Projection of Benefits for the Livestock, Climate and System Resilience (LCSR) One CGIAR global initiative

Todd S. Rosenstock[1,2]; Julian Ramirez-Villegas[2,3,4]; Camila Bonilla-Cedrez[3,4]; Fiona Flintan[5]; Mounir Louhaichi[6]; Polly Ericksen[5]

[1] Current address: Center for International Forestry Research (CIFOR) / World Agroforestry Center (ICRAF)
[2] CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)
[3] Wageningen University and Research, Wageningen, The Netherlands
[4] Alliance of Bioversity International and CIAT
[5] International Livestock Research Institute (ILRI)
[5] International Center for Agricultural Research in the Dry Areas (ICARDA)

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Contents

1. Summary of projected benefits

Breadth	**x (multiplied by)**[a]	**Depth**[b]	**Probability**[c]
Numeric indicators from the 5 impact areas	(million)	Categories of impact (Lifesaving, transformative, substantial, significant, or perceptible)	Chance of success (very high, high, medium, low, very low)
1. **Food security, nutrition, and health:** #people benefiting from relevant CGIAR innovations	1.97	Significant	High
2. **Poverty reduction, livelihoods & jobs:** #people benefiting from relevant CGIAR innovations	2.96	Significant	Medium
3. **Gender, equality, youth & social inclusion:** #women benefiting from relevant CGIAR innovations	4.94 (3.71/1.24)	Total (Responsive/transformative)	Medium
4. **Climate adaptation and mitigation:** #people benefiting from climate-adapted innovations	9.87 (2.96/5.92/0.99)	Total (Substantial/Significant/ Perceptible)	Very high
5. **Environmental health and biodiversity:** #ha under improved management	2.0	Transformative	High

[a] Note that the figures presented are not exact predictions of what the LCSR initiative will deliver by 2030. Rather, they are reasonable, illustrative projections to help CGIAR and its funders understand the potential benefits of LCSR.

[b] Depth is defined based on the *Projected Benefits Guidance* provided by CGIAR, as follows:

- For Impact Area 1: (i) Life-saving = avoiding a death; (ii) Transformative = 100% permanent impact on income or in case of health preventing a severe disability; (iii) Substantial = 500% of annual income, 50% permanent impact on income, or if health benefit one disability-adjusted life year averted; (iv) Significant = 100% annual income or 10% permanent impact on income; and (v) Perceptible = 10–50% of annual income or 1–5% permanent impact on income.
- For Impact Area 2: (i) Transformative = 100% permanent impact on income; (ii) Substantial = 500% of annual income, 50% permanent impact on income; (iii) Significant = 100% annual income or 10% permanent impact on income; and (iv) Perceptible = 10–50% of annual income or 1–5% permanent impact on income.
- For Impact area 3: (i) Transformative = Constraining gender norms and dynamics are shifted and reduced, and norms and dynamics which support gender equality are strengthened, leading to greater gender equality; and (ii) Substantial = the different needs of men and women are identified and differentially met (but the underlying process by which these differing needs are generated are not affected)
- For Impact Area 4: Same as for Impact Area 1
- For Impact Area 5: (i) Transformative = Improved management delivers improvements in soil health and fertility (A), delivers biodiversity gains (B), and provides additional ecosystem service improvements (C); (ii) Substantial = Improved management delivers improvements in two of A, B, and C; (iii) Significant = Where improved management delivers in one of A, B, and C.

[c] Probability is defined using the current level of certainty that the projected impacts will be achieved by 2030 (based on CGIAR guidance document): (i) Very high: >80% expectation of achieving these impacts by 2030; (ii) High: 50–80% expectation; (iii) Medium: 30–50% expectation; (iv) Low: 10–30% expectation; and (v) Very low: <10% expectation.

2. Brief narratives per impact area

Nutrition, health & food security: we project **1.97 million** people, which arise taking into account the total number of benefitted people from LCSR (9.87 million, equal to Impact Area 4 benefits) times the percentage of food insecure people within LCSR target countries. Past evidence on income improvements of example LCSR interventions range between an average of 21% and 68% depending on the value chain (ERA, alpha release - http://era.ccafs.cgiar.org). Thus, we foresee **Significant** impacts. Given direct impacts on food availability from healthier and more productive livestock, and benefits mediated through income and reductions in asset loss (due to greater capacities to manage climatic extremes), the probability that these impact projections will come to pass by 2030 is **High.**

Poverty reduction, livelihoods and jobs**:** we project **2.96 million** people, arising by multiplying the total number of people benefitting from LCSR (9.87 million) times the poverty headcount ratio in LCSR countries. Based on the same evidence as for Impact Area 1, we foresee **Significant** impacts. LCSR will work to improve resilience, and protect assets and facilitate asset recovery through resilient, low emissions (RLE) practices and digitally enabled services that bundle climate information, insurance, and credit. LCSR will also go beyond the production process and into improving the dynamism and profitability of value chains. However, people in extreme poverty (as considered for this Impact Area) also generally lack adaptive capacity to adopt innovations, and therefore scaling pathways are often more constrained than for other types of beneficiaries. Thus, we give this projection a **Medium** probability.

Gender, equality, youth and social inclusion: we project **4.94 million women** (50% of total beneficiaries) to benefit from LCSR by 2030. Women are both vulnerable to climate change, but also powerful agents of change, yet the depth of impact for women and youth is difficult to determine. This is due to the difficulty to separate impact levels based on literature and past work, and to the lower levels of evidence of gender impacts from CGIAR climate change research compared to other areas of work. LCSR will work with a gender lens to address capacity needs of women and youth and empower them with knowledge, practices, technologies, and tools to enhance their decision making. LCSR will also work to foster policies that seek to transform gender dynamics. We argue that LCSR will likely yield a combination of Gender sensitive and Transformative impacts, with the majority (70–80%) of direct and indirect beneficiaries likely in the category of **Gender sensitive**. Due to the uncertainty in the impact levels (depth), we assign a **Medium** probability to this projection.

Climate adaptation and mitigation: we project **9.87 million people** benefitting from climate-adapted innovations by 2030. These benefits are computed through a bottom-up approach takes the project budget and assumptions about innovations and innovation scaling readiness as the starting point. Briefly, we use Cost per Beneficiary (CpB) from past and current investments in the areas of work of LCSR and multiply these times the total investment over the 2022-2030 period. For 2022-2024 we assume US$ 60 million, and for the remaining 6 years, we conservatively assume that LCSR is capable of leveraging assume a total of US$ 150 million. We account for innovation diffusion; that is, each beneficiary in the 2022-2024 period influences five beneficiaries in the remaining six years. Based on a review of income gains from RLE agriculture practices, climate information services, and insurance, we find that income gains of up to 50% are possible (Substantial impacts). However, the actual probability distribution of expected impacts is not known at this point. We argue that most (60–70%) beneficiaries will perceive, on average, **Significant** impacts. Based on past outcomes and achievements, the existence of scaling networks, and LCSR's ToC, we assign a **Very High** probability that these impacts come to pass by 2030.

