.D. students and 14 M.Sc. students. Her main area of work is the development of maize germplasm with high nutritional quality, including high quality protein maize, high zinc and high provitamin A maize. This includes assessing the nutritional quality of food products and phenotyping of genetic diversity for the nutritional, end-use and culinary quality of maize.

Selected Recent Publications


Cluster of Activities (CoA) Leaders

Gideon Kruseman, CIMMYT

Flagship Project 1, CoA 1.1

Biodata
Gideon Kruseman studied development economics in Wageningen, The Netherlands, where he obtained his Ph.D. degree with research on bio-economic modeling for sustainable intensification at the household level. He has worked as a researcher, post-doc and senior research fellow at CIAT, Development Economics Group and the Environmental Economics Group at Wageningen University, the Institute for Environmental Studies, Free University Amsterdam, and the Agricultural Economics Research Institute LEI, The Hague. He has worked as an ex-ante and foresight specialist with CIMMYT since 2015. His specialties include a variety of subjects such as water management, soil degradation and non-point source pollution versed in environmental and ecological economics besides agricultural and development economics. He combines excellent quantitative analysis skills with the ability to unravel complex issues related to sustainable development, especially regarding ex-ante assessment of policies, technologies and their impact on rural livelihoods. He has worked on integrated rural development in Egypt, adaptation to climate change in Tunisia, deforestation in Pakistan, soil and water conservation in Kenya, Ethiopia, Mali and China, and on national and international agricultural research in Europe, Latin America, Africa and Asia. He is well versed in a wide variety of modeling languages.

Selected Recent Publications
Sika Gbegbelegbe, IITA

Flagship Project 1, CoA 1.1

Biodata
Sika Gbegbelegbe is a scientist in IITA whose research interests involve the use of bio-economic modeling to quantify the impact of climate change and promising agricultural technologies at various scales: from global to farm. She earned her PhD in agricultural economics (international development) from Purdue University and a Master’s degree in agricultural economics (environmental economics) from the University of Guelph.

Selected Recent Publications
Michelle Guertin, CIMMYT

Flagship Project 1, CoA 1.2

Biodata
Michelle Guertin is Senior Monitoring, Evaluation and Learning Specialist for both MAIZE and WHEAT CRPs, based at CIMMYT, Mexico. She studied Agricultural and Environmental Sciences at McGill University and did her master’s degree in Environmental Sciences at Université de Sherbrooke, Canada. Michelle joined CIMMYT in July 2014. Prior to joining CIMMYT, she worked for over 12 years with the Government of Canada, where she was Senior Evaluation Manager in two ministries: the Ministry of Environment and the Canadian International Development Agency [now the Department of Foreign Affairs, Trade and Development (DFATD)]. She has worked on developing policies and programs, implementing complex national regulatory programs and international negotiations, and monitoring and evaluating programs and policies. She has managed multidisciplinary teams for over 10 years and led DFATD’s Development Evaluation Directorate as Interim Director for prolonged periods. She has represented Canada at several multilateral forums, including the OECD Development Assistance Committee (DAC) and the Multilateral Organisation Performance Assessment Network (MOPAN). She received multiple Government of Canada awards for exceeding performance expectations and making an outstanding contribution to the success of the organization. Most of her publications are focused on technical evaluation reports that she managed. The reports were reviewed by an independent advisory committee and published by the Government of Canada.

Selected Recent Publications
Lone Badstue, CIMMYT

Flagship Project 1, CoA 1.3

Biodata
Lone Badstue is CIMMYT’s strategic leader for Gender Research and Mainstreaming, based in Mexico. She holds a Ph.D. in rural development sociology as well as an M.A. in social anthropology with specialization on gender and livelihood strategies in agriculture and natural resource management. With over 20 years of experience working with international development issues, Badstue has broad experience working with different types of social actors and multi-disciplinary teams on issues related to rural development processes, including: smallholder agriculture, natural resource management, social organization and gender relations, collective action, knowledge processes and technology diffusion, institutions and capacity building. She is fluent in English and Spanish, and has a good working knowledge of French.

Appointments
- October 2011 till present: Strategic Leader for Gender Research and Mainstreaming, International Maize and Wheat Improvement Center (CIMMYT), Mexico.
- October 2006 – June 2007: Consultant on gender and rural development (Swiss Development Corporation, Nicaragua), and on participatory crop improvement (CIMMYT, El Salvador)
- October 2000 – May 2006: Associate Scientist, CIMMYT, Mexico.

Selected Publications
Amare Tegbaru, IITA

Flagship Project 1, CoA 1.3

Biodata
Amare Tegbaru is IITA Gender Specialist, Gender Unit Head and Humid Tropics Gender Research Coordinator based in IITA Tanzania Eastern Africa Regional Hub. He was educated in Ethiopia, France and Sweden. He received his Ph.D. from Stockholm University in Social Anthropology in 1998. He undertook his undergraduate studies in Economics and Political Science from Paris Sorbonne University (1973-1976), and graduate studies at Addis Ababa University (1970-1973). Amare has over 25 years of progressively responsible work experience in research and rural development, program coordination, management and implementation in Southeast and South Asia as well as eastern and western Africa. He is an experienced project manager, who successfully managed productive projects for FAO in Thailand (1990-91), CIAT in Rwanda (2005-2007), and for IITA in Nigeria (2008-2010) and Liberia (2010-2014). He has experience in managing projects through difficult times. He is instrumental in the development of Gender Research Strategy of the CRP1.2 Humid Tropics, and has made contributions to the Gender Strategy of CRP 3.2 MAIZE and CRP 3.4 Roots, Tubers and Bananas.

Selected Recent Publications
Christine Okali, Mike Loevensohn and Amare Tegbaru (2014) Interpreting the agricultural transformation agenda – women’s roles in seed systems. FAO Discussion Paper, Institute of Development Studies, UK.
Jon Hellin, CIMMYT

Flagship Project 1, CoA 1.4

Biodata
Jon Hellin has 25 years of experience in agricultural research and rural development (farmers’ access to markets, land management, and climate change adaptation and mitigation) including 12 years’ field work in Latin America, East Africa, South Asia and the Caribbean. He has authored and co-authored two books and over 80 articles (including 50 in peer-reviewed journals). He has lectured at universities in the United Kingdom, United States and Central America. His current research interests include making markets work for the poor; index insurance and farmers’ uptake of climate-smart agricultural technologies; and agricultural development in the Western Highlands of Guatemala focusing on farmers’ use of maize landraces and also soil conservation.

