Harnessing Digital Technologies for Timely Decision-Making across Food, Water, and Land Systems

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Proposal

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A list of abbreviations and acronyms used throughout the proposal can be found here.

Summary table

Initiative name	Harnessing Digital Technologies for Timely Decision-Making across Food, Land, and Water Systems
Primary Action Area	Systems Transformation
Geographic scope	Mexico, Guatemala, Egypt, Kenya, Rwanda, Malawi, Bangladesh (Ganges Delta), India (Odisha), Nepal, Limpopo River Basin
Budget	US$28,000,000

1. General information

Initiative name

Full name	Harnessing Digital Technologies for Timely Decision-Making across Food, Land and Water Systems
Short name	Digital Transformation
Acronym	DX1

Primary Action Area

Systems Transformation

Initiative Design Team

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2. Context

2.1 Challenge statement

Our food system is unsustainable. In 2020, between 720 and 811 million people faced hunger [1], while one-third of food goes to waste [2]. To realize the transformative potential of digital technologies in shifting food-land-water systems toward climate resilience and sustainability, we identified three challenge areas that CGIAR's multidisciplinary expertise could help address.

1. **The digital divide:** The potential of digital technologies is clear, yet their reach is not universal. The Global South – and especially women and rural areas – are underserved by digital technologies and infrastructure. More than 600 million people still live outside of mobile network coverage, 67% of whom are from Sub-Saharan Africa [3]. Fewer than 40% of small farms are covered by mobile internet [4], and only 13% of small farmers in Sub-Saharan Africa have ever accessed a digital service [5]. Across low- and middle-income countries, women are 15% less likely than men to use mobile internet [6]. Africa has only-one eighth of the minimum density of weather stations recommended to issue timely early warnings [7]. The cost of deploying and maintaining rural infrastructure can be two to five times the cost in an urban area, with 10 times less revenue generated [3]. Enabling policies and investments are urgently needed, yet policy makers and investors do not always agree on priorities to address the digital divide.
2. **Inadequate information:** Real-time monitoring of food-land-water systems is possible at a lower cost and a higher accuracy than ever before using digital technologies [8], yet decision-makers lack access to timely, reliable, and actionable information across the Global South [9]. Weak information systems waste budget [10], exacerbate poverty [11], and slow economic growth [12]. More than 300 million small-scale producers lack access to digital climate advisory services [13], and unmanaged risks hinder producers' adoption of improved technologies [14]. Existing knowledge is often outdated and difficult to apply in practice [15]. Public, private, and civil society actors are insufficiently coordinated to develop win-win digital solutions leveraging data and technologies [9]. Siloed data do not support evidence-based policy responses that synergistically manage systems-level issues and risks such as price hikes, pest infestations, floods, and droughts.
3. **Limited digital capabilities:** Any technological investments should be supplemented by digital capability initiatives that invest in the "soft" infrastructure to foster the digital ecosystem and build forward-looking skills [16,17]. Digital literacy and skills levels across the Global South remain low [18], particularly for the most marginalized and food-insecure individuals and communities, such as women. Social norms in many cultural contexts determine women's access to and use of technology, including mobile phones [19]. Promising pilots of decision-support tools exist, yet research, codesign, and capacity strengthening are needed to channel new evidence to decision-makers, tailor digital advisory content, and serve food-water-land systems stakeholders in their risk management decisions.

2.2 Measurable 3-year (end-of-Initiative) outcomes

By early 2025, we aim to achieve the following outcomes across 5 focus countries, addressing three DX1 challenge areas.

The digital divide

- The digital agrifood ecosystem is strengthened through >5 policies, investments, and partnerships supporting inclusive innovations.
- Digital agrifood start-ups are engaged in >10 triangular cooperative partnerships with a technology company and National Agricultural Research and Extension Systems (NARES) to benefit women, youths, and vulnerable groups.

Inadequate information

- At least 10 digital agrifood services improve the gender-responsiveness of their content and services, reaching 100% more users, among whom the shares of women and youths are >40%.
- Natural resource management organizations improve early warning systems and disseminate reliable, actionable information to 100% more people.
- Pilots utilizing real-time data benefit >1,000 food-water-land system actors to increase productivity and profitability, manage risks, reduce food waste, and consume healthier diets.

Limited digital capabilities

- At least 1,000 agrifood system actors participate in digital capability strengthening programs enabling women, youths, and vulnerable groups to manage climate risks.
- At least 10 agrifood research-for-development organizations boost institutional digital capabilities to incorporate high-frequency data and underutilized datasets into decision-making.

Work Packages (WPs) will contribute to these outcomes by enabling policy makers and investors to reach informed decisions towards bridging digital divide (WP1), by supporting innovators in improving the gender-responsiveness of their digital services (WP2), by empowering natural resource managers to manage food-water-land systems better at the river basin-level (WP3), by allowing food value chains to monitor food systems functioning in real-time (WP4), and by building practitioners' capabilities to fully harness digital technologies for informed decision-making (WP5).

2.3 Learning from prior evaluations and impact assessments (IA)

Our strategic direction reflects crosscutting learning from prior evaluations and impact assessments of the CGIAR Platform for Big Data in Agriculture (Big Data) [17,20] and Research Program on Climate Change, Agriculture and Food Security [21], as well as recommendations from partner organizations [5,9,22].

1. CGIAR is well-positioned to leverage its global partnerships, data infrastructure, and domain expertise to serve as a trusted intermediary in the increasingly digital field of agricultural research for development. We will build on CGIAR's multi-stakeholder platform to support digital innovations, communities of practice, and data or analytics services that drive progress toward One CGIAR Impact Area Goals and the Sustainable Development Goals (SDGs) [17]. As a research-for-development Initiative, to the extent relevant, we will coordinate with CGIAR Digital Services to respond to the (forthcoming) evaluation of Big

Data's research-supporting work. For example, we will contribute to cultivating digital innovation processes [20] and investing in data interoperability and reusability [23].

2. While digital technologies can be transformative, local digital ecosystems are at different levels of capability and policy support. Sustainable adoption of digital solutions will be pursued by adapting programs already underway to achieve greater impact in the social-ecological-technological context [20,21].

3. We will bundle new digital solutions and improved information services within local decision-making frameworks. The potential impact of digital technologies largely depends on whether agrifood system actors can access the right information when and where it matters most [5]. Rather than supplying a general-purpose framework, we will utilize purpose-built transdisciplinary research tools and novel techniques aligned with our partners' specific intent and capacity. Crosscutting gender and equity approaches in the context of socio-technical design will be broadly applied [9,22].

2.4 Priority-setting

DX1's programmatic priorities address three challenge areas – the digital divide, inadequate information, and limited digital capabilities – identified through consultations with 83 stakeholder groups. The Mobile Connectivity Index [3] was used to select focus geographies amongst countries prioritized by the Regional Integrated Initiatives (RIIs).

1. **The digital divide:** Investors are concerned about low returns on investment that hinder the expansion of rural infrastructure. To encourage public investment, research was demanded to illuminate the intersectoral value of digital infrastructure for the rural poor engaged in agrifood systems. WPs 1, 2, and 4 will generate evidence of equitable connectivity and technology impacts towards Impact Area goals such as reducing poverty, gender equality, and growing livelihoods and jobs. A range of forward-looking solutions will be considered, including emerging communication technologies currently being field-tested by DX1 partners like low-earth-orbit satellites [24] and optical wireless [25]. Nepal and Kenya were prioritized based on their lower-than-expected levels of network coverage relative to their enabling infrastructure development. Guatemala and Egypt were additionally chosen as countries with higher-than-expected network coverage and similar levels of infrastructure.

2. **Inadequate information:** Across food-water-land systems, further research can optimize data collection; produce localized, gender-responsive solutions; improve information systems; and unlock valuable, underutilized data assets. Based on gap assessments, WPs 3 and 4 will codesign and copilot digital solutions for effective, timely risk management towards climate adaptation. Case studies will be codeveloped with partners across the transboundary river basin and across food value chains, leveraging recent advances in earth observation and sensor technologies from DX1's innovation partners including National Aeronautics and Space Administration (NASA), Open Data Cube, and X Development. WP5's data sharing frameworks will allow interoperability between private and public data assets while ensuring their ethical use. Rwanda, Kenya, and Bangladesh were prioritized based on their lower-than-expected levels of digital content and services relative to infrastructure. Guatemala and Indonesia were additionally selected as comparable countries that have more content than expected with similar infrastructure.

3. **Limited digital capabilities:** Strengthening capabilities in local digital ecosystems can ensure the adoption, scaling, and sustainability of innovations. WP1 will facilitate triangular

cooperative partnerships through the South x South Collaboration Lab, involving key local organizations, NARES, and government agencies. WP4 will support government agencies in incorporating real-time food systems data into policy decisions to mitigate supply chain disruptions. WP5 will enable partner organizations and other CGIAR Initiatives to build institutional capability to utilize real-time data for risk-management decisions. Digital research support teams will be jointly recruited with RIIs to fill local capability gaps and enable in-region digital research. Private data hubs will manage sensitive assets such as animal health records from One Health and phytosanitary information from Plant Health. Rwanda, India, and Guatemala were prioritized based on their lower-than-expected skill levels and gender equality relative to their infrastructure. Mexico, Egypt, and Kenya were additionally selected as comparable countries that have more content than expected with similar infrastructure. Mexico serves as a living lab since it offers a broad diversity of production and consumption environments, with contrasting socioeconomic and cultural conditions. Additional geographies were strategically chosen to deliver on identified demands, such as the Limpopo River Basin for WP3.

Gender inclusion is prioritized as a crosscutting issue to ameliorate the worsening gender digital divide. WP2 will focus on codeveloping approaches that increase women's and youths' active participation in local digital ecosystems and will yield benefits.

2.5 Comparative advantage

DX1's comparative advantage is threefold.

1. Drawing from CGIAR and a network of partners, including NARES, DX1 leverages a strong applied scientific, social science, and institutional understanding of incorporating human context into digital innovation across focus geographies. DX1 is directed by a diverse team of scientists, including leaders in multiple disciplines across digital agriculture, gender, value chains, nutrition, health, natural resource management, and collaborative design for innovation, focused on creating and delivering digital innovations for food-water-land systems in the Global South. Human-centered design, socio-technical systems understanding, and participatory development enable demand-driven implementation.
2. DX1 scientists complement their domain knowledge in food-water-land systems with strong technical capabilities. Managing massive datasets, developing technology products, and deploying cutting-edge machine learning techniques require very strong core software development and project management competencies. DX1 scientists have these competencies and can situate them within the complex natural and human systems in which the WPs operate. This combination of domain knowledge and technical expertise – a breadth and depth of proficiency across countries, digital technologies, and tailored solutions for food-water-land systems – is our distinct comparative advantage.
3. DX1 builds on CGIAR's earned reputation in the innovation ecosystem as a trusted intermediary. CGIAR's strong relationships have been established over decades of work with national teams to inform design, fill capacity gaps through partnerships, and accelerate at-scale delivery. In addition, DX1 leverages strong international research partnerships – for example with government agencies, universities, thought leaders, and think tanks – and global and regional scaling partners such as technology specialists, multinational companies, and mission-driven practitioners.

2.6 Participatory design process

Codesign with key partners is a top DX1 priority. Throughout proposal development, DX1 held a series of consultation meetings to engage 83 stakeholder groups, including multilateral, national, and private-sector organizations, covering all focus geographies. They provided the Initiative Design Team (IDT) with an opportunity to learn about stakeholder challenges, the current use of digital solutions, and the scope to better utilize real-time data for social and business impacts. These meetings also raised awareness of One CGIAR, which yielded specific demands for research that will necessitate coordination across multiple Initiatives. For example, WP3 will address specific food-water-land resource management challenges in the Limpopo River Basin expressed by the Limpopo Watercourse Commission (LIMCOM), in collaboration with four other Initiatives, including NEXUS Gains, National Policies and Strategies, Foresight and Metrics, and UU.

Additionally, as a crosscutting Initiative linked with all three Action Areas, DX1 consulted with 19 Initiatives to jointly plan activities to achieve synergies and economies of scale. Outputs from WP5 will support the development of fit-for-purpose data platforms and information services for the National Policies, One Health, Plant Health, TAFSSA, Excellence in Agronomy, and Market Intelligence Initiatives. DX1 also actively participated in RIIs – organized regional consultations to scope region-specific demands for exploring the role of digital technologies. In Southeast Asia, DX1 collaborated with Grow Asia to organize a learning event, where the IDT members met with digital start-ups to discuss how CGIAR can help scale their innovations. Collectively, we defined DX1's three main challenge areas – the digital divide, inadequate information, and limited digital capabilities – based on our engagement with all stakeholders and Initiative partners.

2.7 Projection of benefits

The projections below transparently estimate reasonable orders of magnitude for impacts which could arise as a result of the impact pathways set out in the Initiative's theories of change. Initiatives contribute to these impact pathways, along with other partners and stakeholders. For each Impact Area, projections consider breadth (numbers reached), depth (the expected intensity of effect per unit), and probability (a qualitative judgement reflecting the overall degree of certainty or uncertainty that the impact pathway will lead to the projected order of magnitude of impact). Projections will be updated during delivery to help inform iterative, evidence-driven, dynamic management by Initiatives as they maximize their potential contribution to impact. Projected benefits are not delivery targets, as impact lies beyond CGIAR's sphere of control or influence.

As per our theory of change, we anticipate synergies with other Initiatives, including thematic Initiatives like National Policies, MITIGATE+, ClimBeR, HER+, Food Markets, Excellence in Agronomy, SHiFT, Market Intelligence, One Health, Plant Health, and Livestock, plus all of the RIIs. We have not assumed additional impacts from these synergies in these projections at this stage, to ensure projections are conservative with no double counting. We will further develop the synergies and factor these into future projections during the inception period. Find the full list of synergistic opportunities identified with other 19 Initiatives here.

Finally, we used a subset of Initiative focus geographies on the projections. The final selection of countries may be adjusted when the planned activities are coordinated with partner institutions and other Initiatives.

Impact Area	Breadth	Number	Depth	Probability
Nutrition, health, and food security	# People benefiting from relevant CGIAR innovations	6.08M	Significant	Medium
Poverty reduction, livelihoods, and jobs	# People benefiting from relevant CGIAR innovations	6.08M	Significant	Medium
Gender equality and youth and social inclusion	# Women benefiting from relevant CGIAR innovations	2.43M	Substantial	High
Climate adaptation and mitigation	# People benefiting from climate-adapted innovations	108K	Perceptible	Medium
		360	Lifesaving	Low
Environmental health and biodiversity	# Ha under improved management	8M	Substantial	Low

2.7.1 Nutrition, health, and food security

For WPs 2, 4, and 5, to quantify the breadth across five focus countries – Guatemala, the Ganges Delta in Bangladesh, Odisha State in India, Kenya, and Rwanda – we conducted a spatial coincidence analysis on a stack of geospatial datasets with extrapolated values, overlaying the gridded population [26] with factors such as urban or rural residence [27], mobile network coverage [4], mobile phone ownership [3], climate hazards [28], and the value of food production [28]. The share of the rural population using digital services in 2030 was estimated at 17%, applying the linearly extrapolated growth rate from the Mobile Connectivity Index to the CTA-reported value of 13% in Sub-Saharan Africa [5]. This analysis suggested that 6.08 million rural residents in food-production areas with climate hazards would be using digital services by 2030. Our theory of change assumes that, through the adoption of DX1-developed data, services, and gender-responsive design tools, people will benefit from better information systems to manage risks and improve food security.

We also conservatively presume the depth of benefits is “Significant” based on literature. In Sub-Saharan Africa and India, farmers who subscribed to digital services increased yields by 4% [29]. Subscribers' incomes improved between 20% and 40% in Sub-Saharan Africa [5]. In Kenya, digital finance services boosted rural annual household income by 71% [30]. We assume the probability of success is “Medium (30%-50% expectation)” based on the CTA-reported value indicating that about 26% of digital agricultural services in Sub-Saharan Africa are financially sustainable.