<u>Environmental health and biodiversity:</u> we project **2 million hectares** under improved management by 2030. Applying the same approach as for Impact Area 4, we convert the CpB and breadth figures above to area under improved management. Households are assumed to adopt improved practices on a quarter of the average land holdings, 0.5 and 5 ha per household in Africa and Latin America, respectively. We apply these conversions to 75% and 25% of the beneficiaries calculated in IA4, based on the assumption that this is the expected relative Initiative effort between the two regions. Where LCSR targets improved rangeland management directly (WP1), we estimate a cost per ha (CpH), using a CpH value of US$ 62 based on historical and existing similar donor funded projects in the target region. Improving land management at the scale suggested will be **Transformative**. The land use and land cover change processes associated with livestock and landscape, rangeland and forest degradation contribute significantly to pushing Earth's support systems beyond its safe operating space. With these systems linked with important biodiversity and influencing infectious disease emergence, achievement of IA5 becomes one the most compelling reasons for LCSR, in collaboration with the other livestock Initiatives SAPLING and OneHealth. Based on the success of previous projects, and taking into account the scalability of the approaches proposed in LCSR, we assign this projection a **High** probability.

3. Projecting benefits from the bottom up

There are at least two complementary ways to estimate the number of beneficiaries that LCSR may reach. A top-down approach starts with the target population—e.g., small scale producers—in the region, as the baseline to establish the scaling domain and makes assumptions about the rate of adoption (e.g., 2%, Herrero & Thornton 2010; Annex 1). This approach tends to predict impact at scale because adoption starts with the first year. Such an approach, however, is divorced from logistical and budgetary practicalities of project implementation, which tend to have more modest initial impacts that then increase over time with the diffusion of innovations, increases in programmatic efficiency, and leverages of future funding. Furthermore, defining reasonable top-down estimates is contingent on clearly defined programmatic locations and scaling domain (and accuracy of associated data). At this time, these assumptions are challenging for the One CGIAR, given uncertainties about resources. Furthermore, defining realistic rates of adoption even with a well-defined scaling domain is difficult, as many factors affect adoption, and these factors and their effect vary by system, geography, and socio-economic status (Arslan et al., 2020).

In contrast, a bottom-up approach takes the project budget and assumptions about innovations and innovation scaling readiness as the starting point. This information informs assumptions about the size of the scaling domain to project the number of beneficiaries (Yet et al. 2020). Assumptions about costs per beneficiary (CpB) are informed by past projects, providing historically calibrated estimates. CpB estimates can themselves be tailored to specific work packages or innovations, which provides a disaggregated view of the projected benefit that is typically not possible with a top-down approach. Because bottom-up estimates are funding sensitive, they can be scaled up or down matching the resources available, with caveats about how changes in funding levels affect implementation and theories of change.

4. Inter-initiative synergies

LCSR developed these estimates independently of other proposed CGIAR Initiatives. We anticipate synergies with other Initiatives as per our ToC and based on discussions with ClimBer, SAPLING, OneHealth, Ukama Ustawi, MITIGATe+, LACResiliente, and Digital Harnessing. Annex 2 provides a synthesis of these synergies both topically and geographically. We have not assumed additional impact from these collaborations in this set of projections, to ensure the estimates are conservative and to avoid double counting of beneficiaries between initiatives. We will be further developing the synergies and factor in the outcomes of these into projections during the inception period.

5. Projected benefits for impact areas 1 to 4

1. Nutrition, health & food security; 2. Poverty reduction, livelihoods & jobs; 3. Gender, equality, youth & social inclusion; 4. Climate adaptation and mitigation

Indicator: #people benefiting from relevant CGIAR innovations

Assessing breadth

LCSR estimates for Impact Areas 1 (nutrition, health & food security), 2 (poverty reduction, livelihoods & jobs), 3 (gender, equality, youth & social inclusion); and 4 (climate adaptation & mitigation) follow the bottom-up approach to estimate the # of beneficiaries. This approach requires three fundamental pieces of information: i) budget, ii) CpB and iii) the theory of change. The budget and CpB values fuel the estimate while the theory of change orients it logically. Critical assumptions such as those for total budget, CpB, among others are listed in Tables, as are the justification and/or evidence supporting the selection of the values. Additional factors used in the calculations are explained throughout the narrative. Though LCSR report a bottom-up and budget-constrained estimate, we additionally computed a top-down estimate for the number of beneficiaries that is closer in line to the Guidance's examples to provide an aspirational expectation for LCSR outcomes (see Annex 1).

Table 1 | Select LSCR assumptions affecting the projected benefits. Additional assumptions described in narrative.

Assumption	Justification	Source
Annual budget US$20 million per year	LCSR is 1 of 2 livestock Initiatives and the only livestock and climate initiative. LCSR merged two Initiatives (ANIMALS and ASPIRE)	J Smith & I Wright (personal comm.)
The five work packages receive equivalent funding amounts (4 M/yr)	Simplifying assumption because budgets and countries are still being discussed	P Ericksen (personal comm.)
Beneficiaries represent a household, not an individual, and thus number of people reached is actually 3.7 x the beneficiaries	Average family size is 3.7 across the Global South. This is a conservative estimate given it includes urban households in addition to rural. The latter tend to have larger size.	Population Reference Bureau
Leveraged funds and complementary programs started post 2024 are implemented at the same level of efficiency (e.g., cost per beneficiary) as LCSR 2022-2024	LCSR's creates conditions for successful livestock programs reducing the risk of future projects but we are unable to forecast a change in efficiency.	Authors, based on experience and the Climate Funds Update database[1]

We expect that LCSR will reach about 300,000 beneficiaries by 2024. Here, we assume these beneficiaries represent farming households, and thus assuming a conservative value of 3.7 members per household, a total of about 1.1 million people may be reached for the anticipated US$ 60 million investment. When considering indirect beneficiaries through i) diffusion of LCSR innovations (e.g., producer imitation) and ii) multiplier effects derived from the expected US$ 150 million in co-financing

[1] https://climatefundsupdate.org/data-dashboard/

LCSR will generate, LSCR's total impact is projected to be 2.7 million households and 9.9 million people by 2030.

Although these values seem ambitious at first glance, they may be conservative. Firstly, indirect beneficiary adjustments account for relatively modest levels of innovation diffusion. We assume that each beneficiary in Phase I (2022-2024) influence 5 additional beneficiaries over the remaining 6 project years. Producer to producer diffusion for livestock innovations in East Africa, where much of LCSR will be directed, have been shown to train an order of magnitude more (Kiptot and Franzel 2015). We selected multipliers that represent only a small fraction of that number because we assume diffusion will occur through more informal processes rather than structured producer-trainers. This level of diffusion is modest and only assumes beneficiaries influence less than 1 additional beneficiary per year. In practice, however, WP5 efforts, supported by WP2 and WP3 evidence, could help design government policies that foster the creation of innovation and scaling hubs and improve digital infrastructure, therefore significantly raising and accelerating multiplicative and spillover effects.

LCSR's impact will be further magnified by the nearly 3:1 matching investment (US$ 150 million) it supports/leverages through WP4. We expect to directly support development of US$ 50 million investment during the 2022-2024 period. The additional US$ 100 million will be the consequence of investment risk reduction resulting from WP4 science and all the Work package results improving operating conditions and effectiveness for livestock projects in the target countries. The Climate Funds Update documents about 89 investments in the agricultural sector (virtually all of which include livestock) valued at about US$ 150 million per year (http://climatefundsupdate.org). But LCSR target countries only receive only a fraction of this amount, about US$ 50 million per year (33%), despite clear evidence of the priorities (see Ramirez-Villegas et al. 2021).