Selected Recent Publications
Kate Dreher, CIMMYT

Flagship Project 2, CoA 2.1

Biodata
Kate Dreher is Germplasm Data Coordinator of CIMMYT. She studied biology and economics at Williams College in Williamstown, USA. She then worked for one year at CIMMYT, based in El Batan, México before going on to carry out her doctoral studies in plant biology at the University of California, Davis, USA. She transitioned from her lab-based research in plant molecular biology to work in biological curation and data management at the Carnegie Institution for Science in the Department of Plant Biology. There she worked to help make data available to the international scientific community through The Arabidopsis Information Resource (TAIR) and the Plant Metabolic Network. She has been working as a Germplasm Data Coordinator at CIMMYT since 2013. She has 12 articles published in peer-reviewed journals and one book chapter. At UC Davis and the Carnegie Institution for Science she helped to supervise 12 undergraduate students. At CIMMYT, she helps to coordinate efforts to implement institutional databases and tools for storing and utilizing maize and wheat phenotypic, genotypic, and genealogical data. She also collaborates with the members of the Knowledge Management unit who focus on the management of agronomic and socio-economic data. Her responsibilities include helping CIMMYT to further develop its Open Access policies, resources, and implementation plans in conjunction with other CGIAR centers.

Selected Publications
Mike Olsen, CIMMYT

Flagship Project 2, CoA 2.2

Biodata
Mike had 14 years of private sector experience in conventional and molecular maize breeding as part of Syngenta and Monsanto North America breeding teams. He was recognized as Monsanto Fellow in 2012. He was the co-inventor of 23 commercially utilized maize inbred lines and 8 hybrid varieties with US patents issued between 2009 and 2015. He has two years of public sector experience leading the molecular breeding team of the CIMMYT Global Maize Program and providing strategic direction for upstream research efforts. He has been serving as Project lead for Improved Maize for African Soils (IMAS), a multi-institutional public-private partnership to develop maize varieties with improved performance under low fertility conditions common in Sub-Saharan Africa. He is presently Principal Investigator for the Genomics and Open source Breeding and Informatics Initiative (GOBII), a partnership between Cornell University, ICRISAT, IRRI, and CIMMYT to enable routine use of genomic data in applied CGIAR breeding programs through integration of appropriate infrastructure, databases, analysis pipelines, and user interfaces.

Selected Recent Publications
Melaku Gedil, IITA

Flagship Project 2, CoA 2.2

Biodata
Melaku Gedil has worked for IITA, Nigeria, since April 2007 and is presently the Head of the Bioscience Center and Molecular Geneticist/Breeder. He obtained his B.Sc. in Plant Sciences from Addis Abeba University, Ethiopia, and his M.Sc. in Plant Breeding from Alemaya University of Agriculture, Ethiopia. His Ph.D. thesis project (Oregon State University) focused on molecular biology (linkage mapping, candidate resistance gene, diversity analysis). He did his postdoc at IITA and worked at Georgetown University, USA, before returning to IITA in 2007. Later, he earned his M.Sc. in biotechnology/bioinformatics to enhance his computational skills for application in molecular breeding. He hopes to draw on his background in plant breeding, statistical genetics, molecular biology, and bioinformatics for developing and applying an efficient and effective molecular breeding program for pest and disease resistance, quality traits, and abiotic stresses such as drought. Among the approaches he uses are marker-assisted recurrent selection (MARS), genome wide association study (GWAS), genome selection, linkage/QTL mapping, comparative genomics and bioinformatics. He is also heavily involved in training and mentoring graduate students and technicians, and has served as a resource person in many workshops.

Selected Recent Publications
Sarah Hearne, CIMMYT

Flagship Project 2, CoA 2.3

Biodata
Sarah Hearne is Senior Scientist, molecular geneticist and pre-breeder at CIMMYT, Mexico. Her work includes development of new analytical approaches to explore and understand maize genetic diversity through the application of next generation sequencing; assessment of the genetic diversity of the CIMMYT genebank collection of maize and other publically accessible maize genetic resources including ex-PVP temperate materials; GWAS for high priority traits across the world’s most diverse maize panel; and genomic selection for abiotic stress characters from maize landraces. She has a PhD degree from the University of Sheffield, The John Innes Centre and Syngenta (UK). During 2005-2011, Sarah served as a Scientist at; IITA-Ibadan and IITA-Nairobi as Plant Molecular Geneticist/Physiologist, and prior to that as a Post-Doctoral Fellow at CIMMYT, Mexico, from 2001-2003, and at IITA-Ibadan from 2004-2005.

Selected Recent Publications
Terence Molnar, CIMMYT

Flagship Project 2, CoA 2.4

Biodata
Terence (Terry) Molnar is Senior Scientist at pre-breeder at CIMMYT, Mexico, since 2013. His work includes phenotypic evaluation and breeding of maize genetic resources in the Seeds of Discovery (SeeD) project at CIMMYT. Terry had 13 years of work experience in DuPont-Pioneer in USA. He was the Lead Scientist for a maize breeding program developing inbreds and hybrids for the central Corn Belt of the United States (Pioneer 108 – 113 CRM) during 2011-2013, and was Lead scientist for a maize breeding program that developed inbreds and hybrids for the early silage and grain markets of northern France, Germany, and the rest of northern and eastern Europe (~100 to 250 FAO maize maturity), during 2002-2010. While serving DuPont-Pioneer, Terry developed inbreds that are parents in 9 commercial hybrids registered in EU member countries and 14 inbreds currently patented or submitted into the patenting process, and was listed on more than 15 inbred & hybrid hybrid patent applications. Terry obtained his MS and PhD degrees in Crop Science from North Carolina State University, USA.

Selected Publications


Felix San Vicente, CIMMYT

Flagship Project 3, CoA 3.1 (Latin America)

Biodata
Felix San Vicente is a plant breeder, with broad experience in tropical maize breeding. He has spent more than 30 years developing and adapting breeding methods for increasing genetic gains in tropical maize. During his time at CIMMYT, he has developed 12 hybrids and 8 open pollinated varieties (OPVs) which are grown commercially on about 500,000 ha in 10 countries of Latin America. He has also been part of a team that has developed 15 CIMMYT Maize Lines (CMLs), which are elite germplasm used as parents of maize hybrids in at least 25 different countries worldwide.

Selected Publications
Jill Cairns, CIMMYT

Flagship Project 3, CoA 3.1 (Africa)

Biodata
Jill Cairns is Senior Maize Physiologist in the CIMMYT Global Maize Program, based at Harare, Zimbabwe. She is leading the efforts for incorporating heat stress tolerance into the CIMMYT and IITA maize breeding pipelines in sub-Saharan Africa (SSA). Using a combination of climate modelling and field experiments, she showed heat stress will become an issue of increasing importance in SSA under climate change, particularly in drought prone environments, while current commercial varieties are highly sensitive to heat stress. Jill has also identified key drought tolerant and heat tolerant donors for maize breeding through systematic screening of inbred lines within CIMMYT and IITA maize breeding programs. The publication and promotion of these results has resulted in these lines being widely incorporated into international and national breeding programs in sub-Saharan Africa, Mexico and Asia. She has also established remote sensing capacity within the national maize breeding program of Zimbabwe, and facilitated linkages between advanced research institutes and the Crop Breeding Institute (Zimbabwe). Jill has quantified genetic gains within the maize breeding pipeline in eastern and southern Africa, providing the baseline for measuring future success of the maize breeding pipeline through the addition of new tools and techniques.