2.7.2 Poverty reduction, livelihoods, and jobs

As described above for the nutrition, health, and food security Impact Area, we project that 6.08 million people across five focus countries can benefit from our work to strengthen digital

ecosystems and build the digital capabilities of agrifood system actors. This is a conservative estimate, assuming the current trend of mobile connectivity grows linearly between the base year of 2020 and the target year of 2030. As explained above, we project the potential depth of benefits will be "Significant," conservatively triangulating income-related impacts based on relevant literature.

Additionally, we presume the probability of success is "Medium (30-50% expectation)." The literature-reported rate of digital agricultural services becoming financially sustainable in Sub-Saharan Africa is 26%, which we adopted as our baseline.

2.7.3 Gender equality and youth and social inclusion

Drawing on the user analytics of digital solution providers from the Digital Agri Hub (DAH), we estimated a plausible range of targets for the share of women users benefiting from digital innovations by 2030. Because some digital solutions already achieved a share of women users above 40%, including seven initiatives profiled in Rwanda, we assume that, with WP2's support to make digital solutions more gender-responsive, the share of women benefitting from digital advisory and financial services can increase up to 40%, doubling from the current baseline of 20%. Applying this calculation to the previously estimated number of people benefitting from CGIAR innovations, we estimate the breadth of impact for gender equality and youth and social inclusion at 2.43 million women.

The WP2 theory of change assumes that DX1-developed bundles of data, services, and gender-responsive design tools will support innovators to improve the gender-responsiveness of their solutions to better serve the needs of women actors in food-water-land systems. The definition of the "Substantial" category in the guidance document is aligned to our theory of change process. In other words, we assume that the different informational and technical needs of men and women in agrifood systems are identified and differentially met through strengthened, gender-responsive digital ecosystems. Since evidence suggests some existing digital agriculture services have more than 40% of women users' engagement, we set the probability of success as "High (50-80%)."

2.7.4 Climate adaptation and mitigation

We selected the early warning systems to be codeveloped with the Limpopo Watercourse Commission (LIMCOM) in WP3 as the representative innovation to estimate projected benefits in this Impact Area. To quantify the number of people at risk of flooding across three countries in the Limpopo River Basin, we used the Aqueduct Floods tool, which estimated that the share of flood-affected population in 2030 will range from 0.4% in South Africa to 2.7% in Mozambique. Applying these estimates to the projected populations within the basin [26], overlaid with the mobile network coverage dataset [4], we predict that 107,830 people will be at risk of flooding and can benefit from improved early warnings. Due to the occasional nature of flood events, we defined the depth as "Perceptible," with a potential 1%-5% permanent income impact.

Additionally, we assessed how many lives could be saved based on the 2000 Limpopo River flood that cost 800 lives in Mozambique [31]. Globally, there were 45% fewer flood-related casualties in 2017 than in 2000 [32]. This progress was partially attributed to better early warning systems. Assuming a similar magnitude of flooding between 2022 and 2030, with an improved flood early warning system fully operationalized, we applied the same reduction rate (45%) to the historic casualties (800), assuming that 360 people can benefit at the "Lifesaving" depth.

For both projections, based on the strong demand expressed by LIMCOM, which coordinates the dissemination of early warnings across the basin, we assume the probability of success is "High (50-80%)."

2.7.5 Environmental health and biodiversity

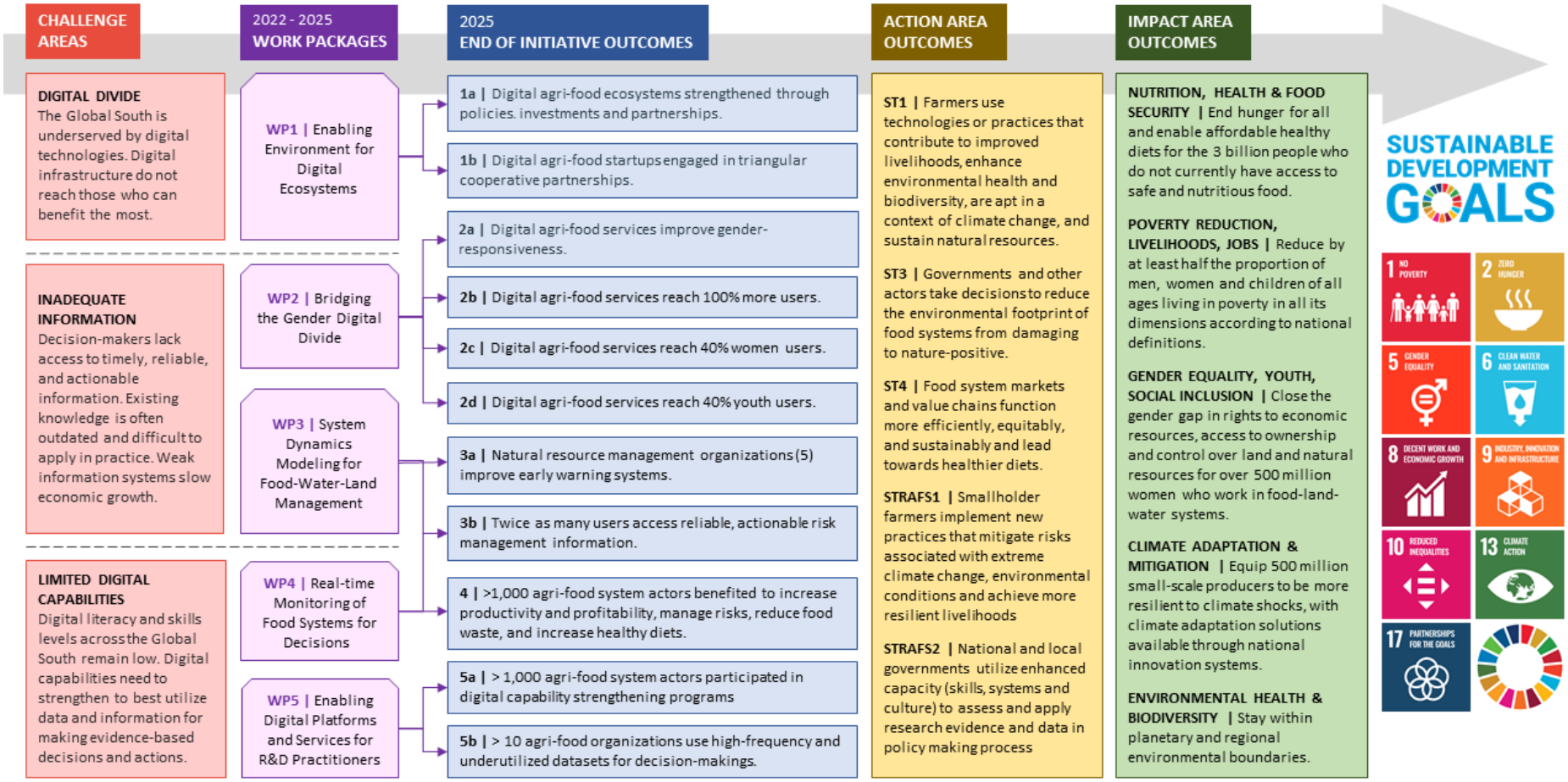
The Country Case Studies to be developed under WP3 with the Limpopo Watercourse Commission will support natural resource managers' sustainable water- and land-use planning towards environmental health and biodiversity impact outcomes. Specifically, one of the studies will focus on the Massingir Dam area in the lower Limpopo River Basin, which plays a critical role in supplying irrigation waters to expand croplands in the region. We use the scope of this case study as a representative work to evaluate the environmental health and biodiversity Impact Area. The Massingir Dam covers about 80,000 km² within the basin [33]; hence, we use this value as the breadth.

We assessed the depth as "Substantial," given how the Country Case Studies, including the one focusing on the Massingir Dam area, will deliver biodiversity gains and additional ecosystem service improvements by investigating trade-offs in different land and water management scenarios related to multiple objectives, including food security, resilience, environmental health, and biodiversity. Since this impact pathway involves policy makers' uptake and decisions, beyond the control of this Initiative, we assume the probability of success is "Low (10-30%)."

3. Research plans and associated theories of change (TOC)

3.1 Full Initiative TOC

3.1.1 Full Initiative TOC diagram



3.1.2 Full Initiative TOC narrative

DX1's five WPs collectively aim to achieve 11 End-of-Initiative outcomes, contributing to five Action Area outcomes and nine SDGs. DX1's theory of change is designed to address three challenge areas identified as key bottlenecks in the digital transformation.

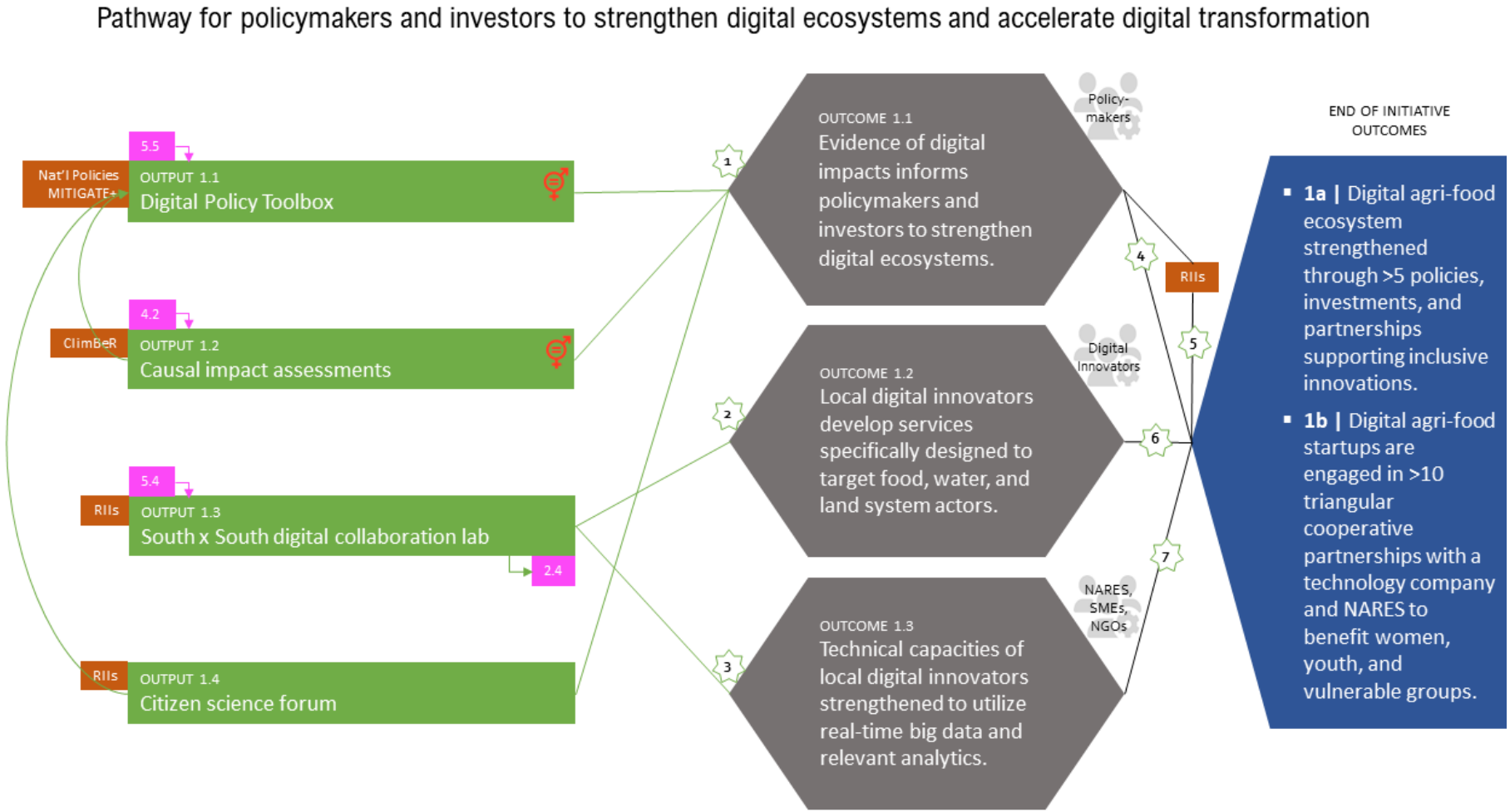
1. **The digital divide:** To support policy makers' efforts to reduce the digital division that hampers equitable access to technology and information in rural areas, WP1 will generate evidence of the impacts of digital infrastructure and develop enabling policies, plans, and strategies that can collectively strengthen local digital innovation ecosystems. We assume policymakers and investors will use these outputs to create strong investment cases toward rural digital infrastructure, digital ecosystems, and information systems for the poor, about the poor. WP2 will particularly contribute to digital inclusion for women and youths. Digital innovation developers will be supported to use bundles of data, services, and gender-responsive design guidance and measurement tools to scale their services to reach 100% more users, including >40% women and >40% youth.
2. **Inadequate information:** To support diverse stakeholders across food-water-land systems in accessing timely, reliable, and actionable information, WP3 will codevelop real-time monitoring, integrated modeling, and enhanced early warning systems for natural resource management (NRM) and research organizations to manage climate risks in agrifood systems. Through the provision of data and decision-support tools, we assume transboundary stakeholders will better coordinate the planning and allocation of shared land and water resources. WP4 will contribute to the generation and frictionless flow of key information and codevelop use cases demonstrating the power of real-time data and advanced analytics, such as the digitization and traceability of food and farm inputs, for >1,000 food-system actors to make informed decisions towards reducing food waste, improving food quality, choosing healthy food, and stabilizing prices.
3. **Limited digital capabilities:** To build the digital capabilities of agrifood system actors, WP5 will support >10 research and development organizations, including other Initiatives, to fill data and knowledge gaps, establish South x South triangular cooperation, and develop pilot solutions that promote sustainability across food-water-land systems. We assume partnering organizations and practitioners will improve institutional digital capabilities to utilize real-time data in making informed risk-management decisions. Targeted digital literacy and skills training will be co-organized with local digital extension partners for small-scale producers and other food systems stakeholders. Evidence of impacts will be generated by conducting impact analyses in rural communities whose livelihoods depend on food-water-land systems' sustainability.

Building on CGIAR's expertise in designing innovations, generating impact evidence, and providing research-based policy solutions, DX1 is envisioned as a trusted digital research-for-development partner supporting public and private information and innovation systems. Initiative scientists possess both domain knowledge and advanced technological skills to succeed in this role. We assume that prior work with key stakeholders across all focus countries will help to further develop fruitful partnerships, achieving the desired outcomes. Also, we assume that co-designing with end-users through user-centric strategies will allow services, data, and evidence meet identified needs, resulting in organic scaling and sustainable models. While each WP will conduct demand-driven research in specific focus geographies, their outputs and approaches will be developed as a global public good delivered

for RIIs to scale across their respective regions. More details on synergies, agreed collaboration and potential added value with other Initiatives can be found here.

3.2 Work Package TOCs

3.2.1 Work Package 1 diagram: The enabling environment for digital ecosystems



3.2.2 Work Package 1 research plan

Title	Enabling environment for digital ecosystems
Main focus and prioritization	WP1 focuses on the enabling environment, including policies, investment plans, frameworks, and innovation support systems, to strengthen local digital ecosystems and support the access of agrifood system actors to digital technologies and their management of climate and market risks. For policy makers to make an informed investment case, WP1 will generate intersectoral evidence of digital infrastructure impacts in rural communities. For local digital innovators, WP1 will facilitate the establishment of public-private precompetitive partnerships through the South x South Collaboration Lab, leveraging enabling platforms and services developed under WP5. Findings and learnings in focus countries will scale to other regions through collaboration with the RIIs.
Geographic scope	Global; country case studies in Guatemala, Kenya, Egypt, and Nepal

The science

RQ1.1 | What are the impacts of investments in rural digital infrastructure on inclusion, poverty reduction, food security, and jobs?