We thus assume that in the period 2028–2030, LCSR's work would have leveraged these US$ 100 million in investment. Based on past experience with the CCAFS and LIVESTOCK CRPs, we believe this assumption is conservative. For instance, between 2015 and 2016 the CCAFS low emissions and climate-smart agriculture Flagships helped catalyze US$ 223 million for the dairy sector NAMA (CCAFS, 2018) and US$ 250 million for climate smart-agriculture in Kenya (CCAFS, 2019). In Colombia, CGIAR is working with the Government to design the CSICAP (Climate-smart initiatives for climate change adaptation in agricultural production) program –a US$ 100 million investment from the GCF. Likewise, CCAFS tools helped catalyze Government investment in improving index insurance in India, reaching an estimated one million farmers (CCAFS, 2015). Further refinement of leveraged investments is possible only once LCSR implementation is underway.

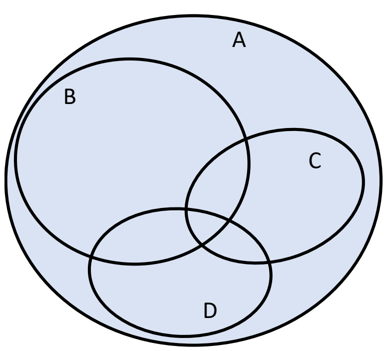
Table 2 | Project estimates of cost per beneficiary. Values are based on each project's own *ex-ante* predictions or *ex-post* evaluations and were derived from project documents. Regions: Central Asia (CA), East Africa (EA), Latin America (LAM), Sub-Saharan Africa (SSA), West Africa (WA). Source: Rosenstock and Ramirez-Villegas unpublished.

Project	Region	Select interventions	Cost per beneficiary (US$)	Donor	LCSR WP Relevance
MasAgro	LAM	Farmer extension and scaling	83	Mexican Govt.	1, 2
East African Dairy Development	EA	Scaling services (AI, postharvest, business scaling)	239 (Phase I) 188 (Phase II)	BMGF	1, 2, 4
Climate-smart initiatives for adaptation in Colombia	LAM	Digital agriculture and climate information services	186	GCF and Colombian Govt.	3
Climate-smart initiatives for adaptation in Colombia	LAM	New technological options for producers	708	GCF and Colombian Govt.	1, 2
Resilient Central America Honduras	LAM	Climate information services	98 (w/o DIG) 23 (w/ DIG)	TNC	3
DryDev	SSA	Landscape restoration	242	DGIS	1, 5
Climate Resilient Agribusiness for Tomorrow	EA	Accelerators	146	SNV and SMEs	4
Rwanda Climate Services for Agriculture	EA	Climate information services	44	USAID	3
Regreening Africa	EA & WA	Landscape restoration	24	EU	1, 5
Increasing carbon sequestration in Kyrgyzstan by supporting climate investments in forests and rangelands	CA	Landscape restoration, avoided deforestation	51	GCF	1, 4, 5

The value above provides the total number of beneficiaries expected through LCSR and represents the sum of Work package specific estimates, subject to the CpB for the types of interventions envisaged under each. Reliance of our estimates on previous but similar project CpBs introduces uncertainty into the calculation. The CpB values used were derived from a combination of *ex-ante* estimates and end-of-project results (Table 3). However, limitations exist. For instance, there are incentives for project developers and donors to set ambitious goals and fund aspirational projects, that present significant value for money, which could lead to unrealistically low CpBs. *Ex-post* estimates would clearly be more desirable, but no database of these values exists at this time. In addition, the CpBs used here only account for livestock producing households, whereas LCSR will benefit other parts of the value chain, especially through WP3 and WP4. But CpBs for value chain interventions are even more scarce and difficult to compile. To our knowledge, our compilation of estimates in Table 2 is the only existing one of its kind in the CGIAR. We argue that CpB uncertainty is at worst on par with, if not markedly lower than, the uncertainty of adoption rates, a critical parameter for the top-down approach (see Annex 1). It has been shown repeatedly that adoption lags behind expectations (Stevenson et al. 2019). Furthermore, adoption rates are notoriously difficult to specify correctly and the literature on barriers to adoption is in the midst of an external validity crisis (Arslan et al., 2020; Ruzzante et al. 2021) making extrapolation dependent upon adoption assumptions particularly problematic.

Thus, despite the CpB uncertainty, we believe that our estimates represent a reasonable first approximation of benefits by 2030 for One CGIAR investments on LCSR since they introduce no greater uncertainty than the alternative and even more so, are consistent with, and indeed based upon, a diverse envelope of investable and successful projects—with Theories of Change consistent with LCSR's—derived from a range of donors, interventions, and locations.

The bottom-up approach used here yields a projection of beneficiaries at the Initiative and work package level, but these need to be disaggregated into each of the One CGIAR action areas. To achieve this, we first define the a 'universe' of beneficiaries, and then use the initiative's theory of change to define relationships between this universe and each of the action areas. LCSR's theories of change offer direction to allocate the total number of people reached (9.8 million) to each indicator (Figure 1). In LCSR, the universe of beneficiaries constitutes all the population that will implement climate adaptation, resilience-building, and or mitigation options (A). Hence, <u>the beneficiaries assigned to each indicator are not unique groups; they often overlap</u>. This means that the total added across the four indicators will exceed our total reached. Our theory of change necessitates this.



Letter	ToC meaning	Impact area relevance
A	Universe of beneficiaries for LCSR: Population that will implement climate adaptation, resilience-building, and/or mitigation options	Impact Area 4: # people benefiting from climate-adapted innovations
B	Women beneficiaries: Portion of the total beneficiaries that are women	Impact Area 3: #women benefiting from relevant CGIAR innovations
C	Poor beneficiaries: Portion of the total beneficiaries that are in extreme poverty (<1.9 USD/day)	Impact Area 2: #people benefiting from relevant CGIAR innovations
D	Food insecure beneficiaries: Portion of the total beneficiaries that are food insecure	Impact Area 1: #people benefiting from relevant CGIAR innovations

Figure 1 | Definition of the universe of beneficiaries and their breakdown into specific characteristics of interest (gender, poverty, food insecurity) relevant to OneCGIAR Impact Areas.

This means that during LCSR implementation most of the nutrition, health, and food security (IA1) or poverty, livelihoods, and jobs (IA2) benefits will be through adaptation measures (IA4) whether it is land use planning (WP1), improved farm management (WP2), climate information services or insurance (WP3), or increased resilience finance (WP4). Similarly, women and youth (IA3) will derive nutrition benefits from the availability of animal-source foods (WP2) or the increase in jobs based on supporting small and medium enterprises (WP4).

Based on this, a scaling factor was developed to estimate the proportion of the total people reached for each indicator based on the LCSR's theory of change (Table 3).

We derive projected benefits for all impact areas using our understanding of the characteristics of the universe of beneficiaries in terms of gender, poverty, and food insecurity. Because all of LCSR beneficiaries will benefit from LCSR's interventions on adaptation, resilience-building and/or mitigation, it follows that they need to be exposed to climate hazards and have inefficient production practices. Based on this premise, the disaggregation of beneficiaries by impact area is done as described below. Table 3 shows the resulting projected benefits per impact area.

- For IA4 (Climate adaptation and mitigation), we assume the projected beneficiaries equal the total number of beneficiaries.
- For IA3 (Gender), we compute the percentage of women in climate hazard-exposed areas using geospatial data on population by sex from WorldPop.org and the hazard layer used in the prioritization analysis (Ramirez-Villegas et al., 2021). We apply this percentage to the total number of beneficiaries.
- For IA2 (Poverty), we determine the percentage of people living in extreme poverty (i.e., with less than 1.9 USD/day) as reported in the World Bank sub-national poverty dataset, in all hazard exposed areas. We apply this percentage to the total number of beneficiaries.
- For IA1 (Food insecurity and nutrition), we determine the percentage of people with insufficient food consumption, as reported by the World Food Programme (WFP) Hunger Map[2], within hazard exposed areas. We apply this percentage to the total number of beneficiaries.