Selected Recent Publications
**Vivek B.S., CIMMYT**

**Flagship Project 3, CoA 3.1 (Asia)**

**Biodata**

Vivek obtained his BSc (Agriculture) from the University of Agricultural Sciences, Bangalore, India; MS and a PhD in Plant Breeding and Plant Genetics from the University of Wisconsin-Madison, USA. After joining CIMMYT in 1997, he has worked as a Maize Breeder in Mexico, Zimbabwe and India, where he is presently based. His contributions to maize germplasm improvement figure in the releases of numerous maize hybrids and open-pollinated varieties (OPVs) in sub-Saharan Africa. He trained several maize breeders in Africa and Asia, including supervision of 9 Master’s and 5 PhD students. He led the development of a software “Fieldbook” that is used by many maize breeders. His research findings are published in over 23 refereed journal articles and at least two practical manuals. Notable contributions of Vivek on the professional partnership front is the formation of the International Maize Improvement Consortium for Asia (IMIC-Asia), a consortium of over 40 seed companies, in an effort to better engage the private seed industry of Asia and to enable focused development and deployment of high-yielding, stress tolerant maize hybrids for markets in South and South-East Asia.

**Selected Recent Publications**


Biodata
Lava Kumar is the Head of the Germplasm Health Unit/Virology at IITA. He obtained M.Sc. and Ph.D. degrees in virology from Sri Venkatewara University, India. His areas of research involve characterization, diagnosis and control of plant viruses affecting maize, banana, cassava, yam, cowpea and soybean in sub-Saharan Africa. His program is also involved in the production of disease-free planting materials of seed and vegetatively propagated crops, surveillance of invasive transboundary pathogens, development of cost-effective diagnostics and phenotyping for virus disease resistance. He has more than 50 articles in peer-reviewed journals, 10 book chapters, 2 edited books and several conference presentations to his credit. He is actively involved in technology dissemination and capacity development of NARS through training courses and workshops on plant disease diagnostics and control. He has co-supervised more than 10 Ph.D. students. He has ongoing research programs on maize streak and maize lethal necrosis, including phenotyping maize lines and hybrids for virus resistance; identifying genetic determinants and markers; developing low-cost diagnostic tools; and investigating disease epidemiology and control measures.

Selected Recent Publications
Biodata

P.H. Zaidi obtained his master degree in Plant Physiology from Awadh University, Faizabad, India, and did his doctorate studies in crop physiology from N.D. University of Agriculture & Technology, Kumargunj, India. He did over three years post-doctoral research at Indian Agricultural Research Institute (IARI), New Delhi, India. He joined as Maize Physiologist at Directorate of Maize Research, Indian Council of Agricultural Research (ICAR), and India in 1997 and led the Abiotic stress program of All-India Co-ordinate Maize Improvement program. He has been working at CIMMYT Asia maize program since 2007 and focused on strengthening CIMMYT germplasm base relevant for the Asian region. As lead of abiotic stress program of CIMMYT-Asia, he developed/standardized screening protocol and selection criteria for various stresses, and identified source germplasm and trait donors for various abiotic stresses. He played a key role in further strengthening the collaborative research activities of CIMMYT with all the Asian NARS, and initiated collaborative research activity with new partners in the region. He published over 80 articles, including research papers in refereed journals, reviews and book chapters, wrote 4 books on abiotic stress and co-authored several proceeding and books. His main area of work is abiotic stress tolerance in maize including precision phenotyping tools and methods, developing new sources of germplasm and trait donors for complex abiotic stresses, including drought, heat, water-logging, and more recently combined stress tolerance, such as drought + heat or drought + water + logging stress.

Selected Recent Publications


Baffour Badu-Apraku, IITA

Flagship Project 3, CoA 3.5

Biodata
Baffour Badu-Apraku is a Senior Scientist at IITA. Baffour has a Ph.D. in Genetics and Plant Breeding from Cornell University, Ithaca, USA. He was the Coordinator of IITA’s West and Central Africa Collaborative Maize Research Network from 1992 to 2006. Before joining IITA, he was the leader of the Ghana National Maize Program and also the Joint Coordinator of the Ghana-CIDA Grains Development Project from 1987 to 1992. Under his leadership, a QPM laboratory was established in Ghana for screening maize genotypes for high lysine content. The QPM variety Obatanpa GH was developed and released, and has been widely adopted in Ghana, Benin, Togo, Mali, Senegal, Cameroon, Côte d’Ivoire, Burkina Faso, Nigeria, Chad, Guinea, Uganda, Malawi, Swaziland, Zimbabwe, Mozambique, South Africa, and Ethiopia. In addition, appropriate recommendations for maize and legume-based cropping systems and several maize, cowpea, and soybean varieties were released and widely adopted in Ghana. Through his maize breeding program at IITA since 1992, several Striga-resistant and drought-tolerant early and extra-early populations have been developed and are serving as valuable sources of varieties and inbred lines for breeders of the sub-region. Over the years, many early and extra-early Striga, drought and low soil nitrogen-tolerant varieties and, more recently, hybrids have been developed in his program, formally released, and widely adopted by farmers in the sub-region. Baffour has also conducted research to improve maize selection and evaluation procedures including breeding for resistance to multiple stresses, identification of indirect selection criteria, and grouping of evaluation sites into mega-environments using GGE biplot analysis of genotype × trait interaction and factor analysis of repeatability estimates. His most recent achievement includes the development of Striga-resistant and low soil nitrogen-tolerant extra-early varieties and hybrids with genes for tolerance to drought at the flowering and grain-filling periods. He led a group of scientists to develop a heterotic grouping method, designated HGCMAT. He has published nearly 80 journal articles and 14 books and book chapters and over 78 conference papers.

Selected Publications
Jens A. Andersson, CIMMYT

Flagship Project 4, CoA 4.2

Biodata
Jens Anderson currently works as an Innovation Scientist and Rural Development Sociologist at CIMMYT. Trained as a rural development sociologist, his research has focused on understanding smallholder farming practices, rural-urban linkages, and the significance of land and agriculture in rural livelihoods. More recently, he has also focused on the organization of agricultural research. The engagement with, and participation of, different stakeholders - notably farmers - in the development of new technologies and design of agronomic experiments is central to his work at CIMMYT.