Despite broad governmental support for digital transformation, there is no clarity about which priority investment options will support inclusion and scale climate-smart digital innovations in food-water-land systems. Research and support can enable policy makers and investors to make informed decisions that foster the functioning of digital ecosystems. To this end, based on rapid gap assessments in local digital ecosystems and stocktaking of effective digital policies and their documented consequences, WP1 will investigate the impacts of rural digital infrastructure investments on key outcomes including gender equality, social inclusion, poverty reduction, food security, and jobs. Across focus countries and regions to be determined, we will follow a convergent parallel design approach of mixed methods. By collecting data through quantitative analysis of digital development-relevant indicators and qualitative interviews with key stakeholders (e.g., Horvat et al. 2021), our research team will delve into the various pathways whereby rural digital infrastructure propagates impacts towards multiple outcomes. Findings from this assessment will help policy makers prioritize specific high-impact investment options: for example, network coverage, inclusivity, affordable connectivity, institutions, e-government, and citizen's digital capabilities, literacy, and skills.

RQ1.2 | How can CGIAR help build effective, sustainable, and impact-driven public-private partnerships for digital innovation?

Strengthening local digital ecosystems for the sustainable transformation of food-water-land systems will necessitate public-private partnerships. Many digital agrifood innovations are rooted in start-ups exploring business opportunities while solving complex food system issues that public sector alone, such as NARES, cannot fully address at scale [35]. Building on CGIAR's expertise in designing innovations, generating impact evidence, and providing research-based policy solutions, WP1 will create an effective, sustainable, and impact-driven public-private partnership model based on the review of successful and less-successful models [36]. Network and behavioral analysis, quantitative analysis, and qualitative methods will be combined to systematize effective stakeholder interactions. A core element of the design process will involve mapping the incentives, skills, power relations, and roles of networks of various actors

to create a framework and space for building collaborations. Additionally, the formation of an official Citizen Science Forum (CSF) will be scoped and piloted, following the model of the U.S. Government's CitizenScience.gov, officially supported by the Crowdsourcing and Citizen Science Act [37]. Through the CSF, rural citizens will be encouraged to actively engage in and contribute to local digital ecosystems. They will be invited to conduct various tasks, such as validating research questions, providing feedback about digital solutions, and collecting ground-truthing data to improve the quality of the information underlying digital solutions.

WP1's outputs include a Digital Policy Toolbox (Output 1.1), causal impact assessments (Output 1.2), the South x South Digital Collaboration Lab (Output 1.3), and the CSF (Output 1.4).

The theory of change

We expect the activities and outputs of WP1 will make change at two levels: for policymaking and digital innovation.

- Policy makers will make evidence-based investment decisions targeted to achieve synergies among multiple development outcomes (Causal Linkage, or CL, #1) supported by enabling policy options (Output 1.1) and the results of causal impact assessments (Output 1.2). Through the multi-stakeholder CSF (Output 1.4), rural citizens will actively engage in local digital ecosystems and provide feedback about the decision-making process, which will further contribute to agile policy making.
- Local digital innovators will establish effective, impact-driven public-private partnerships through the South x South Collaboration Lab (Output 1.3) with win-win models through iterative learning processes. WPs 1 and 5 will foster enabling environments to create synergies and accelerate cooperation in sharing and managing data responsively and codeveloping digital solutions (CL#2). Digital innovators will improve their services to better serve the needs of users in food-water-land systems (Outcome 1.2), incorporating novel data and advanced analytics (Outcome 1.3). Resulting products will be demand-driven, codesigned with users, and built on a careful incentive analysis.

Evidence of digital impacts will be delivered to relevant decision-makers (CL#4) and channeled through RIIs to local actors at different scales. RIIs are a natural avenue for collaboration and feedback loops involving local partners and will support this WP to be locally present, for example through policy forums, and to scale across regions (CL#5). Via the multiplication of inclusive digital innovations through vertical scaling and their users through horizontal scaling, access to relevant data and informed decision-making will increase (CL#6). Capacity development supports the long-term sustainability of healthy digital ecosystems because of consistent engagement and collaboration processes (CL#7). Finally, we anticipate that WP1 outcomes will collectively influence policy-making processes, producing at least five policy, plan, or framework documents.

Related risks include the following: (1) evidence is not used, (2) public-private cooperation does not work because competition exceeds the benefits of collaboration, (3) data sharing is not fully implemented, (4) incentives are not realized for each participating party, and (5) there is a lack of human capabilities, such as digital skills among households and governments, and of the infrastructure required for scaling.

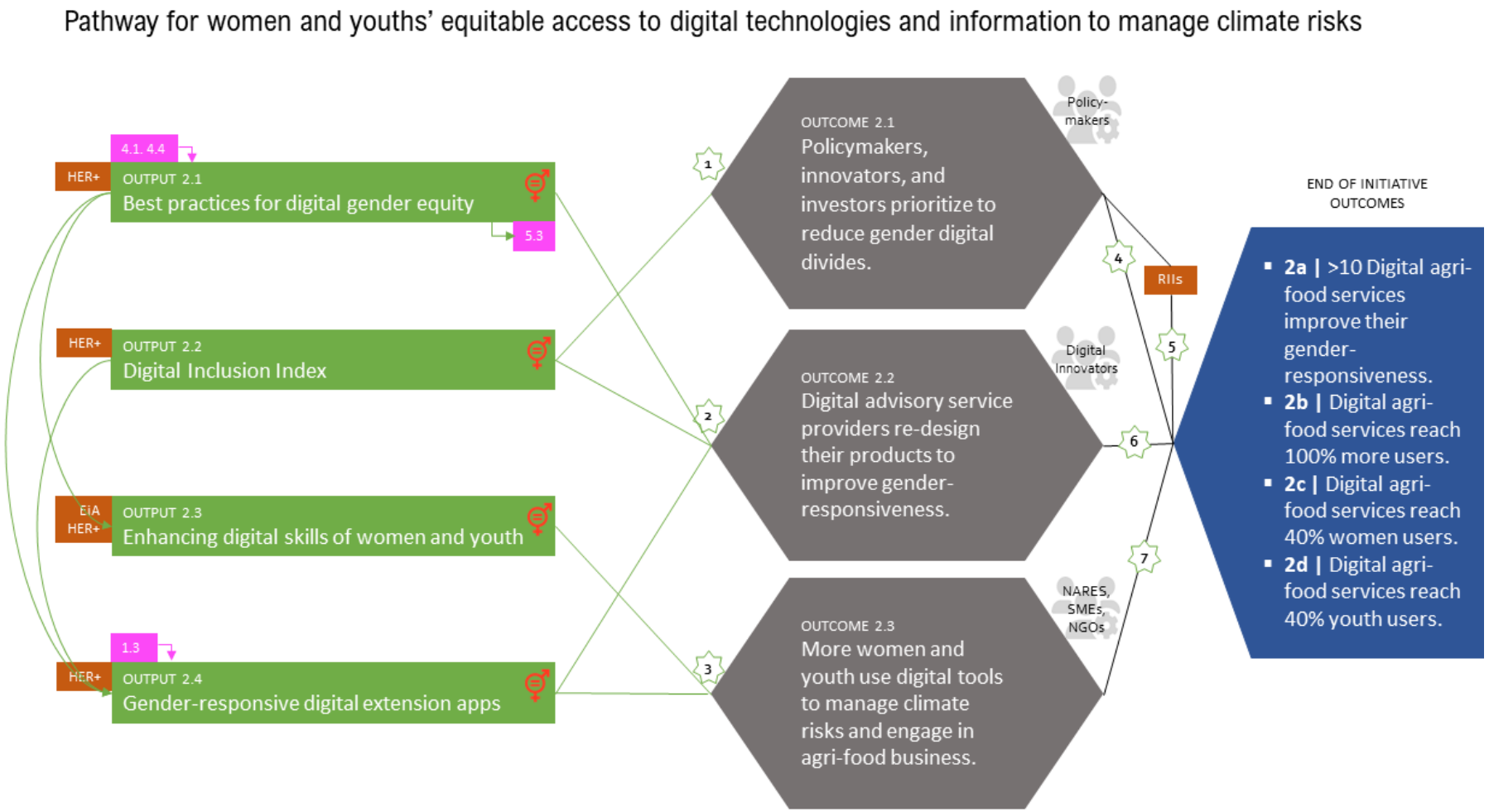
Key identified partners are NARES and other government agencies that have recently moved towards digital transformation but still require investment prioritization. Private social enterprises are willing to collaborate and improve their product design and impact; examples

include Yapu and Viamo; non-governmental organizations (NGOs) like the One Acre Fund, Rainforest Alliance, and Grameen Foundation; and digital startups like iCow, HelloTractor, and Plantix.

We aim to support up to 20 local digital innovators in scaling their services to reach twice as many users. We will incorporate the core principles of Innovation Packages and Scaling Readiness in WPs 1 and 2.

Within DX1, the real-time monitoring system in WP4 will validate data and processes in the CSF. The South x South Collaboration Lab, meanwhile, will foster public-private partnerships in other WPs. WP1 will link with all the RIIs, specifically with AgriLAC, in partnership models leveraging data hubs and digital service provision. WP1 will also link with National Policies and Strategies, MITIGATE+, and ClimBeR on the use of impact evidence in policy-making processes and scoping to tap into climate and green finance for digital infrastructure investment.

3.2.3 Work Package 2 diagram: Bridging the gender digital divide



3.2.4 Work Package 2 research plan

Title	Bridging the gender digital divide
Main focus and prioritization	WP2 will develop a suite of tools and guidelines to track digital inclusion and present options to strengthen the empowerment and resilience of marginalized women and girls. The Digital Inclusion Index for Food, Water, and Land Systems and a set of Best Practices for Digital Gender Equity will be developed and promoted based on user-centered design and a socio-technical understanding of gendered norms, barriers, and opportunities for change. Training programs targeting first-time female users from marginalized communities will be conducted. Existing digital services will be enhanced towards gender-transformative outcomes addressing key gaps within their solutions, while strengthening their business models.
Geographic scope	Bangladesh, Guatemala, India, Kenya, and Rwanda

The science

Recent research shows that the policy attention to the gender digital divide does not adequately take into account contextual, relational dimensions of digital inequality, which occurs along multiple fracture lines [38], as well as the deep-rooted social exclusions in digital innovations [39]. Further research can illuminate key causes of these divides in relation to food-water-land systems and promising strategies to address them. Related research has also probed the different factors that shape people's ability to access, use, and benefit from technology. In addition, further quantitative and qualitative research on the interaction of the different factors impeding digital inclusion for marginalized women and girls could disaggregate data and produce a multidimensional analysis. Therefore, WP2 will focus on gaining a better understanding of gender equality and social inclusion in digital services in targeted countries in order to inform digital policy, service design, and capacity development.

RQ2.1 | How can digital technologies assist women and girls in managing market and climate risks across food-water-land systems?

A range of digital innovations are being developed to reduce the risks associated with climate change, malnutrition, poverty, and market instability – and to meet many of the SDGs. WP2 will assess, evaluate, and categorize these innovations in relation to digital gender responsiveness and inclusion. From this catalogue of approaches and services, we will work with development partners and digital innovators to assess and benchmark them in order to identify opportunities and constraints related to gender inclusion. As a result, a set of best practices toward digital gender equity (Output 2.1) will be generated for food-water-land systems innovators, to promote gender responsiveness, inclusion, and risk management based on user-centered design approaches and a socio-technical understanding of women's roles. The work will help enlarge opportunities for women by highlighting existing constraints related to gender inclusivity in knowledge and attitudes as well as by providing opportunities to grow their skill base around actions to reduce the gender digital divide.

Understanding rural women's roles and their potential to use digital technology as a positively disruptive solution will also guide the re-design of digital extension apps towards gender-responsiveness (Output 2.4). It will be done by open-ended interviews, life stories, and focus

group discussions which will complement quantitative analysis with gender-disaggregated demographic, socioeconomic, and digital-related secondary data about literacy, access, and existing gender-responsive services. In addition to examining who benefits from digital inclusion in food-water-land systems, we will consider modes of production to understand and challenge how social relationships in our physical world are being reproduced in the digital world.

This assessment of how digital services address challenges faced by women will inform other research questions and will power the development of a Digital Inclusion Index for Women in Food-Land-Water Systems (Output 2.2). This index will be composed of relevant domain areas at two levels – the public digital ecosystem and private digital services – to collectively assess gender-related and other inequalities across countries and sectors.

The theory of change

We expect the activities and outputs from WP2 will make changes at three levels – among policy makers, digital innovators, and women and girls as the users of digital innovations.

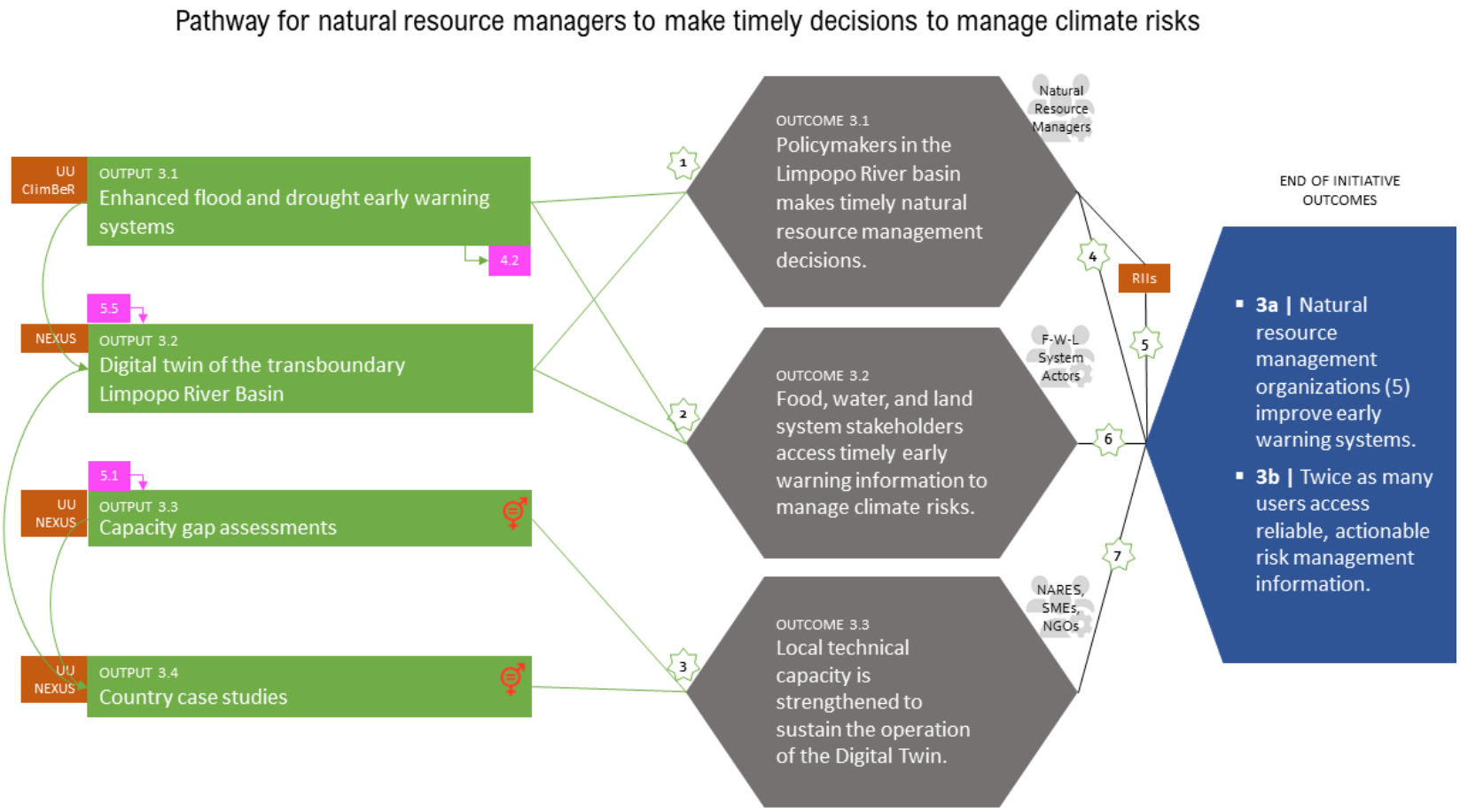
- Policy makers will use the synthesis report about the Digital Inclusion Index for Women in Food-Water-Land Systems to assess the level of the digital gender divide in their respective countries (CL#1). They will use this information to identify weaknesses and opportunities in their digital ecosystems and reflect this finding in their digital transformation strategies, aiming to reduce gender digital divides (Outcome 2.1).
- Digital innovators will diagnose the gender and inclusion gaps in their digital agrifood solutions, incorporating the Digital Inclusion Index (Output 2.2) in their analytics of users' demographic, behavioral, and engagement activities. We assume they will identify a sizeable scaling opportunity for improving business and impact by understanding women roles locally and by serving their needs better in a targeted way. They will prioritize addressing gender inclusion in their workflow and the provision of services overall, such as in their data collection, analytics, dissemination, and communication with users. DX1's Best Practices for Digital Gender Equity (Output 2.1) will provide practical guidance about how best to improve gender-responsiveness in their work, considering the dynamic and specific needs of food-water-land systems actors (CL#2), leading to the release of co-designed gender-responsive digital extension apps (Output 2.4). Real-time food systems monitoring data (Outputs 4.1, 4.4) will offer additional opportunities to improve the value of information provided to users. Inspiring examples from fellow innovators will be provided through the South x South Collaboration Lab (Output 1.3).
- Women agrifood system actors will build their digital capabilities to find appropriate information and services when needed and to make informed decisions towards sustainable and climate-resilient farming and livelihoods (Output 2.3). Youths, who are more likely own a mobile phone in rural households, will support other household members more directly engaged in agrifood systems in accessing information and technologies. In so doing, they may become interested in agriculture and may choose to pursue agrifood business opportunities (Outcome 2.3).