[2] https://hungermap.wfp.org

Table 3 | Scaling factors used to disaggregate projected benefits per impact area

Impact area	Scaling factor	Theory of change-based justification	Beneficiaries (million)	People (million)
Nutrition, health & food security	0.2	LCSR improves nutrition, food insecurity and health at the household level mediated through productivity and income gains, and in consumers through better management of climate-related shocks in value chains and synergies with OneHealth	0.53	1.97
Poverty reduction, livelihoods & jobs	0.3	Adoption of new technologies will increase productivity and resilience to climate stress, therefore increasing producer annual and permanent income, lifting people out of poverty.	0.80	2.96
Gender, equality, youth & social inclusion	0.5	We aim for gender parity, with at least 50% of program directed toward women.	1.33	4.94
Climate adaptation & mitigation	1.0	Every intervention in the program targets climate adaptation or mitigation directly.	2.67	9.87

The estimates provided here are a first approximation to projected benefits of LCSR by impact area. We recognize that the data-based methods employed here to derive the scaling factors used to breakdown overall projected benefits into each impact area have inherent limitations. For example, we use the percentage of people under extreme poverty (people with <1.9 USD/day), whereas other poverty levels could also be considered (e.g., <3.2 USD/day). Likewise, largely due to lack of reliable data, our metric to define benefits for nutrition, health, and food security is limited to food consumption, and does not differentiate between acute or chronic food insecurity, human health benefits from better pest and disease management of livestock, and malnutrition. Finally, the current estimates do not account outcomes that result from enhanced dynamism in livestock value chains (including job creation and consumer health and nutrition) expected to occur through investments leveraged by WP4, and digitally-enabled services related to WP3.

Assessing depth and probability

We assembled recent meta-analyses and data on LCSR interventions to assess the depth of likely impacts. Where syntheses were unavailable, we report results of exemplar studies, scoping reviews, or other pieces of evidence. Estimating depth based on only a few or even a single study is necessary for livestock systems because, as mentioned, numerous times in the proposal, there is a serious lack of data on livestock systems and solutions (Riccardi et al. 2020). Projections based on limited data may raise concerns about accuracy. However, the depth category bands are differentiated beyond the likely levels of uncertainty. For example, the difference between significant and substantial impact on income for

IA1 is 5x. Furthermore, the first process measurement typically yields the greatest reduction in uncertainty and thus we subscribe to the idea that some data are better than no data.

IA1 & IA2. Depth for Nutrition, health, and food security and Poverty, Jobs, and income are assessed together, as both address changes in income (see Guidance). LCSR's impact will be **Significant**. Evidence suggest that improving livestock management through feeds and breeds will increase productivity and income, but that these effects vary, sometimes significantly, across value chains and target areas. Bateki et al. (2020) conducted a meta-analysis (on the impact of livestock interventions underlying East African (N= 36 studies) and found that improved feeding practices and improved breeds increase productivity by 10-50% with the greatest benefit being derived from producers using both technologies. The Evidence for Resilient Agriculture (ERA) meta-dataset includes more than 400 livestock studies that took place in Africa. Synthesis of those data suggest that productivity will increase 6.1, 37.2, and 32.8% when supplementing diets of broilers, cattle for beef, and goats and improved breeds produce 11.4, 33.6, and 16.4% by comparison to producers' common techniques. Income improvements for uptake of these interventions range between an average of 21% and 68% depending on the species (ERA, alpha release - http://era.ccafs.cgiar.org). The economics of landscape restoration is also favorable, with efforts in Kenya showing increases of 21 to 145% gains in Net Present Value (Lutta et al. 2020). While the improvements may be modest, livestock often contribute a disproportionate amount of household income and thus even modest increases in livestock productivity can have disproportionate influence on household welfare (because they are important assets). The probability of these projections to come to pass is **High** for IA1 and **Medium** for IA2. The probabilities were assigned relative to likelihood of productivity (IA1) and income (IA2) increases with the use of indicative LCSR interventions, with distributions derived from ERA's extensive database (http://era.ccafs.cgiar.org). Data in ERA show that in some cases productivity increases but incomes decline (e.g., due to increased costs). Therefore, the probabilities reflect this and were assigned separately for IA1 and IA2, despite the depth indicator being the same (i.e., income)

LCSR targets the 'number of beneficiary' indicator for IA1, but LCSR may have impacts on the micronutrient indicator too. Animal source foods are an important source of micronutrients, particularly for pregnant women and children under 5 years of age. Where mortality rates are high, it is also possible that LCSR's work will lead to saving lives (but this is very difficult to determine with precision due to lack of historical evidence). LCSR interventions aim to help increase the availability of animal source foods, through building productive and adaptive capacities of producers (WP1,2,3) and resilient agrifood systems (WP4). A recent study of more than 130,000 children provides an indication of the potential benefits. Consumption of dairy, eggs, and meat/fish is associated with 6.6 points decline in stunting across all regions (3.4 from dairy, 1.3 from eggs, and 2.1 from fish) and consumption of any animal source food in LAM translates to an 8.8-point reduction, 1.8 in MENA, 2.2 in WCA 2.2, ESA 4.5 (Headey et al. 2018). If we assume that our approximate 2.67 million beneficiaries have 2 children, a 6.6 percentage point reduction would mean about 300,000 children would not be stunted as a result of LCSR interventions.

IA3. Women are both vulnerable to climate change, but also powerful agents of change (Jost et al., 2015; Kristjanson et al., 2017; Nyasimi and Huyer, 2017), yet the depth of impact for women and youth is difficult to determine. This is partly due to the difficulty to separate impact levels based on literature and past work, but also due to the lower levels of evidence of gender impacts from CGIAR climate change research compared to other areas of work (but see Ingabire, 2021; Mulema et al., 2021; Giraldo et al., 2020). LCSR's Theory of Change addresses gender from the outset, seeking to understand and address the needs of women, youth and other vulnerable groups (e.g., in terms of technologies, information, capacities), but also aiming to disentangle the social norms that can affect uptake of practices and technologies at scale. Based on LCSR's ToC, we believe WP1, WP2 and WP3 will be primarily gender sensitive. Existing evidence shows that climate-smart agriculture and climate information services can enhance 'voice' and empower women in their decision-making process and asset management, but not fundamentally transform gender dynamics (e.g., Giraldo et al., 2020; Ingabire, 2021). Furthermore, WP2 and WP3 will seek to work with women-centric organizations to build their capacity to adapt to climate change and manage climate risk, empowering these organizations as well as the women that are part of them in relation to household decision making in response to climate change. WP4 and WP5 have the potential to be gender transformative. While results from policy-oriented work with respect to gender are varied, it is possible to identify mechanisms to address gender-related power relations and inclusion of women in decision-making processes (Mulema et al., 2021). Together with SAPLING, LCSR will work to enhance existing challenges in monitoring and evaluation of gender outcomes, which will in turn help build evidence for policy makers. Furthermore, LCSR's policy and institutional strengthening work around climate-security programming carries an explicit gender lens, which by definition seeks to transform the power relations to reduce climate-triggered conflict, migration and food insecurity. Based on these considerations, we argue that LCSR's impact will likely yield a combination of **Gender sensitive** and **Transformative** impacts, with the majority (70–80%) of direct and indirect beneficiaries likely in the category of **Gender sensitive**, and the remainder in the **Transformative** category. Due to the uncertainty in the impact levels (depth), we assign a **Medium** probability to this projection.