Selected Recent Publications
Stephen K. Boahen, IITA

Flagship Project 4, CoA 4.3

Biodata
Stephen K. Boahen is a Systems Agronomist at the International Institute of Tropical Agriculture (IITA), Nampula, Mozambique. He received his Bachelor of Science degree in Crop Science from the University of Ghana, Master of Science degree in Agronomy from the University of Helsinki and Doctorate degree in Plant Science from the University of Saskatchewan, Canada. He has vast experience in agronomy, soil fertility management, plant stress physiology and seed systems. His main research interests include the development of improved crop management strategies for legume-based cropping systems with a focus on identifying the physiological and management constraints to agronomic performance; development of sustainable soil fertility management through nitrogen fixation, P application and cropping systems; and the development of community-based seed systems. He has published more than 20 articles in refereed journals and over 15 papers in conference proceedings. He has co-supervised eight M.Sc. and four Ph.D. students.

Selected Publications:
Timothy J. Krupnik, CIMMYT

Flagship Project 4, CoA 4.3

Biodata
Timothy J. Krupnik, Systems Agronomist, is currently based in Dhaka, Bangladesh, and has worked with CIMMYT since 2011. His training is in Environmental Studies with concentration in Agroecology from the University of California, Santa Cruz, and an MSc in International Agricultural Development from the University of California, Davis. At CIMMYT, Timothy's work focuses on sustainable intensification of tropical farming systems through participatory research and extension. Since joining CIMMYT, he has led and managed multi-million dollar USAID and EU research for development programs, and currently manages a portfolio of applied and multidisciplinary research efforts in tropical maize, wheat, and rice systems agronomy, farming systems analysis, scale-appropriate farm machinery, and the integration of environmental and development goals in agricultural production. He has conducted research and consulted in Senegal, India, Madagascar, Bangladesh, Haiti, Ethiopia, and Kenya, and has authored 15 peer-reviewed papers with another 14 submitted or in preparation, one book, five technical reports, three book chapters, two book reviews, 43 published conference proceedings, posters, and presentations, and 15 extension and training materials, including seven farmer training videos with documented viewership of over 110,000 farmers and millions of television viewers. Timothy's science to scaling efforts have resulted in private-sector uptake and sales of efficient seeding, irrigation, and harvesting equipment in Bangladesh, with over 15,000 farmers utilizing improved agricultural machineries on over 6,500 hectares.

Selected Recent Publications


Hugo De Groote, CIMMYT

Flagship Project 5, CoA 5.4

Biodata

Hugo De Groote is an agricultural economist and principal scientist with CIMMYT, based in Kenya. He received an M.Sc. in tropical agriculture from the University of Ghent, Belgium, and a Ph.D. in Agricultural Economics from the University of Wisconsin, U.S.A. His research activities include the economic analysis and participatory evaluation of new technologies (such as stress resistant and nutritionally enhanced maize varieties, crop management, hermetic grain storage), consumer acceptance of new maize products using experimental methods (including vitamin A biofortified maize, quality protein maize and aflatoxin tested maize), and analysis of policies and institutions relevant to these technologies and products (such as seed systems, input subsidies, credit and extension systems, and biosafety policies). Previously, he was coordinator of the biological control project at the International Institute for Tropical Agriculture (IITA), in Benin, conducting economic analysis and participatory evaluation of biological control of pests such as water hyacinth, locusts and mango mealybug. He also worked in Farming Systems Research with the Royal Tropical Institute (KIT), developing and evaluating new technologies, and evaluated group-based credit and loan associations with the International Food Policy Research Institute (IFPRI), both in Mali. Before this research, he worked as an agriculturalist in rural development for Non-Governmental Organizations in Togo and Thailand.

Selected Recent Publications


Tsedeke Abate, CIMMYT

CoA 3.6 (Africa)

Biodata
Tsedeke Abate was formerly Director General of the Ethiopian Institute of Agricultural Research (EIAR) and currently leads the Drought Tolerant Maize for Africa project, implemented in 13 countries across Africa, based at CIMMYT-Nairobi. Prior to joining CIMMYT, Tsedeke led the Tropical Legumes II project jointly implemented by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Center for Tropical Agriculture (CIAT), and the International Institute of Tropical Agriculture (IITA), in Africa and South Asia. Tsedeke is best known for his passion for putting agricultural knowledge into practical use – scaling-up and scaling-out improved technologies to impact the lives and livelihoods of smallholder farmers. Tsedeke has widely published on African agriculture. He obtained his B.Sc. in agriculture (high honors, 1977) from the University of Florida, Gainesville, Florida, USA; M.Sc. in entomology/agriculture (1979), also from the University of Florida; and a Ph.D. in biological sciences (1990) from Simon Fraser University, Vancouver, Canada.

Selected Publications
Abate T. 2012 – 2015: DT Maize, a quarterly bulletin of the DTMA project: www.dtma.cimmyt.org (launched, written and produced 13 issues of this special bulletin).
Abate T; Shiferaw B; Gebeyehu S; Amsalu B; Negash K; Assefa K; Eshete M; Aliye S; Hagmann J. 2011. A systems and partnership approach to agricultural research for development: Lessons from Ethiopia. Outlook on Agriculture 40(3): 213-220.
Sadananda A.R., CIMMYT

CoA 3.6 (Asia)

Biodata
A.R. Sadananda, Maize Seed System Specialist for South Asia, based at CIMMYT-Asia, Hyderabad, has 36 years of research & seed industry experience. He had done his PhD in Genetics from Indian Agricultural Research Institute, New Delhi, post-doctoral work on molecular breeding, as Rockefeller Fellow, at University of Georgia, USA, and business management diplomas from IGNOU, New Delhi and Cornell University, USA. He worked in the rice breeding program of IARI for 16 years, at various capacities, and contributed in development of 7 CVRC notified varieties & hybrids and was recognized by Government of India for development of basmati rice cultivars in India. He also worked in NFCL, Advanta, Emergent Genetics, Monsanto & Vibha seeds, at various capacities and roles in research & technology management, supporting commercial objectives of the business. As CIMMYT Maize Seed Systems Specialist in Asia, his main role is to support institutions of national agricultural research systems and SME enterprises in deployment of maize hybrids to the farming communities in the target regions.

Selected Publications
Arturo Silva Hinojosa, CIMMYT

CoA 3.6 (Latin America)

Biodata
Arturo is leader of the International Maize Improvement Consortium (IMIC) for Latin America, based at CIMMYT, Mexico, since 2014. He graduated from ITESM with a degree in International Business, and holds an MBA from Instituto de Empresa in Madrid. He worked for three major seed companies (Dupont-Pioneer, Syngenta and Monsanto) in diverse geographies, holding positions in Sales, Operations, Marketing and Strategy. Arturo’s responsibilities in his earlier jobs included: establishing the overall product and marketing strategy for the Africa region for DuPont-Pioneer; defining and implementing strategies for corn and sorghum seed business in Mexico for Syngenta; developing the Latin America North supply plan matching demand with cost targets for Monsanto; and supply planning and demand forecasting of the product portfolio in South America for Dupont-Pioneer. As IMIC-Latin America Leader at CIMMYT under the MasAgro-Maize program, Arturo is actively engaged in deploying high-yielding, stress-tolerant, and nutritionally-enhanced hybrids in the Latin American tropics/subtropics, especially in Mexico, through public-private partnerships.