The synthesis of WP2 outputs and outcomes will be used by gender inclusion-conscious policy makers and investors (CL#4) and channeled through the RIIs to other stakeholders at different scales. RIIs will support this WP to scale outputs across regions (CL#5) and to scope for

improving gender inclusion in their digital ecosystems. Via the multiplication of gender-responsive digital innovations through vertical scaling and their women and youth users through horizontal scaling, access to relevant data and informed decision-making will increase (CL#6). Capacity development for women and youths will allow long-term sustainability for healthy, inclusive digital ecosystems because of their consistent engagement and collaboration processes (CL#7). Finally, because of WP2, we anticipate more women in agrifood systems will actively engage in local digital ecosystems; this change will be verified when user analytics from individual partners or aggregated data from the Digital Agri Hub show that at least 40% of digital solution users are women.

In addition to the RIIs, WP2 will have strong strategic linkages with ClimBeR (WP1), EiA (WP2), and HER+ (WP2) when it comes to scaling innovations targeting women actors across agrifood systems. DX1's WP2 will add the digital dimension of financial services design.

3.2.5 Work Package 3 diagram: System dynamics modeling for food-water-land management



3.2.6 Work Package 3 research plan

Title	System dynamics modeling for food, water, and land resource management
Main focus and prioritization	Southern Africa is largely arid, suffering from a highly variable climate and prone to extreme weather. More than 30% of the region's land area is critically exposed to a variety of climate hazards. Building on system dynamics modeling with real-time data, WP3 aims to complement NRM initiatives in the region with a next-generation decision support system. Responding to the technical support and capacity building demands of the Limpopo Watercourse Commission, this WP will focus on the Limpopo River Basin, yet the modeling system will be easily adaptable to other river basins and scales.
Geographic scope	Mozambique, South Africa, Zimbabwe, and Botswana (Limpopo River Basin; transboundary)

The science

To support the sustainable, equitable management of natural resources in a complex, transboundary river basin, a DX1-led consortium of research practitioners and digital innovators will work with the Limpopo Watercourse Commission (LIMCOM) to codevelop a new, real-time, data-driven integrated monitoring and modeling system. Activities of WP3 are designed to address two interrelated research questions, focusing on innovation and capacity building.

RQ3.1 | How can food-water-land system dynamics be monitored and modeled to inform natural resource management organizations in making sustainable and inclusive decisions?

Based on a review of the existing, no longer functioning Limpopo Information System (LIMIS) and other NRM systems, this WP will first identify detailed needs and opportunities to develop the next-generation LIMIS as a "Digital Twin" of the Limpopo River Basin. Digital Twin is a virtual representation of a system that spans its lifecycle, updated with real-time data, to support decision-making using simulations and advanced analytics. Connecting real-time measurements to simulation and decision-support tools, Digital Twin systems are increasingly used in the management of water basins globally. In collaboration with in-region technical partners, DX1 will localize a Digital Twin reference architecture developed by the Smart Water Alliance Network, a global coalition promoting the use of digital technologies for water management, to meet the needs of LIMCOM and its member states. The physical half of the digital twin system will be based on a geospatial analysis framework, and its dynamics will be captured through satellite remote sensing of food-water-land systems, real-time weather information, and seasonal climate forecasts, complemented by internet-connected sensors monitoring water levels and environmental flows. At its analytical core, we will design the new LIMIS as an ensemble of existing and new integrated hydro-economic-crop and livestock open-source modeling frameworks that assesses the consequences of climate-induced biophysical changes such as droughts, floods, and land-use changes for economic development. CGIAR's analytical expertise in integrated hydro-economic modeling, crop modeling, and climate risk management will be leveraged and incorporated into the Digital Twin (Output 3.2).

RQ3.2 | How can real-time data and advanced analytics assist in better preparation for and defense against natural disasters such as floods and droughts across food-water-land systems?

DX1 will first assess technology and data gaps that might constrain the performance of current early warning systems for future extreme climatic events (Output 3.1). Stakeholder consultations highlighted the demand for a drought and flood early warning system with more lead time and the provision of prescriptive, actionable information to help complete anticipatory actions in advance. Leveraging CGIAR's expertise in developing integrated early warning systems, complemented by ongoing flood early warning system development in the region, the Digital Twin system will incorporate an improved early warning system as a part of its decision support system (Output 3.1). Simulation analysis with weather and climate forecasts will inform natural resource managers about potential anomalies in food production, land use, and water productivity due to floods and droughts. This analysis will also provide information about estimated impacts across sectors and potential trade-offs between scenarios. The ClimBeR, NEXUS Gains, and Foresight and Metrics Initiatives will collaborate in the design and development of the early warning system.

The theory of change

We expect that the activities and outputs of WP3 will make changes at three levels – among policy makers, natural resource managers, and research-for-development practitioners in the focus region, which is a transboundary river basin.

- Policy makers will be continuously informed of the extent and severity of extreme weather and climatic events with more lead time than the current system provides (CL#1). For significant events, they will receive a bulletin about recommended actions synthesized from real-time satellite remote-sensing data and integrated modeling analyses conducted using the Digital Twin system, complementing information from local government agencies and ground-truthing efforts. Policy makers will undertake early anticipatory actions, such as declarations of emergencies and the early release of crisis-response funds, to prepare citizens and the economy for shocks from natural disasters (Outcome 3.1). A digital crisis-response framework (Output 5.5) will expedite the flow of information across government agencies.
- Natural resource managers, such as LIMCOM, will use enhanced flood and drought early warning systems to analyze potential natural disaster impacts on local food-water-land systems and disseminate advisory bulletins (Outcome 3.2) with actionable risk management information (CL2).
- Local NRM research-for-development institutions will participate in generating country case studies using the Digital Twin system (Output 3.4). They will adapt the system to operate in their focus geographies to address other NRM challenges (Outcome 3.3), further developing the system beyond the timeline of DX1 (CL#7).

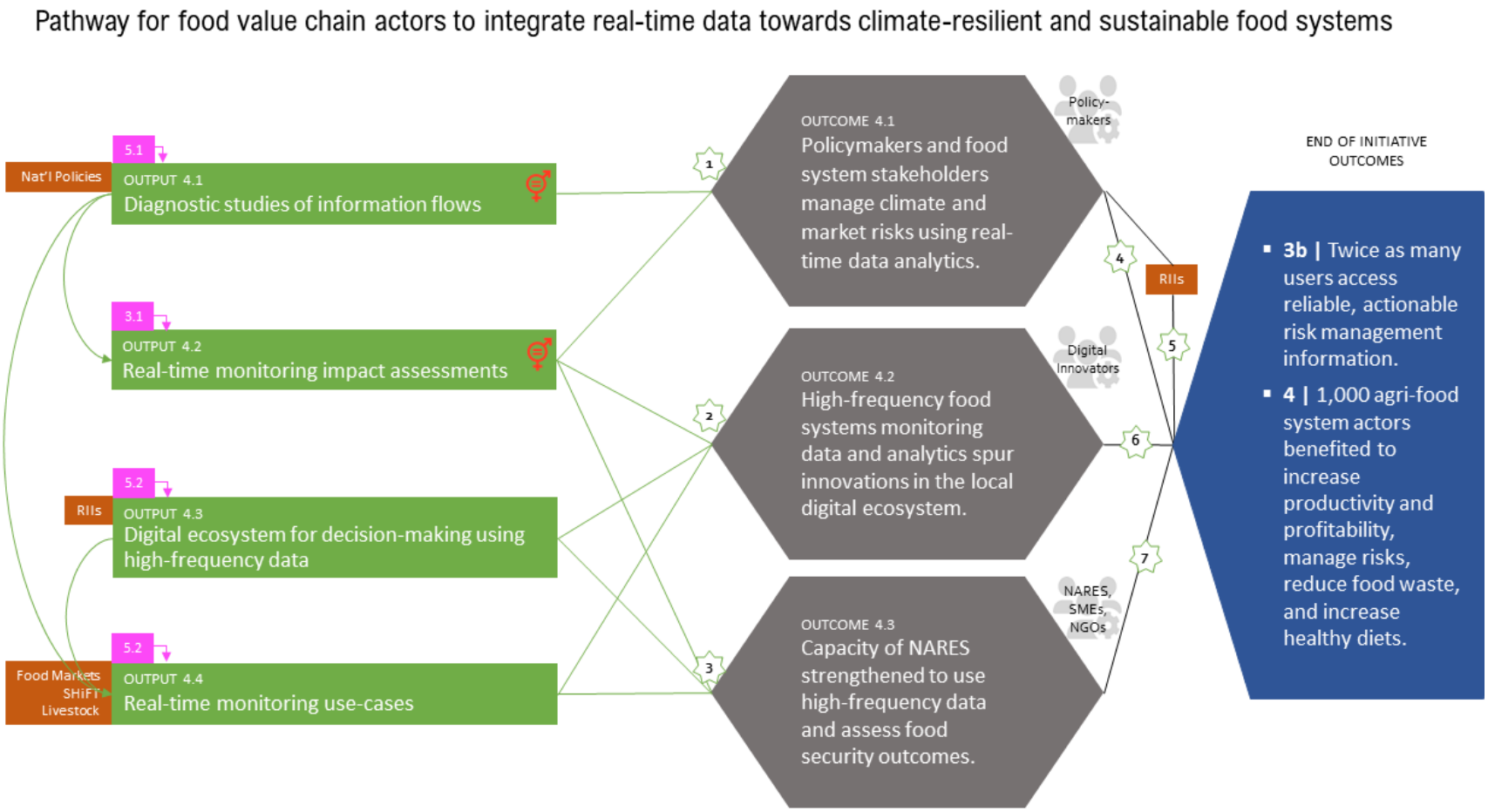
A synthesis of WP3 outputs and outcomes will be useful to policy makers, natural resource managers, and research organizations. This synthesis will be channeled through CGIAR's RIIs, such as UU in East and Southern Africa, to effectively disseminate NRM advisory information via regional multi-stakeholder platforms and to scope for potential scaling (CL#5). RIIs will also support scaling the Digital Twin approach across other regions and scoping to locally adapt the system and enhance NRM in other river basins. Real-time NRM data and

synthesized actionable information will be publicly available through improved open data and public information services (CL#6), helping to fill knowledge gaps (Output 3.3).

WP3's key partners include LIMCOM and its network of technical partners in the region, including the United States Agency for International Development (USAID) Resilient Waters program (Find their Letter of Support here) and academic institutions such as the Universities of Botswana, Pretoria, Johannesburg, and Zimbabwe, the Botswana International University of Science and Technology, and Great Zimbabwe University. DX1 will also coordinate with CGIAR's academic partners with advanced analytics and integrated modeling skills, including the Massachusetts Institute of Technology, the University of Twente, the University of Florida, Griffith University, the International Institute for Applied Systems Analysis, the United Nations Food and Agriculture Organization, and Columbia University.

Other WPs within DX1 will contribute to the success of WP3. WP1 will provide a framework for the basin-wide innovation ecosystem. WP2 will ensure the analyses are inclusive of all actors. WP4 will support real-time data collection and management. WP5 will enable the development of LIMIS using free and open-source technologies. Risks and gaps in technical capacity, funding, and coordination will be addressed by embedding CGIAR's continued strategic engagement in LIMCOM's next Integrated Water Resources Management Plan (IWRM), in coordination with its major funders, namely the Global Environment Facility and USAID, and with other Initiatives with overlapping goals such as NEXUS Gains, National Policies and Strategies, Foresight and Metrics, and UU.

3.2.7 Work Package 4 diagram: Real-time monitoring of food systems for decisions



3.2.8 Work Package 4 research plan

Title	Real-time monitoring of food systems for decisions
Main focus and prioritization	WP4 aims to improve real-time monitoring of food system dynamics to inform multiple stakeholders who make time-critical decisions to respond to variation and shocks. The WP will lead a digital codesign process with stakeholders, building on existing data collection efforts, and make focused investments in digital design and capacities. The emphasis of this WP will fall on improving the flows of information to food systems that facilitate the movement of inputs and produce. Reconfigured, new digital data streams will enhance decision making by actors including producers, market traders, local and national authorities, and international organizations dealing with food security.
Geographic scope	Bangladesh, Guatemala, India, Kenya, and Rwanda

The science

WP4's objectives include identifying the roles of real-time data in serving food system stakeholders' diverse information needs, addressing critical data and knowledge gaps, and developing strategies to improve efficiency towards healthy, resilient, and sustainable food system outcomes.

RQ4.1 | What are the barriers hindering the access of food system actors to timely information, and how do these barriers affect their management of climate and market risks?

To diagnose the current flow of information in food systems and identify the weakest link in terms of data availability, accessibility, quality, and utility, WP4's approach will start with ethnographic interviews, stakeholder consultations, and literature reviews. Key areas of study will include the process of information exchange; how it facilitates the flow of materials such as agricultural inputs, produce, and food in the study areas; and which institutional arrangements involve relevant actors. Publicly available data from sources like market information systems, satellite remote sensing, crowdsourcing, targeted lean data surveys, and weather and climatic information will be used to characterize the spatiotemporal patterns of supply and demand under recent climate shocks. Producers and traders will be interviewed to understand key dynamics and the reasoning underlying their decision-making. To identify entry points for digital solutions that facilitate new information flows, diagnostic studies will cover crops such as cereals, legumes, roots, tubers, bananas, and vegetables; dairy feed and products; and farm inputs. Assessments of data availability will indicate where further information can reduce potential biases and optimize sampling frames for collecting ground-truthing data.

RQ4.2 | How can high frequency agrifood system monitoring data reduce food waste and improve the functioning of markets and their resilience to climate and market shocks?