IA4. All LCSR interventions will be climate specific. For the adaptation and mitigation impact area, we project that LCSR's impact will be, on average, **Significant**. However, we also expect part of the beneficiaries to experience, on average, **Substantial** impact, and likely a very small proportion to have, on average, **Perceptible** impacts. This is because not all technologies have the same effect everywhere, and, while the upper bound of impact according to outcome harvesting, as well as *ex-ante* and *ex-post* impact assessment studies (see below) is commensurate with the **Substantial** depth category, in reality the range of impacts for project beneficiaries follows a probability distribution whose characteristics are largely unknown at this point. The assessment provided here is based on existing evidence of insurance, climate information services, and of climate-smart agricultural practices impact (see below, and also depth evidence for IA1&2 above).

Vyas et al. (2021) review and map research on insurance, identifying 57 studies in the global tropics focusing on the livestock sector; however, focus on impact assessment of livestock insurance is limited (16 studies). Income gains reported by those studies vary between 10 USD/household and 763 USD/household per year. Where the adoption of insurance is sustained in time, these income gains can be permanent (Chantarat et al., 2013, 2017). While expressing the reported income gains by the different studies is not straightforward, existing studies show up to 36% reduction in distress sales of livestock, and 4% lower poverty headcount ratios in insurance adopters as compared to non-adopters. We believe poor households with sustained adoption of insurance (the vast majority of our beneficiaries) will likely perceive permanent income gains of at least 30% (*between significant and substantial*).

Climate information services (CIS) that are adequately tailored to users' needs and connected to the right communication channels scale easily to reach large numbers of individuals and show substantial impact for a relatively low cost. Sixteen studies across SSA show that weather and climate services for agriculture decision support can offer a significant range of benefits, up to as much as a 66% increase in yield or income (Vaughan et al., 2017). A recent global blueprint for digital CIS yield returns of investment in the range 1:10 to 1:70, with greater efficiency where institutional empowerment and capacities are enhanced substantially (Ferdinand et al., 2021). The same analysis shows that income gains average 25% (*between significant and substantial*). Furthermore, feed interventions triggered by early warning systems give a 7x return in avoided losses and added benefits (Osorio and Gallina, 2018). Similarly, a total of 1.7m USD in losses were avoided in a single year by the use of seasonal forecasts by 170 rice farmers in Colombia (CCAFS, 2015). Estimates suggest if all farmers in Kenya, Malawi, Mozambique, Tanzania, and Zambia leveraged seasonal forecasts, GDP gains would average USD 113 million annually (USD 3 per hectare) (Rodrigues et al., 2016). Evidence from Latin America (Giraldo et al., 2020) and Africa (Birachi et al., 2020) shows that where institutional capacities to co-produce, translate, transfer, and use CIS are strengthened, the use and impact of CIS on farmer's decision making and incomes can be sustained in time.

WP3 seeks to bundle CIS, insurance, and loans, working to reduce transaction costs by MFIs (micro-finance institutions), remove barriers in the uptake of insurance by producers and value chain actors, and reaching scale by leveraging digital technologies. Together with the technologies implemented by WP2, which can boost productivity by up to 50%, these interventions will *very likely* improve permanent incomes by up to 50% or more. However, given the variable performance of these technologies and their impact across the geographic and socio-economic space, and the fact that the actual probability distribution of expected impacts is not known at this point, we argue that most beneficiaries will perceive, on average, **Significant** impacts. A second (smaller) group will likely perceive, on average, **Substantial** impacts, and a third portion (very small, likely under 10% beneficiaries) will likely perceive, on average, **Perceptible** impacts. Based on past outcomes and achievements, the existence of scaling networks, and LCSR's ToC, we assign a **Very High** probability that these impacts come to pass by 2030.

LCSR's projected benefits quantification for IA4 focuses on adaptation. However, LCSR expects to have measurable effects on greenhouse gas (GHG) emissions too. The livestock sector is responsible for about 12% of annual global greenhouse gas emissions. Enteric methane emissions are among the largest agricultural source in each target LSCR country. The IPCC AR6 report highlights the opportunity and need to reduce methane emissions and in methane from livestock agrifood system is a substantial source.

Emissions will be reduced through i) avoiding deforestation and guarding against irreversible carbon loss in tropical forests due to regional and global value chains (WP1, 4), ii) increasing production efficiency through improved diets (WP2), and reducing heat stress and increasing carbon storage in soils and biomass with expanding silvopastoral systems (WP1, 2), and restoring rangelands and improving land productivity (WP1). While many LCSR's actions directly target mitigation, but adaptation interventions will have cascading effects on emissions too. We do not project emission reductions here due to uncertainties around the funding and partnerships. Given the known benefits of these action (Rosenzweig et al. 2020), and the significant number of land under improved management (see IA5 below), we expect the significant and verifiable emission reductions with LCSR.

However, LCSR does not expect absolute emissions to decline in all system and with all interventions. For example, increasing dietary protein and energy intake of low productivity cattle increases methane emissions by comparison to those eating unimproved diets. Productivity typically increases faster than emissions and thus the GHG intensity (kg product per kg emissions) of production declines. GHG intensity is a better indicator of progress for livestock system where concerns of food and nutrition security exist. LCSR will address this in two ways. One, we will evaluate systems using multiple GHG indicators to be locally relevant including Global Warming Potential (GWP) over 20- and 100-time frames (Tg CO_2), GHG intensity (Tg CO_2eq per kg product), and Global Warming Potential* (Tg CO_2) which accounts for the biogenic source of methane and its degradation to CO_2. Two, LCSR aims to develop and quantify farm and landscape measures that offset enteric methane emissions, such as agroforestry and landscape restoration.

6. Projected benefits for impact area 5

Environmental health and biodiversity

Indicator: #ha under improved management

Livestock are the principal cause of land degradation in semi-arid and arid rangelands and tropical deforestation. Because these ecosystems are home to more than 50% of Earth's biodiversity (Giam et al. 2017), help regulate global climate change (IPCC 2021), make it rain - literally - by influencing local, regional, and global hydrology (Ellison et al. 2017), and play an out sized role in the emergence of zoonotic disease (Allen et al. 2017), the livestock agrifood system presents critical leverage points for human and ecosystem sustainability (Mehrabi et al. 2020).

Assessing breadth

LCSR's approach to IA5 builds upon the bottom-up approach for assessing breadth of the four other Impact Areas. For WPs that focus on households (2, 3, 4), we convert the CpB and breadth figures above to area under improved management. Households are assumed to adopt improved practices on a quarter of the average land holdings, 0.5 and 5 ha per household in Africa and Latin America, respectively. We apply these conversions to 75% and 25% (respectively) of the beneficiaries calculated in IA2-4, based on the assumption that this is the expected relative Initiative effort between the two regions. Where LCSR targets improved rangeland management directly (WP1), we estimate a cost per ha (CpH) value similar to the CpB above. The CpH is needed to project land area benefits for WP1 because number of beneficiaries and area of land are poorly related. We adopt an average CpH value (US$ 62) based on historical and existing similar donor funded projects in the target region (Table 5). Use of an average value despite the significant dispersion of the data introduces uncertainty into the calculation and implementation risk for not hitting targets. However, LCSR's innovations, theory of change and staff's experience suggest this value may be an overestimate. In addition to restoration, WP1 includes institutional improvements which can improve land management through process vs. expensive restorative investments in land, oftentimes over vast areas for relatively modest costs. For instance, in southern Tunisia, the primary interventions is rangeland resting (at almost no cost). It is locally called *Gdel* or *Hima* and is now practiced on 100,000s ha illustrating the potential value for money opportunities to improve rangeland management.