Appointments
- Leader of the IMIC-Latin America at CIMMYT, Mexico (2014 – till date)
- Senior Manager, Marketing and Product Strategy for Africa at Pioneer Hi-Bred (2012-2014)
- Mexico Seeds Manager at Syngenta (2007 – 2011)
- LAN Commercial Seed Planning & Allocations Manager at Monsanto (2002 – 2006)
- Product Manager Southern Cone at Pioneer Hi-Bred (1999 – 2001)
- Sales Manager at ProGenetic SA de CV (1994 – 1998)
David Kahan, CIMMYT

CoA 4.4

Biodata
David Kahan has over 30 years’ developing country experience in agricultural and rural development in Africa, Asia, the Caribbean and the Middle East. David worked for FAO as Senior Officer in Agribusiness and Enterprise Development (2000-2010) and Principal Officer Agricultural Innovation and Extension (2010-2013), leading activities in agri-business development, agricultural innovation and extension. Prior to this, David worked as Project Manager/ Team Leader on various long term-field assignments in Africa (Lesotho, Ethiopia, Swaziland) and Asia (Myanmar). He has also conducted consultancies and specialist assignments for FAO, WFP, World Bank and AfDB. His specialization is in the areas of agribusiness development, agricultural extension, farm business management, farm economics, natural resource management, marketing and value chain development. Kahan is an agricultural economist with a Ph.D. in agricultural management/ rural development from the University of Reading.

Selected Recent Publications
Kahan D. 2013. Market-oriented advisory services in Asia – a review and lessons learned. FAO, Regional Office for Asia and the Pacific.
Alpha Yaya Kamara, a Sierra Leonean national, is a Systems Agronomist and a Senior Scientist working at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. He heads the IITA station in Kano, Nigeria, and coordinates the Consortium Research Program on Water, Land, and Ecosystems. He received his Bachelor of Science degree in General Agriculture from the Njala University College at the University of Sierra Leone in 1986, Master of Science degree in Agronomy from the Christian Albrecht’s University of Kiel, Germany, in 1993 and Doctorate degree in Agronomy and Natural Resource Management from the University of Kassel, Germany, in 1998. Kamara’s experience spans over 20 years, in the fields of agronomy, soil fertility management, seed systems development, crop science, natural resource management, stress physiology and farmer participatory evaluation of technologies, which enables him to initiate, design and efficiently implement research and development-oriented project activities in SSA. Kamara collaborates with National Agricultural Research Centers, extension agencies, NGOs, donors, and policy makers in West, Central, East and Southern Africa in the development and dissemination of complementary crop management practices and in the strengthening of seed systems in West Africa. He has led and is currently coordinating and managing several research for development oriented projects that are meant to improve rural livelihoods in sub-Saharan Africa. Kamara has contributed to many grant-winning proposals at IITA with a combined value of over 60 million US dollars. He has published over 70 journal articles, 20 articles in books of abstracts and over 20 papers in conference proceedings in the areas of natural resource management, soil fertility, weed and crop management and crop physiology. He has traveled widely in Africa, Europe, and North America to promote/participate in discussions on promoting sustainable agriculture in the African continent.

Selected Publications
MAIZE Program Management Staff

Dave Watson, CIMMYT

MAIZE Program Manager

Biodata
Dave grew up on small family farm in northeast England and has over 35 years of commercial farming experience. He has a B.Sc. in Agricultural Botany from the University of Reading, UK, and an M.Sc. and Ph.D. in food system development from the University of Hull, UK. Throughout the 1990s, he taught courses on Sustainable Agriculture and Environment at the University of Hull. During the past 15 years, Dave has managed research-for-development partnerships in sub-Saharan Africa, Latin America and Asia, first as program leader for innovative partnerships in the Innovation Systems Programme of the International Livestock Research Institute (ILRI) and, more recently, in his role as Director for Project Development and Management at the International Institute of Tropical Agriculture (IITA). Dave currently works for CIMMYT as Program Manager for the MAIZE CRP. Major achievements include the adoption of innovation systems and value chain approaches at IITA and promotion of outcomes and impact-focused approaches during MAIZE Phase I. Key aims of his professional career include ensuring that agricultural research is demand-driven and leads to significant development outcomes and impact.

Selected Publications
### 3.2 Major abiotic and biotic stresses affecting maize production in the tropics

<table>
<thead>
<tr>
<th>Region</th>
<th>Major abiotic stresses</th>
<th>Major biotic stresses</th>
</tr>
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</table>
| Sub-Saharan Africa| Drought  
 Poor soil fertility (sub-optimal soil N and P, soil acidity)  
 Heat  
 Combination of stresses (drought + heat; heat + sub-optimal soil N) | Maize lethal necrosis (MLN)  
 Maize streak virus (MSV)  
 Turcicum leaf blight (Exerohilum turcicum)  
 Gray leaf spot (GLS; Cercospora maydis-zeae)  
 Maydis leaf blight (Bipolaris maydis)  
 Common rust (Puccinia sorghi)  
 Southern rust (Puccinia polysora)  
 Stalk and ear rots (Diplodia and Fusarium spp.)  
 Kernel and ear rots (Aspergillus and Fusarium spp.)  
 Parasitic weed Striga (Striga asiatica and S. hermonthica)  
 Stem borers (Chilo spp., Busseola fusca and Sesamia calamistis)  
 Large grain borer (LGB; Prostephanus truncatus)  
 Maize weevil (Sitophilus zeamais) |
| Asia              | Drought  
 Drought + Heat  
 Drought + Waterlogging  
 Heat  
 Waterlogging  
 Cold  
 Salinity  
 Lodging  
 Soil acidity  
 Sub-optimal soil P and N | Downy mildews (Peronosclerospora species)  
 Banded leaf and sheath blight (BLSB; Rhizoctonia solanai f.sp. sasakii)  
 Post-flowering stalk rots (PFSR)  
 Gray leaf spot (GLS; Cercospora maydis-zeae)  
 Turcicum leaf blight (Exerohilum turcicum)  
 Maydis leaf blight (Bipolaris maydis)  
 Common rust (Puccinia sorghi)  
 Southern rust (Puccinia polysora)  
 Kernel and ear rots (Aspergillus and Fusarium spp.)  
 Stem borers (Chilo sp. and Busseola fusca)  
 Maize weevil (Sitophilus oryzae) |
| Latin America     | Drought  
 Soil acidity/Al toxicity  
 Heat  
 Sub-optimal soil P | Tar spot complex  
 Corn stunt complex  
 Turcicum leaf blight (Exerohilum turcicum)  
 Gray leaf spot (GLS; Cercospora maydis-zeae)  
 Maydis leaf blight (Bipolaris maydis)  
 Common rust (Puccinia sorghi)  
 Southern rust (Puccinia polysora)  
 Stalk and ear rots (Diplodia and Fusarium spp.)  
 Kernel and ear rots (Aspergillus and Fusarium spp.)  
 Large grain borer (LGB; Prostephanus truncatus)  
 Maize weevil (Sitophilus zeamais) |
### 3.3 MAIZE target product profiles for Sub-Saharan Africa, Latin America and Asia under CoA 3.1 and 3.2.