Based on diagnostic studies and existing digital solutions, prototype frameworks adapting International Agricultural Productivity [40] to local contexts will be developed for high-frequency, spatially explicit monitoring of agricultural outputs, inputs, and food waste along the value

chain on a weekly or monthly basis. Multiple primary and secondary data sources will be incorporated, including official statistics from government agencies, crowdsourcing, key informant surveys, market surveys, and local market information systems. The quality and utility of the data will be iteratively evaluated and improved with stakeholders. The goal of this codesign process is to identify digital solutions which motivate and reward stakeholders who both share and use information, generating mutual benefits among food-system actors such as enhancing the functioning of markets and informing decisions. Our focus will be on high-frequency data and integration across digital ecosystems through interoperability and innovative approaches such as knowledge graphs and machine learning for causal analysis. We will test how digital tools and capacity building can generate a virtuous cycle of heightened reciprocal information sharing and will build capacity to support digital transformation in close collaboration with WP5.

Evidence will be generated to illuminate the following topics: (1) the motivation of actors to contribute data and use digital solutions; (2) how their use leads to better decisions at the production, market, and policy levels; (3) how these decisions affect food system efficiency and resilience; (4) whether benefits are distributed equitably; and (5) how systems can be sustained across time. Policy evidence and sustainability plans based on insights into the feasibility and benefits of reconfigured data streams will support real-time food system monitoring in the short and long term.

The theory of change

WP4 responds to existing but fragmented demand. Key partners include government agencies, private-sector actors, the World Food Program, and innovators with expertise in high-frequency data acquisition and analytics from academia to private small and medium-sized enterprises (SMEs) in food systems. We expect the activities and outputs from WP4 will cause change at three levels: among food systems stakeholders, local digital innovators, and NARES.

- Food systems stakeholders will use novel digital tools to capture and access high-frequency data and participate in new collaborative arrangements to unlock two possibilities for improved management of food systems: 1) careful design of digital mechanisms that allow actors to generate, share, and use relevant and trusted information that can enhance coordination and decision-making; and 2) matching the short-term scale of real-time data streams with insights that contribute to long-term improvements. Better data systems will support efforts by government agencies to monitor national food security situations in real-time (CL#1). Policy makers will manage climate and market risks better and faster (CL#4).
- Local digital innovators will use high-frequency food systems monitoring data through the private data hub (Output 5.2) and develop content and market intelligence that can catalyze innovations and business opportunities (Output 4.3) in the local digital ecosystem (CL#2).
- NARES will incorporate high-frequency food systems monitoring data into existing information systems and strengthen their capacity through the codesign and co-development of case studies (CL#3)

CGIAR's RIIs will coordinate the dissemination of data through regional multi-stakeholder platforms and will scope for potential to scale up WP4 outputs (CL#5). WP4-collected real-

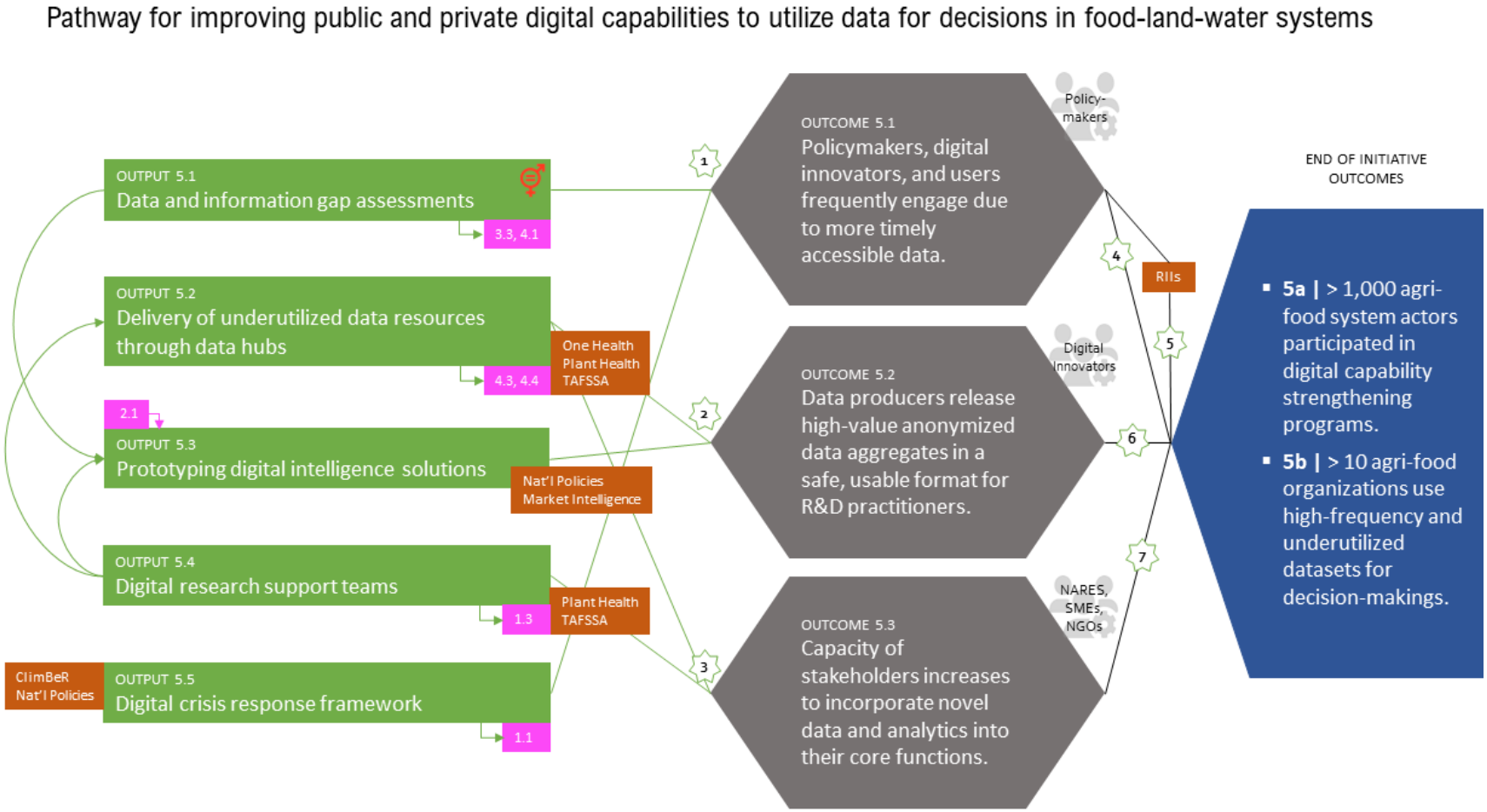
time data and synthesized actionable information will help fill data and knowledge gaps (CL#6) and strengthen the technical capacity of NARES (CL#7). In the downstream, more consumers will be provided with information to choose healthy, sustainable foods. Stakeholders will easily access WP4-generated information through better open data and public information services and will communicate with policy makers through digital channels.

WP4 assumes that it will be possible to gain sufficient understanding of food-system workings, especially the “hidden middle,” to generate solutions that realize mutual benefits among stakeholders. Based on our discussions with stakeholders, we can also reasonably posit that there is a demand for public-private collaboration in the digital innovation space with a win-win business model.

WP4 builds on CGIAR’s presence in focus geographies. In Rwanda, we foresee collaboration with an important use case in EiA. WP4 leverages CGIAR’s long-term engagement with the dairy sector in Kenya and the Livestock Initiative. In Guatemala, WP4 will closely coordinate with the AgriLAC, SHiFT, and Food Markets. Real-time monitoring systems will generate spaces for collaboration on content with several One CGIAR Initiatives, depending on the open-ended nature of the design process. The design teams will explore collaborations where possible and are strongly connected across all three Action Areas.

WP4 will follow the Scaling Readiness methodology, working on the codesign of real-time monitoring systems that consist of a comprehensive Innovation Package in each context and a Monitoring-Evaluation-Learning (MEL) strategy that traces the progress of all components. There will be flexibility as to which components of Innovation Packages can be outsourced or replaced to achieve overall goals. Scaling readiness plans will be developed dynamically as part of WP4, embedded in a digital codesign process.

3.2.9 Work Package 5 diagram: Enabling digital platforms and services for research and development practitioners



3.2.10 Work Package 5 research plan

Title	Enabling digital platforms and services for research and development practitioners
Main focus and prioritization	WP5 aims to facilitate user-specific, appropriate delivery of administrative and private data for the inclusive benefit of the public, and for more effective evidence-based decision making in food-water-land systems in a climate crisis. This WP utilizes a two-pronged approach: RQ5.1 focuses on strategically identifying and mobilizing the most impactful datasets that are currently underutilized and easily deployed, including private data assets; while RQ5.2 focuses on developing demand for and capacity to engage with data to improve decisions and program management, increase accountability and transparency, and enhance livelihoods.
Geographic scope	Bangladesh, Guatemala, India, Kenya, and Rwanda

The science

WP5's research questions are designed to utilize demand-driven, participatory methods to (1) achieve final-mile delivery of high-value, high-resolution, real-time and historical datasets, and (2) develop the capacity of key decision-makers to derive significant insights from these data to aid food-water-land systems.

RQ5.1 | How can underutilized data and advanced analytics fill gaps in knowledge and evidence to support timely decision making?

DX1 will first conduct a gap assessment of data needs in conjunction with WP1, identifying strategic opportunities in each country for efficiently improving data delivery across food-water-land systems. This assessment will facilitate the creation of one or more Minimum Viable Product data portals to effectively mobilize currently underutilized data, including real-time data, from key government ministries, CGIAR data resources, and other sources. These data will facilitate both decision-making and deeper understanding of the problem space in food-water-land systems, for instance through supply chain transparency, earth system monitoring, and program efficiency. Human-centered design principles will be applied throughout, as well as user group codesign, iterative testing and validation, and agile software development practices.

Private data assets will also be prioritized; engagement activities with prospective private-sector data partners in consultation with WP1's South x South Collaboration Lab will lead to the establishment of one or more beta private data hubs to release high-value private data assets in alignment with priorities identified by the gap assessment. This activity will also result in guidance in the form of legal templates and strategic advice about private data hub formation, which will be publicly shared as a springboard for future activities.

A crosscutting theme is the examination of WP5's ramifications upon the digital divide, as well as data safety. Data without safety concerns will be targeted for immediate release, while data with personally identifiable information (PII) will be aggregated as minimally as possible before release or made safely available to researchers through restricted data portals.

RQ5.2 | How can existing local data platforms and digital infrastructure be sustainably maintained and improved to support timely decision making in a climate crisis?

This effort will be led by a report identifying key intelligence needs among policy makers across relevant scales – for example, the country, region, watershed, and issue area – as well as private-sector inefficiencies due to data paucity or technological illiteracy, with the digital divide as a crosscutting theme. This report will target the deployment of data support teams for capacity strengthening activities with national and state governments, development practitioners in the food-water-land system, and private-sector partners. These activities will be designed to deliver upskilling in a demand-driven manner, utilizing people on the ground in target countries to embed with stakeholders for synchronous capacity strengthening. Finally, this research question will facilitate a Digital Crisis Response Framework convening key decision-makers to share data and insights rapidly and collaboratively in response to and anticipation of emergency events. These efforts will leverage CGIAR resources and abilities and mobilize any further necessary capabilities across partner networks to mitigate identified bottlenecks.

The report will utilize participatory research methods, including key informant interviews, reflection workshops, and user research, to identify and iteratively engage with user types and their use cases.

The theory of change

We expect the activities and outputs of WP5 will foster change at two levels: for data users and data producers.

- Data users like policy makers, food systems actors, consumers, and research and development practitioners will build their digital capabilities to find, understand, and use appropriate information in their decision-making. They will manage climate and market risks better and will increase the productivity and profitability of their farming and agrifood businesses.
- Data producers such as value-chain actors, digital innovators, citizen scientists, and research and development practitioners will fill gaps in their data and information systems and generate useful insights across food-water-land systems. Furthermore, they will contribute such insights to intelligence services, such as market information systems and food supply chain management systems, which will provide users with relatively comprehensive information products in a timely manner.

Through strengthened capabilities across digital ecosystems, data producers and users will engage more and develop creative, win-win solutions that benefit food-water-land systems at large. These products will motivate data producers to make better use of underutilized private data (CL#2) and improve data users' risk-management decisions (CL#1) across tiered geographic levels such as the district, country, and watershed (CL#6). National and subnational governments and development partners will strengthen their digital capabilities to make informed decisions and enhance digital ecosystems (CL#3) while improving engagement with data in decision-making processes (CL#7). Policy makers will develop the Digital Crisis Response Framework (Output 5.5) to ensure expedited data and information flows during crises. Partnering research-for-development practitioners and other Initiatives will quickly prototype digital innovations (Output 5.4), which will support adjacent RIIs (CL#5) and directly lead to more agile policy making (CL#4). Anticipated next-level outcomes include an ameliorated open data landscape, better management of food-water-land systems, more efficient markets, and more equitable access to opportunity.

WP5 is crosscutting. The WP1 South x South Collaboration Lab may deliver data via Outputs 5.2 and 5.6. Outputs 5.2 and 5.3 may produce data utilized for WP3 and WP4. The gender assessment of WP2 will inform the gap analysis of WP5, which may mobilize gender data for Outputs 2.2 and 2.4. Furthermore, WP5 would jointly assess the data landscape in India with TAFSSA, including use cases of integrated food systems data, and would collaborate and/or jointly hire to accomplish shared platform development and data processing tasks.

WP5 is designed to deliver core technological innovations with a demonstrated ability to scale with the support of the other outputs, which raise awareness, improve accessibility, increase capacity, and ameliorate the policy environment. WP5 intends to engage with key technical partners with expertise in digital platforms such as Development Data Lab to consider data mobilization and project management approaches that efficiently maximize impact in focal geographies.

4. Innovation Packages and Scaling Readiness Plan

4.1 Innovation Packages and Scaling Readiness Plan

Successful scaling of digital innovations, both from partners and our own research, will be the basis of achieving our end-of-Initiative outcomes. During the stakeholder consultations, local digital innovators pointed out the low levels of digital literacy and skills, inadequate design and content, and expensive internet access in rural communities as key constraints.

So far, we have identified five digital extension and financial innovators in three countries who expressed interest in partnering with us to improve their operation and services. We aim to support up to 20 prominent local digital innovators to scale their services (e.g., digital advisory or financial services) and reach ten times as many users by improving their use of real-time data, gender-responsiveness, and delivery of actionable information in a targeted way. To achieve the scaling goal, our design of theory of change reflected the core principles of Innovation Packages and Scaling Readiness. For each target stakeholder group, we will first conduct the gap assessment in their digital ecosystem (e.g., bottlenecks in data, knowledge, and technical capacity). Then we will profile existing innovations that can effectively address the gaps and collaborate with local innovators to pilot new research-based approaches that can fill the gaps and serve users' needs better.

The Innovation Packages and Scaling Readiness approaches are embedded in WP1 and WP2. WP4 and WP5 will support generating real-time data, localized advisory content, and effective information delivery mechanisms to facilitate the scaling process. We have allocated 2.5% of our budget (US$750,000) over three years to provide dedicated support for 20 Core Innovations, 5 Innovation Packages, and 1 Portfolio Management System. 5. Impact statements

5.1 Nutrition, health, and food security

Challenges and prioritization

Efficient digital ecosystems can provide efficacious solutions across scales in food-water-land systems where billions cannot afford healthy diets, lack access to basic sanitation, have little resilience, and constantly deal with poor food safety and diseases. A risk of excluding the most vulnerable due to the digital divide and restricted data access is present in most of the Global South, however. Nutrition and health datasets are often inconsistent, unharmonized, and sparse; hence, the data become less relevant and useful over time. Food production, purchase,

and consumption data are central to policy and services, yet significant gaps exist. Farmer registries are not reliable, consumption survey participants underreport, and food sales databases do not allow public use.