Table 5 | Examples of cost per ha for rangeland management improvement. The top four rows represent projects of similar size and scope to LCSR. The bottom two rows are shown to contrast with large government programs and to illustrate additional LCSR partnership opportunities

Country	Approximate area (ha)	Investment (US$ million)	Cost per ha (CpH, US$)	Donor
Ethiopia*	1,493,000	165.2	110.7	GCF
Kenya	500,000	34.3	69.0	GCF
Kenya/Tanzania	248,814	1.4	7	IFAD

*Include only grant and loan finance.

According to these assumptions, we estimate that LCSR will improve management on 577,841 ha by 2024 and 2,046,318 by 2030. The ambitious targets are completely possible given the focus on rangelands, where few groups influence management on large tracts (WP1) and breadth of people reached through digital means (WP3). The ability to reach these goals, especially the 2022-2024 target, relies upon a quick start of the Initiative. Efforts that continue and build on previous engagements can help mitigate this risk but it cannot be completely negated. It is feasible that LCSR will improve management over a much larger land area, depending on the participating communities and geographies included in WP1 and which private sector partners are included with WP4. Through governance and value chains, these partners have potential to make dramatic changes over land area meaningful for hydrology, climate, and biodiversity.

Assessing depth and probability

Improving land management at the scale suggested will be **Transformative**. The land use and land cover change processes associated with livestock and landscape, rangeland and forest degradation contribute significantly to pushing Earth's support systems beyond its safe operating space. The IPCC's Special Report on land highlights these intersections among food systems, climate and land (IPCC 2017). With these systems, linked with important biodiversity and influencing infectious disease emergence, achievement of IA5 becomes one the most compelling reasons for LCSR, in collaboration with the other livestock Initiatives SAPLING and OneHealth. The **probability** of achieving multiple soil, land, water outcomes simultaneous is **High** given the impacts that livestock agrifood systems have on the multiple environment systems simultaneously.

7. References

Abate, G.T., Rashid, S., Borzaga, C., Getnet, K., 2016. Rural Finance and Agricultural Technology Adoption in Ethiopia: Does the Institutional Design of Lending Organizations Matter? World Dev. 84, 235–253. doi:10.1016/j.worlddev.2016.03.003

Abdulai, A., Huffman, W.E., 2005. The Diffusion of New Agricultural Technologies: The Case of Crossbred-Cow Technology in Tanzania. Am. J. Agric. Econ. 87, 645–659. doi:10.1111/j.1467-8276.2005.00753.x

Allen, T., Murray, K.A., Zambrana-Torrelio, C., Morse, S.S., Rondinini C., Di Marco, M., Breit, N., Olival, K.J., Daszak, P. Global hotspots and correlates of emerging zoonotic diseases. Nat. Comm. 8: 1124.

Arslan, A., Floress, K., Lamanna, C., Lipper, L., Asfaw, S., and Rosenstock, T. 2020. "The adoption of improved agricultural technologies - A meta-analysis for Africa." IFAD Research Series 63. Rome: IFAD

Birachi, E., Hansen, J., Radeny, M., Mutua, M., Mbugua, M. W., Munyangeri, Y., Rose, A., Chiputwa, B., Solomon, D., Zebiak, S.E., Kagabo, D.M. 2020. Rwanda Climate Services for Agriculture: Evaluation of farmers' awareness, use and impacts. CCAFS Working Paper no. 304. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

CCAFS. 2015. Cracking patterns in big data saves Colombian rice farmers' huge losses. CCAFS Outcome Case. November 2015.

CCAFS. 2015. Scaling up and improving insurance schemes for farmers in India and Nigeria. CCAFS Outcome Case. August 2015.

CCAFS. 2018. Kenya's State Department of Livestock catalyzes investments of USD 223 million in the dairy sector. Available at https://cgspace.cgiar.org/handle/10568/106306

CCAFS. 2019. County-level climate risk profiles guide USD 250 million investment in Kenya. CCAFS Outcome Case. March 2019.

Chantarat, S., Mude, A.G., Barrett, C.B., Carter, M.R., 2013. Designing Index-Based Livestock Insurance for Managing Asset Risk in Northern Kenya. J. Risk Insur. 80, 205–237. doi:10.1111/j.1539-6975.2012.01463.x

Chantarat, S., Mude, A.G., Barrett, C.B., Turvey, C.G., 2017. Welfare Impacts of Index Insurance in the Presence of a Poverty Trap. World Dev. 94, 119–138. doi:10.1016/j.worlddev.2016.12.044

Dayamba, D.S.; Ky-Dembele, C.; Bayala, J.; Dorward, P.; Clarkson, G., et al. 2018. Assessment of the use of Participatory Integrated Climate Services for Agriculture (PICSA) approach by farmers to manage climate risk in Mali and Senegal. *Clim. Serv.* 12, 27–35. http://doi.org/10.1016/j.cliser.2018.07.003

Drewry, J.L., Shutske, J.M., Trechter, D., Luck, B.D., Pitman, L., 2019. Assessment of digital technology adoption and access barriers among crop, dairy and livestock producers in Wisconsin. Comput. Electron. Agric. 165, 104960. doi:10.1016/j.compag.2019.104960

Ellison, D. Morris, C.E., Locatelli, B., Sheil, D., Cohen, J., Murdiyarso, D., Gutierrez, V., van Noordwijk, M., Creed, I.F., Pokorny, J., Gaveau, D., Spracklen, D.V., Bargués Tobella, A., Ilstedt, U., Teuling, A.J., Gebrehiwot, S.G., Sands, D.C., Muys, B. Verbist, B., Springgay, E., Sugandi, Y., Sullivan, C.A.. 2017. Trees, forests, and water: Cool insights for a hot world. Glob. Environ. Change. 43: 51-61.

Ferdinand, T., E. Illick-Frank, L. Postema, J. Stephenson, et. al. 2021. A Blueprint for Digital Climate-Informed Advisory Services: Building the Resilience of 300 Million Small-Scale Producers by 2030. Working Paper. Washington, DC: World Resources Institute.

García de Jalón, S., Silvestri, S., Barnes, A.P., 2017. The potential for adoption of climate smart agricultural practices in Sub-Saharan livestock systems. Reg. Environ. Chang. 17, 399–410. doi:10.1007/s10113-016-1026-z

Gebremedhin, B., Ahme, M.M. Ehui, S.K. 2003. Determinants of adoption of improved forage technologies in crop–livestock mixed systems: evidence from the highlands of Ethiopia. Tropical Grasslands, 37: 262–273.

Giam, X. 2017. Global biodiversity loss from tropical deforestation. PNAS. 114: 575-5777.

Giraldo, D.C., Camacho, K., Navarro-Racines, C., Martinez-Baron, D., Prager, S.D., Ramírez-Villegas, J. 2020. Outcome Harvesting: Assessment of the transformations generated by Local Technical Agroclimatic Committees in Latin America. CCAFS Working paper No. 299. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Hansen JW; Vaughan C; Kagabo DM; Dinku T; Carr ER; Körner J; Zougmoré RB. 2019. Climate Services Can Support African Farmers' Context-Specific Adaptation Needs at Scale. *Front. Sustain. Food Syst.* 3. http://doi.org/10.3389/fsufs.2019.00021

Hoang, N.T., Kanemoto, K. 2021. Mapping the deforestation footprint of nations reveals growing threat to tropical forests. Nat. Ecol. Evol. doi:10.1038/s41559-021-01417

ILRI, IUCN, FAO, WWF, UNEP and ILC. 2021. Rangelands Atlas. Nairobi Kenya: ILRI. ISBN: 978-1-904722-67-0.