#### Sub-Saharan Africa

<table>
<thead>
<tr>
<th>Sub-region</th>
<th>Agro-ecology</th>
<th>Proportion of maize area in the region (%)</th>
<th>Target products*</th>
<th>Improved germplasm providers (with relative ranking)**</th>
<th>Justification for MAIZE investment in Phase-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Africa</td>
<td>Highlands</td>
<td>15</td>
<td>Late maturing (170-190 days), high yielding, nitrogen use efficient (NUE), acid soil tolerant, disease (MLN, MSV, TLB, GLS, PS, ear rots) resistant maize</td>
<td>Seed companies (1), NARS (2), CIMMYT (3)</td>
<td>MAIZE provides improved highland germplasm to help specific countries where seed companies have not invested (e.g., Rwanda and Burundi). Also, overall genetic gain in highlands has reduced and productivity has stagnated over the years due to a very narrow genetic base.</td>
</tr>
<tr>
<td>Upper humid mid-altitudes</td>
<td></td>
<td>25</td>
<td>Medium maturing (130-145 days), high yielding, NUE, DT, acid soil tolerance, aflatoxins, and disease (MLN, MSV, TLB, GLS, PS, ear rots) resistant maize</td>
<td>CIMMYT (1), Seed companies (2), NARS (3)</td>
<td>MAIZE is the major provider of adapted and diverse elite germplasm with relevant traits (e.g., MLN in DT genetic backgrounds); opportunities for upstream research to increase genetic gain and productivity.</td>
</tr>
<tr>
<td>Lower humid mid-altitudes</td>
<td></td>
<td>40</td>
<td>Medium maturing (120-130 days), high yielding, NUE, DT disease (MLN, TLB, GLS, PS, ear rots), Striga, aflatoxin, and insect-pest (B. fusca) resistant maize</td>
<td>CIMMYT (1), Seed companies (2), NARS (3)</td>
<td></td>
</tr>
<tr>
<td>Dry mid-altitudes</td>
<td></td>
<td>10</td>
<td>Early maturing (100-120 days), high yielding, DT, Heat, NUE, MLN, Striga, aflatoxin, and post-harvest insect-pest resistant maize</td>
<td>CIMMYT (1), Seed companies (2), NARS (3)</td>
<td>MAIZE is the major provider of adapted DT, NUE and heat tolerant germplasm, with relevant traits (e.g., MLN); opportunities for upstream research to increase genetic gain and productivity.</td>
</tr>
</tbody>
</table>

*Target products include specific traits such as disease resistance, nitrogen use efficiency (NUE), heat tolerance, etc.