Research question

What are the impacts of investments in rural digital infrastructure on inclusion, poverty reduction, food security, and jobs? (WP1)

Components of Work Packages

WP1 will identify high-potential investment options for strengthening local digital ecosystems, which can improve food security and reduce poverty in food-water-land systems. WP2, in turn, will ensure that gender disparities and social exclusion related to food production, value systems, technical and financial inputs, and extension are ameliorated through digital services designed to increase productivity, profitability, nutrition, and climate resilience. WP4, meanwhile, will map current information flows in food systems in order to discern how they affect the political economy and critical data requirements to deal with distortions and shocks. WP4 will also assess how digitally enabled real-time monitoring can improve food system functioning at critical points and support the design of digital solutions that enhance decision-making to address shocks and variation.

Measuring performance and results

By early 2025, in close collaboration with NARES and other relevant Initiatives such as SHiFT, Food Markets, Excellence in Agronomy, and the RIIs, DX1 aims to at least double the number of users receiving data-driven, context-specific recommendations. Pilots utilizing real-time food systems monitoring data will benefit >1,000 actors towards nutrition, health, and food security outcomes (e.g., data-driven recommendations to increase productivity and profitability, food traceability to reduce food loss and waste, and digital nudging to increase consumption of healthy and sustainable food).

Partners

In addition to the abovementioned partnering Initiative, DX1 will partner with Ministries of Agriculture and Food Security, NARES, and agrifood small and medium enterprises (SMEs) in each of the focus geographies. Activities on data collection, advanced analytics, and generating new locally relevant insights will align with ongoing programs of (socio-)technology-oriented initiatives consulted through the proposal development process, including Research ICT Africa, NASA Harvest, Radiant Earth, and Digital Green. Triangular cooperation (i.e., North-South-South) will be pursued to link local digital agrifood start-ups with large technology companies such as Microsoft, Amazon, and (Google) X Development to address challenges in local digital ecosystems, leveraging their ongoing partnership with CGIAR Platform for Big Data in Agriculture.

Human resources and capacity development of Initiative team

The Initiative team will include experts in nutrition, health, and food security data and analytics. DX1-dedicated gender and social inclusion experts will ensure socio-technological relevance and context of our work. Joint hiring of additional experts will be pursued with partnering

Initiatives, potentially in coordination with the relevant Impact Area Platform. DX1 is engaging with CGIAR Digital Services to align Initiative-level strategies for human resources and capacity development with the (forthcoming) One CGIAR Global Digital Strategy.

5.2 Poverty reduction, livelihoods and jobs

Challenges and prioritization

Food-water-land systems are the world's largest employer, but most jobs are poorly paid and insecure, which is leading to alarming rates of youth leaving agriculture. This trend in turn jeopardizes the long-term sustainability of the sector and food security. Poverty remains disproportionately concentrated in rural areas, where rates are three times as high as in urban areas and agriculture is the predominant livelihood activity. COVID-19 has pushed 150 million people back into extreme poverty. The potential contribution of digital technologies to poverty reduction largely depends on whether the poor can access the right information when and where it matters most. If illiteracy is high, digital information cannot bring meaningful change. Poverty decreases, however, when more women and girls are educated, and women are more likely to invest in achieving health and prosperity, including for future generations.

DX1 will strengthen the local digital ecosystem to enhance the design and operation of digital advisory services and information systems and make them more inclusive and gender responsive. In addition, DX1 will scale these services and systems to reach ten times more local users. When fully scaled, these services can catalyze the digital transformation of food-water-land systems while raising revenues, creating jobs, and increasing rural household incomes.

Research questions

What are the impacts of investments in rural digital infrastructure on inclusion, poverty reduction, food security, and jobs? (WP1)

Components of Work Packages

WP1 will support policy makers in identifying priority investment options and establishing an enabling environment to support inclusive, climate-smart, and poverty-reducing digital innovations. Gap assessments and causal impact analyses will be conducted for supporting policymakers to identify the pathways to inclusively, and digitally, transform food, water, and land systems. These transformation pathways will lead countries to improving the systems' overall performance with timely provided information, while reducing poverty and creating more job opportunities. Impacts of improving digital literacy will be also assessed as a part of the causal impact analyses. WP2 will evaluate the role of marginalized rural women and youths in food-water-land systems and contextual challenges they face. This WP will examine how digital technologies like timely information, enabling services, and communication channels can lead to more gender-equitable livelihoods and higher incomes, while reversing the trend of youth leaving agriculture. WP2 will also support partnerships among digital innovators to improve the inclusivity performance of their services, which will be measured with a new tool, the Digital Inclusion Index for Food-Water-Land Systems. This WP will guide innovators in planning and achieving gender-responsive and gender-transformative outcomes. WP3, meanwhile, will enhance regional flood and drought early warning systems to offer accurate, location-specific information with more lead time to prepare and reduce damage to crops, livestock, businesses, and properties. WP4 will partner with local women- and youth-

led digital-oriented organizations to help DX1 localize research approaches and will boost the technical capacities of these organizations by connecting them with innovators in other regions through the South x South Collaboration Lab.

Measuring performance and results

By early 2025, in close collaboration with NARES and other relevant Initiatives such as HER+, National Policies and Strategies, and the RIIs, DX1 aims to support policymakers in developing at least 5 intersectoral strategies, plans, and drafted or finalized policies addressing the digital divide, broadening access to technologies and information, and reducing poverty. At least 10 partnering local digital innovators will be supported to scale their services and reach 100% more users, including >40% women and >40% youth.

Partners

In addition to the abovementioned partnering Initiative, DX1 will partner with Ministries of Agriculture and Food Security, NARES, and agrifood small and medium enterprises (SMEs) in each of the focus geographies. Local women- and youth-led digital-oriented organizations, such as Youth Mappers, will help DX1 localize research approaches. Triangular cooperation (i.e., North-South-South) will be pursued to link local digital agrifood startups with large technology companies such as Microsoft, Amazon, and (Google) X Development to address challenges in local digital ecosystems, leveraging their ongoing partnership with CGIAR Platform for Big Data in Agriculture.

Human resources and capacity development of Initiative team

The Initiative team will include experts in poverty reduction, livelihoods, and jobs data and analytics. DX1-dedicated gender and social inclusion experts will ensure socio-technological relevance and context of our work. Joint hiring of additional experts will be pursued with partnering Initiatives, potentially in coordination with the relevant Impact Area Platform. DX1 is engaging with CGIAR Digital Services to align Initiative-level strategies for human resources and capacity development with the (forthcoming) One CGIAR Global Digital Strategy.

5.3 Gender equality, youth, and social inclusion

Challenges and prioritization

Across low- and middle-income countries, women are 23% less likely than men to use the internet, and this gap widened by 5% between 2013 and 2019. Barriers to gender equality include the availability of infrastructure, financial constraints, information and communication technology (ICT) ability and aptitude, the perceived relevance of ICT, online safety and security, and socio-cultural and institutional contexts. Additionally, access to digital technologies remains expensive, limiting their reach and benefit not just to women but also to marginalized youths. There is strong potential, however, for women to realize more value by using digital tools. Because of shortcomings in digital access, structural inequalities, and the socialized nature of agriculture practices, we will target key improvements toward marginalized women but also move beyond binary gendered analyses of digital exclusion in relation to agricultural research for development [38].

Advancing women's digital connectivity is key to ensuring their economic empowerment and tackling structural issues. Enhanced and more affordable access to digital tools is critical,

coupled with policy interventions addressing long-term structural biases. Further research is needed to understand the source of the gender digital divide across food-water-land systems, the interactions of crosscutting factors that impede digital inclusion, and at what stages and levels in agrifood systems these inequalities occur. Sex- and age-disaggregated end-user analytics will help identify specific strategies to address gaps through digital solutions in synergistic combination with other interventions.

Research question

How can digital technologies assist women and girls in managing market and climate risks across food-water-land systems? (WP2)

Components of Work Packages

DX1 will focus on how, where, and when disruptions have occurred in the digital ecosystem either worsening or closing the gender digital divide. WP1 will address how public and private digital innovators can work together to contribute to the sustainable and inclusive transformation of food-water-land systems. WPs 1 and 2 will both engage with rural women in collaborative design processes to foster the gender-responsiveness of digital solutions. WP2 will specifically assess the role of women in food-water-land systems, their challenges, and how best digital technologies such as timely information, enabling services, and communication channels can reduce gender disparities and widen women's equitable access to technologies. WP2 will also support partnerships among digital innovators to improve the inclusivity performance of their services, which will be measured with a new tool, the Digital Inclusion Index for Food-Water-Land Systems; this WP will also guide innovators in improving gender-responsiveness. WP4 will partner with local women- and youth-led digital-oriented organizations to help DX1 localize research approaches and build the technical capacities of these organizations by connecting them to innovators in other regions through the South x South Innovation Lab. Finally, WP2 will enhance digital guidelines and services with gender-responsive design and improved gender and social equity strategies to ameliorate existing digital divides.

Measuring performance and results

By early 2025, in collaboration with NARES, with other relevant Initiatives such as HER+, National Policies and Strategies, and the RIIs, and with social and technical entrepreneurs, DX1 aims to support policymakers in developing at least 5 intersectoral strategies, plans, and drafted or finalized policies addressing the digital divide, widening women's access to technologies and information, and multiplying opportunities and entry points for youths in agriculture. The number of women actively using digital tools to manage climate and market risks will increase through heightened digital literacy and skills, and there will be tangible reductions in youth leaving agriculture. Partnering local digital innovations will be supported to scale their services and reach 100% more users, including >40% women and >40% youth.

Partners

In addition to the abovementioned partnering Initiative, DX1 will partner with Ministries of Agriculture and Food Security, NARES, and digital extension and financial services across focus geographies, including iCOW, Plantix, Mediae, Anacafe, and Fundación Génesis Empresarial. DX1 will also partner with socio-technological research organizations with

aligned objectives, including UN Women, International Fund For Agricultural Development (IFAD), Alliance for a Green Revolution in Africa (AGRA), and Research ICT Africa. Local women- and youth-led digital-oriented organizations, such as Youth Mappers and Zindi, will help DX1 localize research approaches.

Human resources and capacity development of Initiative team

The Initiative team will include fully dedicated experts in gender equality, youth, and social inclusion data and analytics. Joint hiring of additional experts will be pursued with partnering Initiatives, potentially in coordination with the relevant Impact Area Platform. DX1 is engaging with CGIAR Digital Services to align Initiative-level strategies for human resources and capacity development with the (forthcoming) One CGIAR Global Digital Strategy.

5.4 Climate adaptation and mitigation

Challenges and prioritization

Climate change and extreme events such as floods and droughts pose a major risk to the sustainability of food-water-land systems and their services for both society and the environment. Most low- and middle-income countries are ill-equipped to adapt and build resilience to the climate crisis, especially regarding monitoring data and analytics use for decision-making. For instance, ground-truthing data from quality-controlled weather stations are necessary to establish high-resolution climate baselines from which scientists can develop reliable forecasting models and contribute to adaptation strategies. These data also enable early warning systems to accurately forecast the timing and extent of flood events. Yet Africa has just one-eighth the minimum density of weather stations recommended by the World Meteorological Organization.

Research question

How can real-time data and advanced analytics assist in better preparation and defense of natural disasters such as floods and droughts across food, water, and land systems? (WP3)

Components of Work Packages

DX1 will support natural resource managers in Southern Africa, where the land is largely arid and suffering from a highly variable climate and extreme weather, to strengthen local technical capacities, fill data and knowledge gaps, and thereby effectively monitor food-land-water systems dynamics and develop advisories for transboundary states to coordinate their management of climate risks. Specifically, WP3 will support LIMCOM to manage climate risks across the transboundary Limpopo River Basin, together with a consortium of research teams including NARES, in-region academic institutes, and CGIAR. Based on a review of the current, no longer functioning LIMIS and other river basin management systems, WP3 will contribute to the development of the next-generation LIMIS as a new, real-time, data-driven integrated monitoring and modeling system based on a Digital Twin framework. In close collaboration with relevant Initiatives, including the NEXUS Gains, National Policies and Strategies, and UU, transboundary stakeholders will be supported in developing regionally coherent strategies for sustainably managing climate risks and equitably allocating water and land resources. WP4 will explore sensor technologies to fill real-time data gaps. WP5 will improve digital platforms and services using open-source software and interoperable technologies. WP1 will scale out

such technical and collaborative institutional arrangement to other regions with acute climate risks in order to build their technical capacities. WP5 will also address how key private- and public-sector institutional partners can fill technological capacity gaps in a manner that enhances evidence-based decision-making in food-water-land systems facing a climate crisis. WP2 will promote inclusive digital solutions that benefit stakeholders across food-water-land systems and mitigate their climate risks. WP3 will implement flood and drought early warning systems using real-time data from satellite remote sensing and internet-connected sensors for policy makers to make anticipatory decisions about risk mitigation. Finally, WP3 will also generate country case studies codeveloped by CGIAR, LIMCOM, and local technical partners to characterize each country's natural resource management challenges under a climate crisis and assess best-bet pathways toward stronger resilience of society and the environment.

Measuring performance and results

By early 2025, Natural resource management organizations will improve floods and drought early warning systems and disseminated reliable, actionable information to 100% more people. Five government agencies will incorporate high-frequency data to manage food supply chain anomalies proactively, in close communication with citizens through digital channels. Pilots utilizing real-time data will benefit >1,000 food-water-land system actors to increase productivity and profitability, manage risks, reduce food waste, and increase healthy diets.

Partners

In addition to LIMCOM and the abovementioned partnering Initiative, DX1 will partner with NARES and the NRM-relevant government agencies in LIMCOM member states. Other key partners include USAID Resilient Waters project (Find their Letter of Support here) and its network of academic institutions in Southern Africa such as the Universities of Botswana, Pretoria, Johannesburg, and Zimbabwe, the Botswana International University of Science and Technology, Great Zimbabwe University, and Universidade Eduardo Mondlane. DX1 will also coordinate with CGIAR's academic partners with advanced analytics and integrated modeling skills, including the Massachusetts Institute of Technology, the University of Twente, the University of Florida, Griffith University, the International Institute for Applied Systems Analysis, the United Nations Food and Agriculture Organization, and Columbia University.

Human resources and capacity development of Initiative team

The Initiative team will include experts in hydro-economic modeling, crop modeling, foresight modeling, and satellite remote-sensing analysis for natural resource management. DX1-dedicated gender and social inclusion experts will ensure socio-technological relevance and context of our work. Joint hiring of technical experts will be pursued with NEXUS Gains and UU, potentially in coordination with the relevant Impact Area Platform. DX1 is engaging with CGIAR Digital Services to align Initiative-level strategies for human resources and capacity development with the (forthcoming) One CGIAR Global Digital Strategy.

5.5 Environmental health and biodiversity

Challenges and prioritization

Environmental health and biodiversity are essential for human health and well-being, economic prosperity, food safety, and security; a balancing act is required to respond to as

many requirements as possible. Agriculture accounts for about 70% of global freshwater withdrawals. Driven by agriculture, nitrogen cycles are transgressing planetary boundaries, and phosphorus cycles are under threat. Maintaining environmental flows necessary for ecosystem sustainability represents a significant challenge to water resource management. In the Limpopo River Basin in Southern Africa, river flows are highly variable from season to season. Real-time data is needed to monitor basin-wide water and land systems and support informed decision-making about the equitable allocation of resources and planning. Where agricultural irrigation dominates consumptive water use, groundwater withdrawals must be effectively managed to ensure sustainability and preserve ecosystem services. When it comes to digital technologies, data management related to biodiversity challenges could be improved, for instance by setting data collection priorities and agreeing on data ownership and privacy standards; and enhancing data analytics would enable assessment of the value of healthy ecosystems and biodiversity and would support stronger economic rationales for action.