Ingabire, C. 2021. Closing Gender Gaps in Farmers' Access to Climate Information: The Case of Radio Listeners Clubs (RLCs) in Rwanda, Preliminary results of a mixed-method analysis. CCAFS Info Note. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Janssen, E., Swinnen, J., 2019. Technology adoption and value chains in developing countries: Evidence from dairy in India. Food Policy 83, 327–336. doi:10.1016/j.foodpol.2017.08.005

Jost, C., Kristjanson, P., Ferdous, N. 2015. Lessons in Theory of Change: Gender and Inclusion. CCSL Learning Brief No. 14. March 2015.

Kiptot, E., Hebinck, P., Franzel, S., Richards, P., 2007. Adopters, testers or pseudo-adopters? Dynamics of the use of improved tree fallows by farmers in western Kenya. Agric. Syst. 94, 509–519. doi:10.1016/j.agsy.2007.01.002

Kristjanson, P., Bryan, E., Bernier, Q., Twyman, J., Meinzen-Dick, R., Kieran, C., Ringler, C., Jost, C., Doss, C., 2017. Addressing gender in agricultural research for development in the face of a changing climate:

where are we and where should we be going? Int. J. Agric. Sustain. 15, 482–500. doi:10.1080/14735903.2017.1336411

Lopez, F., and Maffioli, A. 2008. Technology Adoption, Productiv ity and Specialization of Uruguayan Breeders: Evidence from an Impact Evaluation. Inter-American Development Bank Office of Evaluation and Oversight Working Paper: OVE/WP-07/08

Lutta LA, Wasonga VO, Karanja R, Saalu F, Njiru J. 2020. Costs and benefits of sustainable rangeland management practices in Northern Kenya. Report for the Economics of Land Degradation Initiative in the framework of the "Reversing Land Degradation in Africa through Scaling-up Evergreen Agriculture" project. www.eld-initiative.org

Mehrabi, Z., Gill, M., van Wijk, M., Herrero, M., Ramankutty, N. 2020. Livestock policy for sustainable development. Nat. Food. 1: 160-165.

Mulema, A.A., Cramer, L., Huyer, S. 2021. Stakeholder engagement in gender and climate change policy processes: Lessons from CCAFS. CCAFS Working Paper no. 349. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Nyasimi M., Huyer, S. 2017. Closing the gender gap in agriculture under climate change. Agriculture for Development 30: 37-40.

Osorio M; Gallina A. 2018. Gender Opportunities and Constraints in Land-Related Agricultural Investments. Rome: FAO. Available at: http://www.fao.org/family-farming/detail/en/c/1157855/

Ramirez-Villegas, J., Rosenstock, T. S., Bonilla-Cedrez, C., Steward, P., Notenbaert, A., Flintan, F., Crane, T., Arango, J., Louhaichi, M., Bullock, R., Ghosh, A., Bahta, S., and Ericksen, P. 2021. Data and evidence-driven assessment of priorities for the Livestock, Climate and System Resilience (LCSR) One CGIAR global initiative. Working draft paper. Nairobi: ILRI, Alliance of Bioversity and CIAT, ICARDA, ICRAF and WUR. https://hdl.handle.net/10568/115166

Riccardi, V., Wane A, Sidhu BS, Goode C, Solomon D, McCullough E, Diekmann F, Porciello J, Jain M, Randall N, Mehrabi Z. 2020. A scoping review of research funding for small-scale farmers in water scarce regions. Nat. Sust. 3:8360844. doi:10.1038/s41893-020-00623-0

Rios, D., Perez, L., Labarta, R., Andrade, R., Giraldo, D., Ramirez-Villegas, J. 2018. Ex – Ante evaluation of "Tailored agro-climate services and food security information for better decision making in Latin America" project potential impact on bush bean farmers in Santander, Colombia. International Center for Tropical Agriculture (CIAT).

Rosenzweig, C., Mbow, C., Barioni, L.G., Benton, T.G., Herrero, M., Krishnapillai, M., Liwenga, E.T., Pradhan, P., Rivera-Ferre, M.G., Sapkota, T., Tubiello, F.N., Xu, Y., Contreras, E.M., Portugal-Pereira, J. 2020. Climate change responses benefit from a global food system approach. Nat. Food. 1: 94-97.

Ruzzante, S. Labarta, R., Bilton, A. 2021. Adoption of agricultural technology in the developing world: A meta-analysis of the empirical literature. World Dev. 146: 105599.

Stevenson, J. Vanlauwe, B., Macours, K., Johnson, N., Krishnan, L., Place, F., Spielman, D., Hughes, K., Vlek, P. 2019. Farmer adoption of plot- and farm-level natural resource management practices: Between rhetoric and reality. Glob. Food Sec. 20:101-104.

Sullivan, G. M., Farris, D.E., Yetley, M.J., Njukia, H.J. 1977. A Socio-Economic Analysis of Technology Adoption in an African Livestock Industry. Texas Agricultural Experiment Station, Technical Article No. TA 13513.

Thornton, P.K., Herrero, M., 2010. Potential for reduced methane and carbon dioxide emissions from livestock and pasture management in the tropics. Proc. Natl. Acad. Sci. 107, 19667–19672. doi:10.1073/pnas.0912890107

Vaughan C; Hansen J; Roudier P; Watkiss P; Carr E. 2019. Evaluating agricultural weather and climate services in Africa: Evidence, methods, and a learning agenda. *WIREs Clim. Chang.* 10. http://doi.org/10.1002/wcc.586

Vyas, S., Dalhaus, T., Kropff, M., Aggarwal, P., Meuwissen, M.P.M., 2021. Mapping global research on agricultural insurance. Environ. Res. Lett. doi:10.1088/1748-9326/ac263d

World Bank. 2021. Global Subnational Poverty Atlas – International Poverty Line, Subnational Poverty. The World Bank Group. Available at https://datacatalog.worldbank.org/search/dataset/0042041

Yet, B., Lamanna, C., Shepherd, K.D., Rosenstock, T.S. 2020. Evidence-based investment selection: Prioritizing agricultural development investments under climatic and socio-political risk using Bayesian Networks. PLoS One. doi: 10.1371/journal.pone.0234213

Annex 1 – Projected benefits based on the top-down approach

LCSR takes a bottom-up approach to the projection of benefits (see Main text). However, an alternative approach to projecting benefits of OneCGIAR research for development work first defines a target extrapolation domain, and then computes the projected beneficiaries using a prescribed adoption rate (top-down). In Table 6 below, we illustrate the estimates resulting from this method in comparison to the bottom-up estimates presented as the main results for LCSR. In each case, we provide a range, arising from the uncertainty in adoption rates identified in the literature.