**Providers are ranked based on their relative ranking, with 1 being the highest and 3 being the lowest.**
<table>
<thead>
<tr>
<th>Region</th>
<th>Days</th>
<th>Description</th>
<th>Provider</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humid lowlands</td>
<td>5</td>
<td>Early maturing (90-120 days), high yielding, DT, heat tolerant, NUE, disease (including MLN), aflatoxin, <em>pre- (C. partellus)</em> and post-harvest (LGB, maize weevil) insect-pest resistant maize</td>
<td>CIMMYT (1), Seed companies (2), NARS (3)</td>
<td>MAIZE is the major provider of diverse, well-adapted, early-maturing drought, NUE, and heat tolerant germplasm with specific traits of high demand (e.g., MLN); potential for further increasing productivity.</td>
</tr>
<tr>
<td>Dry lowlands</td>
<td>5</td>
<td>Extra-early maturing (80-100 days), high yielding, DT, <em>heat tolerant</em>, NUE, aflatoxin, <em>pre- (C. partellus)</em> and postharvest (LGB, maize weevil) insect-pest resistant maize</td>
<td>Seed companies (1), CIMMYT (2), NARS (3)</td>
<td>MAIZE is the major provider of diverse, well-adapted, early-maturing drought, NUE, and heat tolerant germplasm with other relevant traits (e.g., MLN); potential for further increasing productivity. Also, overall genetic gain in highlands has reduced and productivity has stagnated over the years due to a very narrow genetic base.</td>
</tr>
<tr>
<td>Southern Africa</td>
<td>2.1</td>
<td>Early to late maturing (115 to 145 days to PM), high yielding, DT, <em>heat tolerant</em>, NUE, disease (GLS, TLB, PLS, MSV and ear rots) resistant, and photoperiod sensitive maize.</td>
<td>Seed companies (1), NARS (2), CIMMYT (3)</td>
<td>MAIZE provides diverse, well-adapted, early to late maturing drought, NUE, and heat tolerant germplasm with other relevant traits (e.g., photoperiod sensitive germplasm with unique plant ideotype); potential for further increasing productivity.</td>
</tr>
<tr>
<td>Sub-tropical temperate</td>
<td>29.6</td>
<td>Early to late maturing (115 to 145 days to PM), high yielding, DT, <em>heat tolerant</em>, NUE, disease (GLS, MSV, HT, PS, PLS, MLN and ear rots) resistant, <em>acid soil tolerant, low P tolerant</em>, stem borer and post-harvest insect-pest resistant maize</td>
<td>Seed companies (1), CIMMYT (2), NARS (3)</td>
<td>MAIZE is the major provider of stress resilient and diverse elite germplasm with appropriate and gender preferred traits (e.g., heat tolerance, NUE, MLN, aflatoxin, stem borers, post-harvest pests, in DT genetic backgrounds); opportunities for upstream research to increase genetic gain and productivity.</td>
</tr>
<tr>
<td>Mid-altitude humid warm</td>
<td>26.4</td>
<td>Early to Late maturing (115 to 145 days to PM), high yielding, DT, <em>heat tolerant</em>, NUE, disease (GLS, MSV, HT, PS, PLS, MLN and ear rots) resistant, acid soil tolerant, low P tolerant maize</td>
<td>Seed companies (1), CIMMYT (2), NARS (3)</td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td>Altitude Range</td>
<td>Maturing Range</td>
<td>Traits and Characteristics</td>
<td>Sources</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Mid-altitude dry</td>
<td>19</td>
<td>Extra-early to medium maturing (90 to 135 days to PM), high-yielding, DT, heat tolerant, NUE, disease (PS, MSV, MLN and ear rots) resistant, low P tolerant and <em>Striga</em> tolerant maize</td>
<td>CIMMYT (1), Seed companies (2), NARS (3)</td>
<td>MAIZE is the major provider of diverse, well-adapted, extra-early to medium maturing drought, NUE, and heat tolerant germplasm with specific traits (e.g., DM, heat tolerance) of interest, with potential for further increasing productivity (especially in Mozambique and Angola).</td>
</tr>
<tr>
<td>Lowland tropical humid</td>
<td>6.8</td>
<td>Extra-early to medium maturing (90 to 135 days to PM), high yielding, DT, heat tolerant, NUE, disease (DM, MSV, MLN, PS, GLS, HT and cob rots) resistant, acid soil tolerant, low P tolerant, and <em>Striga</em> tolerant maize</td>
<td>CIMMYT (1), NARS (2), Seed companies (3)</td>
<td>MAIZE is the major provider of diverse, well-adapted, extra-early to medium maturing drought, NUE, and heat tolerant germplasm with specific traits (e.g., DM, heat tolerance) of interest, with potential for further increasing productivity.</td>
</tr>
<tr>
<td>Lowland tropical dry</td>
<td>15.1</td>
<td>Extra-early to medium maturing (90 to 135 days to PM), high yielding, combined heat and drought tolerant, disease (PS) resistant, aflatoxin, NUE, stem borer resistant, and <em>Striga</em> tolerant maize</td>
<td>CIMMYT (1), Seed companies (2), NARS (3)</td>
<td>MAIZE is the major provider of diverse, well-adapted, extra-early to medium maturing drought, NUE, and heat tolerant germplasm with specific traits (e.g., DM, heat tolerance) of interest, with potential for further increasing productivity.</td>
</tr>
<tr>
<td>Highlands</td>
<td>1</td>
<td>Early-medium to late maturing (120 to 145 days to PM), high yield potential, NUE, disease (PS, GLS, MLN, HT, and ear rots) resistant, acid soil tolerant, low P tolerant, photoperiod-sensitive, and cold/frost tolerant maize.</td>
<td>CIMMYT (1), Seed companies (2)</td>
<td>MAIZE provides improved highland germplasm to help specific countries in southern Africa. These areas do not have the genetics required to address the needs of highlands in the areas. Germplasm has to be sourced from as far Ethiopia or south America.</td>
</tr>
<tr>
<td>West Africa</td>
<td>15</td>
<td>Extra-early (80-85 days) and early (90-95 days) maturing, high-yielding, DT and heat stress tolerant, resistant to <em>Striga hermonthica</em>, foliar disease (SLR, SLB, CLS, and MSV), aflatoxin, and NUE.</td>
<td>IITA (1), Seed companies (2), NARS (3)</td>
<td>MAIZE is the major supplier of extra-early and early maturing improved maize germplasm, with relevant abiotic and biotic stress tolerant traits, meeting the needs of the smallholders under short growing period and further enhancing</td>
</tr>
<tr>
<td>Region</td>
<td>Count</td>
<td>Description</td>
<td>Source</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>-------</td>
<td>-------------</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td>Guinea Savannah</td>
<td>40</td>
<td>Early (90-95 days), medium (105-110 days) and late (110-130 days) maturing, high yielding, DT and HT, resistant to <em>Striga hermonthica</em>, foliar diseases (SLR, SLB, CLS, and MSV) and aflatoxin, and NUE.</td>
<td>IITA (1), Seed companies (2), NARS (3)</td>
<td></td>
</tr>
<tr>
<td>Southern Guinea Savannah</td>
<td>25</td>
<td>Early (90-95 days), medium (105-110 days) and late (110-130 days) maturing, high yielding, DT, resistant to <em>Striga hermonthica</em>, foliar diseases (SLR, SLB, CLS, and MSV), ear rots, aflatoxin, and NUE.</td>
<td>IITA (1), Seed companies (2), NARS (3)</td>
<td></td>
</tr>
<tr>
<td>Forest / Transitional Zone</td>
<td>20</td>
<td>Early (90-95 days), medium (105-110 days) and late (110-130 days) maturing, high yielding, resistant to foliar diseases (SLR, SLB, CLS, and MSV), ear rots, aflatoxin, insect pests (<em>Sesamia calamistis</em> and <em>Eldana saccharina</em>), and NUE.</td>
<td>IITA (1), Seed companies (2), NARS (3)</td>
<td></td>
</tr>
</tbody>
</table>

*Traits highlighted in bold are particularly limiting genetic gains, and are important for product success.

**Improved maize varieties deployed by SME seed companies and NARS are largely based on MAIZE germplasm, except highlands in eastern Africa and mid-altitude areas in southern Africa where unique germplasm is used by seed companies.
## Latin America