Research question

How can food-water-land system dynamics be systematically monitored and modeled to inform natural resource management organizations to make sustainable and inclusive decisions? (WP4)

Components of Work Packages

DX1 will build the technical capacities of natural resource managers and enable them to make decisions towards environmental health and biodiversity. WP3 will codevelop basin-wide food-water-land system dynamics modeling, which will allow natural resource managers to conduct what-if scenario analyses and estimate the environmental impacts of resource management decisions under extreme weather scenarios. In collaboration with NEXUS Gains, scenarios exploring the impacts of hydropower, infrastructure, and other forms of development on surface water availability, deforestation, and biodiversity will be also included in the trade-off analysis, accounting for their environmental costs. To better understand the dynamics of food-water-land systems and the political economy of stakeholders across transboundary regions, WP1 will assess how public and private partners can collaborate to share data, codevelop innovations, and contribute to sustainable and inclusive digital transformation. WP5 will support infrastructure development for private and public actors to access novel, underutilized data assets that can bridge the data gap for stakeholders monitoring environmental health and biodiversity. The platform Data Hub will address concerns about data ownership, production, privacy, and standards, as well as the shared benefits of utilizing the data.

Measuring performance and results

By early 2025, in close collaboration with NARES and other relevant Initiatives like NEXUS Gains, SHiFT, Food Markets, and the RIIs, DX1 aims to at least double the number of users receiving data-driven, context-specific recommendations to enhance resource use efficiency, contributing to environmental health and biodiversity. Digital nudging of households will significantly increase their likelihood of choosing healthy and sustainable foods. Producers will improve productivity, resiliency, and profitability using real-time data and data-driven recommendations, leading to the adoption of improved management practices and contributing to food security and environmental sustainability outcomes.

Partners

Partnerships with research organizations and in-region universities will provide additional proficiency in the local context.

Human resources and capacity development of Initiative team

DX1 will include food-water-land system-level expertise in environmental health and biodiversity dynamics. Partnering researchers will be trained to broaden their analytical scope and consider environmental health and biodiversity impacts from digital applications.

6. Monitoring, evaluation, learning and impact assessment (MELIA)

6.1 Result framework

6.1.1 Impact Area indicators and SDG targets

CGIAR IMPACT AREAS				
Nutrition, health and food security	**Poverty reduction, livelihoods and jobs**	**Gender equality, youth and social inclusion**	**Climate adaptation and mitigation**	**Environmental health and biodiversity**
COLLECTIVE GLOBAL 2030 TARGETS (The collective global 2030 targets are available centrally here to save space).				
End hunger for all and enable affordable healthy diets for the 3 billion people who do not currently have access to safe and nutritious food.	Reduce by at least half the proportion of men, women, and children of all ages living in poverty in all its dimensions according to national definitions.	Close the gender gap in rights to economic resources, access to ownership and control over land and natural resources for over 500 million women who work in food, land, and water systems.	Equip 500 million small-scale producers to be more resilient to climate shocks, with climate adaptation solutions available through national innovation systems.	Stay within planetary and regional environmental boundaries.
COMMON IMPACT INDICATORS				
# People benefiting from relevant CGIAR innovations	# People benefiting from relevant CGIAR innovations	# Women benefiting from relevant CGIAR innovations	# People benefiting from climate-adapted innovations	# Ha under improved management
SDG TARGETS				
SDG2 (Zero hunger) 2.3, 2.4, 2.a, 2.c	**SDG1 (No poverty)** 1.2, 1.4, 1.5, 1.a, 1.b **SDG8 (Decent work)** 8.2, 8.3, 8.10 **SDG9 (Innovation)** 9.3, 9.4, 9.a, 9.c **SDG17 (Partnerships)** 17.6, 17.8, 17.9, 17.17, 17.18, 17.19	**SDG5 (Gender equality)** 5.5, 5.a, 5.b **SDG10 (Reduced inequalities)** 10.1, 10.2	**SDG13 (Climate action)** 13.1, 13.2, 13.3, 13.b	**SDG6 (Clean water)** 6.3, 6.4, 6.5, 6.6, 6.a, 6.b

6.1.2 Action Area indicators

ACTION AREA: SYSTEMS TRANSFORMATION	
Action Area outcomes	**Action Area outcome indicators**
ST 1 - Farmers use technologies or practices that contribute to improved livelihoods, enhance environmental health and biodiversity, are apt in a context of climate change, and sustain natural resources.	STi 1.1 - Number of farmers using climate smart practices disaggregated by gender STi 1.3- Measurable implications of adoptions such as production, profitability, input use, product quality and associated price, environmental and health damage avoided, livelihood, and employment
ST 3 - Governments and other actors take decisions to reduce the environmental footprint of food systems from damaging to nature-positive.	STi 3.2 Area under improved water use plans (or water use efficiency measures – more ambitious and longer term)
ST 4 - Food system markets and value chains function more efficiently, equitably, and sustainably and lead towards healthier diets.	STi 4.1 Number of commodity value chain x country combinations that use tested innovations to improve efficiency, inclusion, sustainability and nutrition objectives. STi 4.2 Gaps between farm/processor gate and consumer prices (with some measures focused on smallholder farmers if possible) STi 4.3 Domestic market price integration, both spatial and temporal STi 4.4 Improved international price and exchange rate transmission STi 4.5 Trends in relative prices of healthy to unhealthy foods
ST & RAFS 1 - Smallholder farmers implement new practices that mitigate risks associated with extreme climate change and environmental conditions and achieve more resilient livelihoods	STRAFSi 1.1 Number of smallholder farmers who have implemented new practices that mitigate climate change risks, disaggregated by gender and type of practice
ST & RAFS 2 - National and local governments utilize enhanced capacity (skills, systems and culture) to assess and apply research evidence and data in policy making process	STRAFSi 2.1 Number of policies/ strategies/ laws/ regulations/ budgets/ investments/ curricula (and similar) at different scales that were modified in design or implementation, with evidence that the change was informed by CGIAR research

6.1.3 End-of-Initiative outcomes and outputs by Work Package

Result type	Result	Indicator	Unit	Geographic scope	Data source	Data method	Data frequency	Base value	Base year	Target value	Target year
Outcome 1a	Digital agrifood ecosystems strengthened through enabling policies, investments, and partnerships supporting inclusive innovations.	Number of policies/ strategies/ laws/ regulations/ budgets/ investments/ curricula modified in design or implementation, informed by CGIAR research.	Number	Guatemala, Kenya, Egypt, Nepal	Primary Policy documents	Key informant interviews	Annual	0	2022	5	2025
Output 1.1	Digital Policy Toolbox with policy options and examples that address DX1's key challenge areas.	Number of innovations	Number	Global	Primary Innovations database	Systematic review	Annual			10	2025
Output 1.2	Causal Impact Analyses that generate evidence of connectivity, digital literacy, real-time data impacts on food security and poverty reduction.	Number of other information products (reports)	Number	Guatemala, Kenya, Egypt, Nepal (expandable to include Mexico, Rwanda, Bangladesh, India)	Primary Research report	Research review	Annual			3	2025
Outcome 1b	Digital agrifood startups are engaged in triangular cooperative partnerships with a technology company and NARES.	Number of beneficiaries (i.e., agrifood startups) using the CGIAR innovation.	Number	Bangladesh, Guatemala, India, Kenya, Rwanda	Primary Innovations database	Key informant interviews	Annual	0	2022	10	2025
Output 1.3	South x South Digital Collaboration Lab that establishes synergistic partnerships.	Number of other information products (partnership agreements)	Number	Mexico, Guatemala, Kenya, India, Bangladesh	Primary Technical reports	Key informant interviews	Annual			10	2025

Output 1.4	Citizen Science Forum that helps government agencies accelerate digital innovation addressing DX1's key challenge areas through public participation.	Number of other information products (projects)	Number	Mexico, Guatemala, Kenya, India, Bangladesh	Primary Progress reports	Key informant interviews	Annual			10	2025
Outcome 2a	Digital agrifood services improve their gender-responsiveness.	Number of beneficiaries (i.e., agrifood services) using the CGIAR innovation.	Number	Bangladesh, Guatemala, India, Kenya, Rwanda	Primary End-users database	Application analytics Key informant end-users' forms	Annual	0	2022	10	2025
Outcome 2b	Digital agrifood services reach 100% more users.	Growth rate (%) of the number of users since the baseline (2022).	%	Bangladesh, Guatemala, India, Kenya, Rwanda	Primary End-users database	Application analytics Key informant end-users' forms	Annual	N/A	N/A	100%	2025
Outcome 2c	Digital agrifood services reach more women users.	Share (%) of women users.	%	Bangladesh, Guatemala, India, Kenya, Rwanda	Primary End-users database	Application analytics Key informant end-users' forms	Annual	N/A	N/A	40%	2025
Outcome 2d	Digital agrifood services reach more youth users	Share (%) of youth users.	%	Bangladesh, Guatemala, India, Kenya, Rwanda	Primary End-users database	Application analytics Key informant end-users' forms	Annual	N/A	N/A	40%	2025
Output 2.1	Best Practices for Digital Gender Equity that provide guidance for digital innovators to improve gender equity in their products.	Number of other information products (reports)	Number	Global	Primary Research reports	Code audit, app analytics, end-user surveys	Annual			3	2025

Output 2.2	Digital Inclusion Index, composed of three domains (i.e., access, use, benefit) that collectively assesses gender and other inequalities in local digital ecosystems.	Number of other information products (report, website, data collection and analysis tools)	Number	Bangladesh, Guatemala, India, Kenya, Rwanda	Primary Research reports	Research reports review	Annual			3	2025
Output 2.3	Enhanced digital skills of women and youth in agrifood systems	Number of people trained disaggregated by gender	Number	Bangladesh, Guatemala, India, Kenya, Rwanda	Primary Training events reports	Field forms	Bi-annual			1.000	2025
Output 2.4	Digital Extension Apps that adopted gender-responsive design principles	Number of other information products (computer software, models and code)	Number	Bangladesh, Guatemala, India, Kenya, Rwanda	Primary Digital extension database	Code audit, app analytics, end-user surveys.	Annual			10	2025
Outcome 3a	Natural resource management organizations improved early warning systems and are disseminating reliable, actionable information.	Number of beneficiaries (i.e., NRM organizations) using the CGIAR innovation, disaggregated by gender.	Number	Limpopo River basin (South Africa, Botswana, Zimbabwe, Mozambique)	Primary Informed official documents database	Key informant interview, DX1's literature review	Annual	0	2022	5	2025
Outcome 3b	Improved early warning systems are providing more people with reliable, actionable risk management information.	Growth rate (%) of the number of beneficiaries (i.e., people receiving the early warning information) since the baseline (2022).	%	Limpopo River basin (South Africa, Botswana, Zimbabwe, Mozambique)	Primary End-users database	Application analytics Key informant end-users' forms	Annual	0	2022	100	2025
Output 3.1	Enhanced flood and drought early warning systems that forecast the extent of climate hazards and recommend responses to mitigate risks.	Number of other information products (computer software, models and code)	Number	Limpopo River basin (South Africa, Mozambique, Zimbabwe, Botswana)	Primary Research reports	Research reports review				1	2025

Output 3.2	Digital Twin of Limpopo River Basin developed as an open-source database and modeling decision-support system.	Number of other information products (computer software, models and code)	Number	Limpopo River basin (South Africa, Mozambique, Zimbabwe, Botswana)	Primary Research reports	Research reports review				1	2025
Output 3.3	Gap assessments conducted to identify critical gaps in data, knowledge, skills, gender-balance, and enabling-environment to harness digital technologies for decision-making.	Number of other information products (reports)	Number	Regional Limpopo River basin (South Africa, Mozambique, Zimbabwe, Botswana)	Primary Research reports	Research reports review				4	2025
Output 3.4	Hydro-economic modeling case studies that showcase the potential of integrated modeling with real-time data to support transboundary water management decisions.	Number of other information products (reports)	Number	Regional Limpopo River basin (South Africa, Mozambique, Zimbabwe, Botswana)	Primary Research reports	Research reports review				3	2025
Outcome 4	Pilots utilizing real-time data benefitted >1,000 agrifood system actors to increase productivity and profitability, manage risks, reduce food waste, and increase healthy diets.	Number of beneficiaries using the innovation, disaggregated by gender.	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary End-users database	Application analytics Key informant end-users' forms	Annual	0	2022	1,000	2025
Output 4.1	Diagnostic studies of information flow	Number of other information products (reports)	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary Research report	Research review	Annual			3	2025
Output 4.2	Real-time monitoring impact assessment	Number of other information products (reports)	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary Research report	Research review	Annual			3	2025

Output 4.3	Digital ecosystem for decision-making using high-frequency data.	Number of other information products (report, website, data collection and analysis tools)	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary Decision-making report	Key informant interviews, high-frequency data success metrics	Annual			1	2025
Output 4.4	Real-time monitoring use-cases.	Number of other information products (report, website, data collection and analysis tools)	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary Research report	Research review	Annual			3	2025
Outcome 5a	At least 1,000 agrifood system actors participated in digital capability strengthening programs targeting women, youth, and vulnerable groups to manage climate risks.	Number of actors evidencing change in their capacity disaggregated by level of maturity.	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary	Application analytics	Annual	0	2022	1000	2025
Output 5.4	Digital Research Support Team that trained to support on-demand data management, computer programming, and data engineering tasks, hosted in partnering local institutions and Initiatives.	Number of people trained, long-term and short-term, disaggregated by gender (data analysts).	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary Training events reports	Field forms	Bi-annual			500	2025
Outcome 5b	At least 10 agrifood research-for-development organizations boost institutional digital capabilities to incorporate high-frequency data and underutilized datasets into decision-makings.	Number of beneficiaries (digital service providers) using the innovation.	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary	Application analytics	Annual	0	2022	10	2025
Output 5.1	Data and information gap assessment	Number of other information products (reports)	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary Research report	Research report review	Annual			1	2025

Output 5.2	Delivery of underutilized data resources through data hubs developed and deployed for partners to release underutilized private data assets as public goods.	Number of other information products (data sharing agreements, data and databases, web-based services)	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary Data resources database	Key informant interviews	Annual			3	2025
Output 5.3	Prototyping digital intelligence solutions co-created with key stakeholders to improve distillation of insights from underutilized data.	Number of innovations (e.g., dashboards, custom analytics, processing pipelines)	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary Innovations database	Key informant interviews	Annual			10	2025
Output 5.5	Digital Crisis Response Framework (draft) that enables food system actors to collect and share real-time monitoring data for agile policymaking under crisis.	Number of other information products (report)	Number	Bangladesh, Guatemala, India, Kenya, and Rwanda	Primary Research report	Research report review	Annual			4	2025

6.2 MELIA plan

6.2.1 Monitoring, evaluation, and learning plan

DX1 will implement an internal management system to monitor the Initiative progress towards WP-level outputs and outcomes, connecting to the partnering institutions' data and information systems. This information will feed CGIAR's Result Management System. DX1's MELIA focal points will ensure timely reporting to show the overall progress of the Initiative.

Outcome baselines will be collected within three months from the Initiative launch. If necessary, Theories of Change will be adjusted based on the gap assessments results. Identified key metrics of success include the number of actively engaged public-private stakeholders, achieved gender-responsiveness in digital services, number/type of data products used for decision-making. These will be measured and reported along the ones indicated in the Result Framework. Data collection methods include DX1's analytics, lean surveys, key informant interviews, and structured surveys with end-users and key stakeholders. This will feed an internal dashboard shared with partners, stakeholders, and funders to track the progress of various activities. A mid-term assessment and the end-line evaluation will be conducted to identify any significant variance from the plan, make course-correction decisions as needed, and assess the progress towards outcomes.