<table>
<thead>
<tr>
<th>Sub-region</th>
<th>Agro-ecology</th>
<th>Proportion of maize area in the region (%)</th>
<th>Target products*</th>
<th>Improved germplasm providers (with relative ranking)**</th>
<th>Justification for MAIZE investment in Phase-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highlands</td>
<td>15</td>
<td>Medium-early maturing (230-240 days), high yielding, cold tolerant (CT), <strong>drought tolerant</strong> (DT), <strong>disease</strong> (common Rust, ear Rot) resistant maize</td>
<td>CIMMYT (1), Seed companies (2), NARS (3)</td>
<td>MAIZE provides unique improved highland germplasm with tolerance to drought and disease resistance (common rust and ear rot) to help smallholders in specific regions where seed companies have not made significant investment (e.g., Mexico Central Highlands).</td>
<td></td>
</tr>
<tr>
<td>Mid-altitude</td>
<td>25</td>
<td>Medium maturing (170-180 days), high yielding, DT, <strong>NUE and disease</strong> (TLB, GLS, stalk and earrots) resistant maize</td>
<td>Seed companies (1), NARS (2), CIMMYT (3)</td>
<td>MAIZE is a relevant provider of adapted and diverse elite germplasm with tolerance to abiotic stresses (drought, crowding stress, nitrogen use efficiency) and disease resistance (e.g. TLB, GLS, stalk and Ear rots). Opportunities for increasing genetic gain by using modern enabling technologies (e.g. DH, genomic selection, precision phenotyping).</td>
<td></td>
</tr>
<tr>
<td>Lowland Tropics</td>
<td>60</td>
<td>Medium maturing (140-150 days), high yielding, DT, <strong>heat tolerant</strong> (HT), NUE and disease (tar spot complex, Northern corn leaf blight, corn stunt complex, ear rot) resistant maize</td>
<td>CIMMYT (1), Seed companies (2), NARS (3)</td>
<td>MAIZE is a major provider of adapted and diverse elite germplasm with tolerance to abiotic stresses (drought, heat, nitrogen use efficiency) and disease resistance (e.g. TSC, NCLB, CSC, and Ear rot). Opportunities for increasing genetic gain by using modern enabling technologies (e.g. DH, genomic selection, precision phenotyping).</td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td>Altitude</td>
<td>Maize Variety Characteristics</td>
<td>Breeders</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
<td>-------------------------------</td>
<td>----------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td><strong>Highlands</strong></td>
<td>5</td>
<td>Medium-early maturing (240-250 days), high yielding, cold tolerant (CT), <strong>DT and disease</strong> (<strong>common rust, ear rot</strong>) resistant maize</td>
<td>NARS (1), CIMMYT (2), Seed companies (3)</td>
<td>MAIZE provides unique improved highland germplasm with tolerance to drought and disease resistance (<strong>common rust and ear rot</strong>) to help smallholders in specific regions where seed companies have not made significant investment (e.g., Mexico Central Highlands).</td>
<td></td>
</tr>
<tr>
<td><strong>Mid-altitude</strong></td>
<td>15</td>
<td>Medium maturing (170-180 days), high yielding, <strong>DT, NUE, and disease</strong> (<strong>TLB, GLS, stalk and ear rots</strong>) resistant maize</td>
<td>Seed companies (1), NARS (2), CIMMYT (3)</td>
<td>MAIZE is a relevant provider of adapted and diverse elite germplasm with tolerance to abiotic stresses (drought, crowding stress, nitrogen use efficiency) and disease resistance (e.g. TLB, GLS, stalk and ear rot). Opportunities for increasing genetic gain by using modern enabling technologies (e.g. DH, genomic selection, precision phenotyping).</td>
<td></td>
</tr>
<tr>
<td><strong>Lowland Tropics</strong></td>
<td>80</td>
<td>Medium maturing (140-150 days), high yielding, <strong>DT, HT, NUE and disease</strong> (<strong>TLB, GLS, ear rot</strong>) resistant maize</td>
<td>Seed companies (1), CIMMYT (2), NARS (3)</td>
<td>MAIZE is a major provider of adapted and diverse elite germplasm with tolerance to abiotic stresses (drought, heat, nitrogen use efficiency) and disease resistance (e.g. NCLB, GLS, and ear rot). Opportunities for increasing genetic gain by using modern enabling technologies (e.g. DH, genomic selection, precision phenotyping).</td>
<td></td>
</tr>
</tbody>
</table>

*Traits highlighted in bold are particularly limiting genetic gains, and are important for product success.

**Improved maize varieties deployed by SME seed companies and NARS are largely based on MAIZE germplasm, except mid-altitude where unique germplasm is used by seed companies.*
<table>
<thead>
<tr>
<th>Moisture regime*</th>
<th>Irrigation</th>
<th>Proportion of maize area in the region (%)</th>
<th>Target products**</th>
<th>Comparative advantage***</th>
<th>MAIZE target countries/areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfed season; High rainfall areas</td>
<td>Nil</td>
<td>15</td>
<td>Medium-full maturity, high-yielding, short to medium height, <strong>waterlogging tolerant</strong> (WLT), disease [TLB, MLB, BLSB, DM (Indonesia), rust, GLS] resistant maize</td>
<td>MAIZE: 80 MNCs: 20</td>
<td>NE India, Indonesia, Bangladesh, Vietnam, Philippines, Cambodia, Sri Lanka</td>
</tr>
<tr>
<td>Rainfed season; Assured moisture areas</td>
<td>Protective</td>
<td>11</td>
<td>Full maturity, high-yielding, <strong>water use efficient</strong> (WUE), <strong>nutrient use efficient</strong>, and disease [TLB, DM, rust, BLSB, GLS] resistant maize</td>
<td>MAIZE: 20 MNCs: 80</td>
<td>South India, Thailand, South China, Indonesia, Sri Lanka</td>
</tr>
<tr>
<td>Rainfed season; Low rainfall (&lt;500 mm) areas</td>
<td>Nil</td>
<td>16</td>
<td>Early maturity, high-yielding, short to medium height, <strong>drought tolerant</strong> (DT) or DT + <strong>heat tolerant</strong> (HT) and disease [PFSR, Ear rots, DM] resistant maize</td>
<td>MAIZE: 80 MNCs: 20</td>
<td>C &amp; W India, Pakistan, Afghanistan, and north-western Bangladesh</td>
</tr>
<tr>
<td>Rainfed; Medium rainfall (800-1200 mm) areas, but with erratic distribution of rainfall</td>
<td>Nil</td>
<td>38</td>
<td>Early to medium maturity, high-yielding, DT + WLT / DT + HT, and disease [PFSR, BLSB, MLB, GLS] resistant maize</td>
<td>MAIZE: 60 MNCs: 40</td>
<td>IGP (India), Sri Lanka, Nepal, Bhutan, Thailand, Myanmar, Laos, Vietnam</td>
</tr>
<tr>
<td>Irrigated; Dry season</td>
<td>Full</td>
<td>13</td>
<td>Full maturity, high-yielding, short to medium height, <strong>cold tolerant</strong>, WUE, <strong>nutrient use efficient</strong>, and disease [<strong>Macrophomina</strong>, DM (Indonesia)] resistant maize</td>
<td>MAIZE: 20 MNCs: 80</td>
<td>India, Bangladesh, southern China, Thailand, Indonesia, Vietnam, Nepal</td>
</tr>
<tr>
<td>Irrigated; Spring season</td>
<td>Full</td>
<td>7</td>
<td>Early maturity, high-yielding, HT, WUE, and shoot fly resistant maize</td>
<td>MAIZE: 80 MNCs: 20</td>
<td>Pakistan, India, Vietnam, Nepal</td>
</tr>
</tbody>
</table>

*In yellow-highlighted seasons, there is high penetration of hybrids from MNCs; however, SME seed companies do serve niche/not-reached markets and require MAIZE germplasm. Also, MAIZE contributes improved donors for abiotic/biotic stress traits to both public and private sectors serving across regions in Asia.

**Traits highlighted in bold are particularly limiting genetic gains, and are important for product success;
***MAIZE largely denotes CIMMYT maize germplasm in Asia, deployed through NARS and SMEs.
3.9 References

3.9.1 References for FP1


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Morris, M. L. (2002). Impacts of International Maize Breeding Research in Developing Countries, 1966-98. CIMMYT, Mexico, D.F.


3.9.2 References for FP2

Not yet available

3.9.3 References for FP3


3.9.4 References for FP4

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3.9.5 References for FP5


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3.9.6 References for Gender


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