Some of key learning questions will focus on the assumptions, risks, and evidence of progress, including:

1) Have the gap analysis results been translated properly into effective solutions?
2) Have the main bottlenecks of information flows been identified and validated by local stakeholders?
3) Have the local digital innovators and government agencies been well engaged and collaborated in each target geography?
4) What is the country-level difference in achieving outcomes, and how can the learning of country-specificity be used to strategize the scaling of innovations?

6.2.2 Impact assessment plan

The Initiative impact assessment is embedded in Work Package 1. Based on the expected end-of-Initiative outcomes, causal impact assessments will be undertaken to assess the causal linkages envisioned in the Theories of Change. These analyses will use data collected throughout three-year period and generate impact evidence of inclusive digital services, improved information delivery, and informed decision-making. Planned methods include randomized encouragement design (e.g., assessing market efficiency changes after accessing price information), randomized A/B testing (e.g., testing better digital inclusion in the design of digital solutions), or non-experimental (e.g., the difference in difference, propensity score matching), depending on the specific research question, data, and resources availability. Additional studies will be conducted within the Initiative on a program evaluation review (e.g., quantification of digital reach of newly mobilized data) and the scaling readiness assessments for at least two core innovations.

Key learning questions of the impact assessments will include:

1) Have policymakers developed intersectoral strategies, plans, and policies with the potential to address the digital divide?

2) Have local digital innovators been able to scale business and secure investments through the South x South public-private partnerships?
3) Are the deployed digital services providing more gender-responsive and inclusive options for women to actively engage and benefit?
4) Have end-users used data-driven, context-specific recommendations to make informed decisions?
5) Is there any potential of the above to achieve causality with food security, poverty reduction, or climate adaptation?

6.3 Planned MELIA studies and activities

Type of MELIA study or activity	Result or indicator title that the MELIA study or activity will contribute to	Year of completion	Co-delivery Initiatives	How the MELIA study or activity will inform management decisions and contribute to internal learning
Baseline studies	Baseline values of the Initiative outcome indicators (Table 6.1.3).	2022	N/A	Outcome baseline values will be used as the basis of monitoring and evaluation of the Initiative's performance.
Program/project evaluation or review	Quantification of digital reach of newly mobilized data assets, private data hubs, and novel technical solutions that fills knowledge gaps (Table 6.1.3).	2023	N/A	Comparative assessment of download metrics, data quality and quantity delivered, user types, and use cases will facilitate iterative improvement of technological and partnership strategies to effectively deploy underutilized data.
Scaling readiness assessments	A series of light-track assessment of how "ready" digital innovations of the partners and DX1 are for scaling to reach ten times as many users and expand to new geographies and markets and strategizing for the acceleration and/or enhancement of the scaling.	2023	Potentially with RIIs (UU, TAFSSA, CWANA)	Assessment of midline successes and failures of the private data hub model will allow us to course-correct the implementation of this innovation, improve effectiveness, and contribute to the development of tools and learnings that facilitate scaling of the model beyond the Initiative.
Causal impact assessment learning studies	Improved digital solutions and information delivery leading to 1) improve citizen's digital literacy and skills to find timely information and use it to manage climate and market risks and 2) more women's active use of digital solutions to manage climate and market risks (Table 6.1.3).	2024	Potentially with RIIs (UU, TAFSSA, CWANA)	This study will improve Initiative understanding of the causal linkages between delivering novel information and downstream market efficiency or equity impacts. This is essential information for improving the investment targeting by policymakers and investors and mitigating their risks of digital investments.

7. Management plan and risk assessment

7.1 Management plan

We will adopt an agile management paradigm given the dynamic nature of digital technologies and real-time data underlying our theory of change. Guided by the strategic directions and enabling actions by the Initiative Management Team (IMT), five WP teams will be empowered to make rapid decisions and iterate learning cycles with partners.

The IMT will include an Initiative lead, a co-lead, five WP leads, a gender expert, a communication and engagement specialist, and administrative support. WP leads will be empowered (and accountable) to ensure coordination, scientific quality, cross-learning, and presenting overall findings to stakeholders. The Initiative staffing will be adequately split across managerial and scientific activities to ensure administrative and coordination duties do not constrain research and innovation. Additional capacities will be hired out as needed. Agile management approach will be complemented by periodic strategic stock-taking, rather than short-term frequent changes.

All WPs will apply the standardized ways of working. Timely decisions will be made based on (near-)real-time tracking of activities, the status of deliverables, and engagement with partners through the Theories of Change. All data collected, outputs generated, and partner engagements will be channeled to an internal MELIA platform and analyzed.

Initiative implementation will build partner capacity through learning-by-doing in all WPs, joint review of results and their significance, and support of coalitions, including relevant other Initiatives. We will regularly revisit the theory of change, test the assumptions, and implement the Scaling Readiness tools to see what works where and why, and adapt plans as needed. We will use the risk management approach (Section 7.3) to mitigate risks and react quickly.

7.2 Summary management plan Gantt table

	2022 Q2	2022 Q3	2022 Q4	2023 Q1	2023 Q2	2023 Q3	2023 Q4	2024 Q1	2024 Q2	2024 Q3	2024 Q4	2025 Q1	Description
WP1 | Enabling environment for digital innovation			1			2					3		1. Digital policy toolbox 2. Citizen science forum 3. South x South digital collaboration Lab
WP2 | Digital inclusion for women				1		2				3			1. Gender-responsive digital extension apps 2. Best practices for digital gender equity 3. Digital inclusion index
WP3 | System dynamics modeling				1			2					3	1. Digital twin of the Limpopo River basin 2. Enhanced flood and drought early warning systems 3. Country case studies
WP4 | Real-time monitoring of food systems			1				2				3		1. Diagnostic studies 2. Real-time monitoring use-cases and digital ecosystem 3. Evidence of real-time monitoring impacts
WP5 | Enabling digital platforms and services				1				2				3	1. Gap assessments and digital intelligence solutions 2. Digital research support teams 3. Private data hubs for underutilized data resources
Innovation Scaling			1				2				3		Scaling digital innovations (WP1) over three stages
MELIA Studies						1				2			1. Causal impact on enabling environment (WP1) 2. Causal impact on real-time data (WP4)
Project Management				1				2				3	1. Annual report for year 1 2. Annual report for year 2 3. Annual report for year 3

7.3 Risk assessment

Top 5 risks to achieving impact	Description of risk	Likelihood	Impact	Risk score Likelihood x Impact	Mitigations
		1-5	1-5		
Lack of incentives to collaborate [WP1, WP2, WP3, WP4, WP5]	Rural citizens, regional partners, and other stakeholders don't find enough incentives in co-designing, building, testing digital innovations as they don´t see direct benefit or impact.	3	4	12	DX1 will conduct a thorough incentive mapping to reduce the risk of ´competition exceeding collaboration´ and guide a proper monitoring process for incentive realization.
Poor engagement from owners of data assets [WP1, WP5]	The most significant risk to WP5 is the ability to identify and engage with champion partners. Without willing engagements from government ministries, private firms, and practitioners, gap assessments and data mobilizations efforts will be poorly targeted, specified, and ultimately unsuccessful.	2	4	8	DX1 is designed to maximally benefit from existing partnerships and relationships across food-water-land systems in target countries. Preparatory conversations and prior working partnerships exist with key stakeholders across all focus countries, and the initial phases of WP1 and WP5 are designed to further develop fruitful partnerships among key stakeholders.
Gaps in technical capacity, funding, and coordination among key partners [WP3]	Since DX1 and LIMCOM will co-develop the new Limpopo Information System as an integrated decision support system, it requires institutional engagement and time allocation and technical capabilities to design, deploy and operate.	2	4	8	Embedding CGIAR's continued strategic engagement in LIMCOM's next IWRM, in coordination with other Initiatives with overlapping goals (NEXUS Gains, National Policies and Strategies, Foresight and Metrics, Eastern and Southern Africa) and its major funders (GEF and USAID).
Gaps along impact pathways [WP1, WP2, WP3, WP4, WP5]	We expect generated evidence, data, and services will be used by relevant decision-makers and data users. However, gaps can exist when reaching them due to	2	4	8	DX1 will identify end users and work with them through user-centric design strategies, allowing services, data, and evidence to serve specific identified needs.

	incorrect channels, missing links, or lack of capacity on the end-user side.				
Biased data, unreliable information, and inaccurate predictive analytics results [WP2, WP3, WP4]	As DX1 aims to provide real-time data and timely information to decision-makers, we may not have enough time to thoroughly evaluate the accuracy of analytics results and adapt to user feedback.	2	5	10	Gap assessments will systemically review the performance of sampling frames with local partners before undertaking data collections and analysis. Algorithms will be reviewed to identify the risks of introducing biases. Information products will always accompany the measure of uncertainties and guidance on the interpretation. Results from prediction skill tests will be openly published. Digital capability training will get the next users familiarized with the probabilistic nature of predictive analytics.

8. Policy compliance and oversight

8.1 Research governance

Researchers involved in the implementation of this Initiative will comply with the procedures and policies determined by the System Board to be applicable to the delivery of research undertaken in furtherance of CGIAR's 2030 Research and Innovation Strategy, thereby ensuring that all research meets applicable legal, regulatory and institutional requirements; appropriate ethical and scientific standards; and standards of quality, safety, privacy, risk management, and financial management. This includes CGIAR's CGIAR Research Ethics Code and the values, norms, and behaviors in CGIAR's Ethics Framework and the Framework for Gender, Diversity, and Inclusion in CGIAR's workplaces.

8.2 Open and FAIR data assets

Researchers involved in implementing this Initiative shall adhere to the terms of the Open and FAIR Data Assets Policy. The Digital Transformation Initiative will align with the OFDA Policy's Open and FAIR requirements, ensuring:

- Rich metadata conforming to the CGIAR Core Schema to maximize Findability, including geolocation information where relevant.
- Accessibility by utilizing unrestrictive, standard licenses (e.g., Creative Commons for non-software assets; General Public License (GPL)) – Massachusetts Institute of Technology (MIT) for software), and depositing assets in open repositories.
- Wider access through deposition in open repositories of translations and requiring minimal data download to assist with limited internet connectivity.
- Interoperability by annotating dataset variables with ontologies where possible (controlled vocabularies where not possible).
- Adherence to Research Ethics Code (Section 4) relating to responsible data (through human subject consent, avoiding personally identifiable information in data assets and other data-related risks to communities).

9. Human resources

9.1 Initiative team

Category	Area of expertise	Short description of key accountabilities
Research	Development economics	Economic policy modeling, cost/benefit analysis, causal impact analysis, multi-market modeling.
Research	Impact evaluation	Gap assessment (data, information, supporting system), evaluating digital technology impacts on outcomes.
Research	Gender equality and social inclusion	Identifying the roles of women and youth and assessing the potential of digital technologies to address challenges.
Research	Geo-statistics	Assessing the sampling frames for real-time data collections and addressing data quality issues.
Research	Earth observation	Developing a workflow of satellite remote sensing data acquisition, processing, identifying system-level anomalies.
Research	Data science	Processing geospatial, ground truth, historical (secondary) data to inform impact evaluation, policy analysis, analytics.
Research	Social and biophysical system dynamics analysis	River basin-level integrated modeling to simulate climate-driven dynamics between food, water, land, energy, biodiversity systems.
Research	Water resources modeling	Landscape-level water balance and accounting to support the sustainable allocation of water resources across sectors.
Research	Hydro-economy modeling	Spatially explicit integrated modeling of distributed water resource, infrastructure, management options and economic values.
Research	Climate risk and forecasts	Analyzing historic climatology to assess risks and incorporating sub-seasonal climate forecasts into system dynamics modeling.
Research	Crop and livestock modelling	Assessing the changes in food productivity and profitability under the scenarios of sub-seasonal climate, water, and market changes.
Research support	Human-centered design/ Digital designer	Guiding the process of improving local digital ecosystems based on the analysis of human-technology interactions at multiple levels.
Research support	Responsible data management	Ensuring the collection, management, and sharing of data with partners are ethical and securely conducted.
Research support	Data engineering	Supporting data cleaning, annotation, harmonization, documenting, and publishing for reproducible science and research.
Research support	Data visualization	Supporting the rapid visualization of large real-time datasets for detecting anomalies and timely informing decision-makers.
Research support	Capacity building for digital capabilities	Provision of training to raise digital capabilities for finding, interpreting, and using timely information for decisions.

9.2 Gender, diversity and inclusion in the workplace

The Initiative team is close to meeting CGIAR's gender target of a minimum of 40% women in professional roles, and it is comprised of individuals from diverse backgrounds. We will follow the guidance outlined in CGIAR's GDI Inclusive Recruitment Toolkit mindfully when we recruit and ensure to include diverse voices into all our project activities. Women, minorities, and other under-represented groups will hold leadership roles in the Initiative team. This will be seen in the composition of our senior team and will extend to the fair allocation of leadership activities and accountabilities.

- Gender, diversity, and social inclusion is key to the DX1 IDT's design, innovations, and operations. The DX1 core team has significantly contributed to a number of gender-focused CGIAR research activities. In this Initiative, we will work with food-water-land systems actors and partners in focus geographies to address the gender divide and social exclusion in digital ecosystems. WP2 will be co-led by an interdisciplinary team of socially inclusive digital innovators and a gender equality and social inclusion (GESI) specialist, supported by additional experts as needed. During the inception phase in 2022, a GESI agenda will be applied across WPs and complemented by training and capacity.
- Based on local gap assessments (WP1 and WP2) and recurrent identification of needs, the Initiative team will adapt and recruit additional gender specialists to co-design inclusion strategies both at the management level and within digital innovation partners in the field. We will pay close attention to women, youth, and vulnerable groups, when selecting digital innovators partnering with us to improve products and services (WP1, WP2, WP5); and we will specifically foster gender-responsiveness along our proposed digital innovation outputs.

9.3 Capacity development

The Initiative's Management Team (i.e., lead, co-lead, Work Package leads, and project management staff) will complete training on inclusive leadership within three months of the Initiative's launch. Within six months, all Initiative team members and leading collaborators from funded partner organizations will complete additional training on gender-responsiveness and user-centric design in digital solutions. These trainings will focus on fostering conditions that enable reducing gender digital divide, easing access to relevant information and meeting needs of the most vulnerable groups in the target countries.

The Initiative kick-off will include an awareness session on CGIAR's values, code of conduct and range of learning opportunities available within CGIAR. Also, development opportunities will be made available for junior level Initiative team members, partners and stakeholders, including mentorship, internships and scholarships with representation of emerging professionals from under-represented groups, conference attendance, training on data science skills.

10. Financial resources

10.1 Budget

10.1.1. Activity breakdown

USD (M)	2022/2023	2023/2024	2024/2025	Total
Cross-cutting across Work Packages	0.82	1.22	0.78	2.81
Work Package 1	1.47	1.72	1.72	4.91
Work Package 2	1.46	1.46	1.25	4.17
Work Package 3	1.18	1.37	1.37	3.92
Work Package 4	2.14	2.14	1.84	6.12
Work Package 5	1.72	1.89	1.78	5.39
Innovation Packages & Scaling Readiness	0.21	0.21	0.25	0.67
Total	**9.00**	**10.00**	**9.00**	**28.00**

10.1.2. Geographic breakdown

USD (M)	2022/2023	2023/2024	2024/2025	Total
Global (no specific country)	1.03	1.43	1.05	3.51
Guatemala	1.40	1.48	1.35	4.23
Mexico	0.15	0.17	0.16	0.48
Kenya	1.40	1.48	1.35	4.23
India	0.89	0.96	0.89	2.74
Egypt	0.17	0.18	0.16	0.51
Rwanda	1.00	1.01	0.89	2.90
Bangladesh	0.17	0.17	0.16	0.50
Limpopo Basin	1.43	1.65	1.62	4.70
Ghana	0.89	0.96	0.89	2.74
Malawi	0.17	0.17	0.16	0.50
Indonesia	0.15	0.17	0.16	0.48
Nepal	0.15	0.17	0.16	0.48
Total	**9.00**	**10.00**	**9.00**	**28.00**

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