Table 6 | Range of projected benefits (breadth only) for LCSR based on the top-down approach

Numeric indicators from the 5 impact areas	Breadth, minimum value (million people)	Breadth, maximum value (million)
1. #people benefiting from relevant CGIAR innovations	1.76	3.89
2. #people benefiting from relevant CGIAR innovations	4.16	9.55
3. #women benefiting from relevant CGIAR innovations	6.50	14.69
4. #people benefiting from climate-adapted innovations	12.95	29.30
5. #ha under improved management	2.00	4.00

The rationale to compute these projected benefits follows a similar logic (i.e., LCSR's ToC), but a different approach to the bottom-up approach. That is, that WP1, WP2 and WP3 contribute to the testing, implementation and scaling of specific options to help livestock producers respond to climate change (adaptation, resilience building, and mitigation options), whereas WP4 and WP5 act as enablers in the process of scaling because they leverage public policy and public and private finance. As illustrated in Fig. 1, our universe of people benefitting is ascribed by **Impact Area 4** (i.e., all people that need adaptation, resilience and/or mitigation strategies), and the people benefitting for **IA1**, **IA2** and **IA3**, are all subgroups of this universe.

To compute these **Impact Area 4** projected benefits, we first determine the rural population exposed to climate hazards in all livestock production systems for all LCSR countries (i.e., Kenya, Senegal, Tanzania, Guatemala/Honduras, Colombia), and then estimate a total number of adopters by 2030 by assuming an annual rate of adoption (see below Sect. Adoption rates). For rural population, we use WorldPop.org, and for climate hazards we use the hazards dataset from the LCSR Prioritization Analysis (Ramirez-Villegas et al., 2021). Adoption rates vary per country but generally vary between 1.5–4% per year for CIS and insurance (WP3 technologies), and 1–3% per year for management options (WP1 & WP2 technologies). The total number of benefitting people for IA4 is then assigned to each CGIAR Impact Area using data on food insecurity, poverty, and gender. For food insecurity and nutrition (**Impact Area 1**), we use the proportion of people with insufficient food consumption as reported by the World Food

Programme HungerMap[3]. We multiply the total number of adopters by this ratio on a country and livestock system basis to obtain the total number of people in food insecurity that would benefit from LCSR interventions. We recognize that food consumption is only a proxy for food insecurity, and that this indicator does not include nutritional insecurity. However, data on nutritional insecurity that covers age groups beyond children is scarce at subnational levels, and evidence that improved income results in improvements in nutritional security within the timeframe of the project is also scarce. Thus, we provide estimates that we believe are consistent with LCSR's ToC and best-in-kind data on food security. For poverty (**Impact Area 2**) we use subnational poverty estimates from the World Bank (World Bank, 2021), to determine how many rural poor exist in the overall estimate of people benefitting from CGIAR climate-adapted innovations. We use the percentage of people under extreme poverty (<1.9 USD/day). For gender (**Impact Area 3**) we use population data disaggregated by gender from WorldPop.org to determine the percentage of women in hazard-exposed areas for each country and livestock system, and then apply this percentage to the total number of benefitting people.

For **Impact Area 5**, we focus on quantifying the projected amount of rangeland area under improved management from the total amount of rangeland area in the LCSR countries. Data on the amount of rangeland area was gathered from the Rangelands Atlas (ILRI, 2021). For improved rangeland management, we assume a minimum of 1.2% adoption rate of improved management by 2030, and a maximum rate of twice that number (F. Flintan, personal communication).

Adoption rates

In a similar way that bottom-up estimates rely on CpB values, top-down estimates rely heavily on adoption rates. Adoption varies per year, sometimes substantially, depending on at least three factors: (i) presence of barriers to adoption and whether their effect and geographic variation is understood; (ii) whether the implemented program or project portfolio works to remove at least some of these barriers; and (iii) normal adoption dynamics, including early adopters within direct beneficiaries, spillovers, and dis-adoption. Adoption rate data covering the wide range of practices and practice portfolios of LCSR is extremely sparse, and difficult to homogenize. Studies do not systematically report adoption rates, and, when they do, these are not reported in a consistent manner. Likewise, analyses of adoption constraints data vary in their scope, and measurement and attribution methods (Arslan et al., 2020). As a result, annual adoption estimates are, at best, highly uncertain.

Table 7 shows a sample of adoption studies (as reviewed here) and the type of evidence these studies report. As the table illustrates, annual adoption rates that are based existing literature are difficult to constrain (see e.g., Arslan et al., 2020), and this creates large uncertainties in the projected benefit estimations. Extending the review of adoption to a greater number of papers and interventions is thus unlikely to reduce uncertainty in the projection of benefits. The analysis is further complicated by the fact that the LCSR ToC and proposed implementation is different to that of previous projects. For instance, LCSR WP3's aim is to bundle the risk management products, and thus the low current adoption rates for insurance shown in Table 7 are unlikely to be representative of the adoption of the service bundles developed by LCSR. Furthermore, LCSR will work to enable the deployment of these service bundles using ICTs, address use capacity gaps, and strengthen and work with existing scaling platforms, all of which will increase the adoption of service bundles. Because of this, we use the sample of studies

[3] https://hungermap.wfp.org

of Table 7 to define a lower and upper bound adoption rate per country for LCSR interventions. The resulting projection (in Table 6) therefore explicitly shows this uncertainty.

Table 7 | Adoption rates reported in the literature used to constrain LCSR top-down projected benefits

Study	**Evidence reported**	**Reported time dimension?**
Garcia de Jalon et al. (2017)	In Kenya and Tanzania, adoption rates were highest for improved varieties and feed (15% median), and lowest for herd and grassland management (5% median). In Ethiopia and Senegal, the rates of adoption were lower (10% for improved varieties and feed, 2% for herd and grassland management).	No
Sullivan et al. (1977)	On average, a maximum of 30% practices gets adopted by any individual farmer in Tanzania	Yes
Lopez and Maffioli (2008)	Adoption rates for livestock reproductive management can be as high as 80% in developed countries (Uruguay) and with explicit program subsidies and extension support for practice implementation	Yes
Rios et al. (2016)	An ex-ante analysis conducted for bean showed that adoption rates for agronomic management are in the range 20-30% after 10 years	Yes
Abdulai and Huffman (2005)	12% adoption after 10 years, and 50% after 20 years for cross-bred cow technologies	Yes
Gebremedhin et al. (2003)	Adoption rates of 41% of forage cultivation for dairy farmers in Ethiopia	No
Herrero and Thornton (2010)	Suggest adoption rates for on-farm technologies of 1–2% per year, which gives 10 to 20% for a 10-year period	Yes
Kiptot et al. (2007)	Suggest adoption rates for on-farm technologies of 1–2% per year for tree fallows in Western Kenya.	Yes
Abate et al. (2016)	Adoption of agricultural technologies can be boosted by credit and financial incentives. A study in Ethiopia shows that the adoption of inorganic fertilizer increases from 74% to 99% when institutional finance is present. Likewise, the use of improved seeds increases from 42% to 63%	No
Janssen and Swinnen (2019)	Comprehensive overview of technology adoption in dairy value chains in India. They show that hygienic practices are widely used (96–98%), whereas the adoption of food safety practices is moderate (20%), and the use of improved feeds can be as low as 8%.	No
Chantarat et al. (2017) ILRI (unpublished)	In the context that overall insurance adoption rates in dryland areas is on average 3%, we assume that current adoption levels are 1% for Kenya and 0.3% for Ethiopia (over a 10-year period). The adoption of insurance, however, increases dramatically when it is a compulsory product to loans. Uptake of insurance products has also been documented to increase where the insurance is accompanied by agricultural advisory.	No
ILRI (unpublished)	ILRI's work as of 2020 shows over 90,000 cumulative policies sold since launch in 2010 in Kenya and Ethiopia. Kenya (Ethiopia) commercial sales are 54,600 (17,398), Kenya Livestock Insurance Programme (KLIP) beneficiaries – 18,000. These correspond to ca. 0.1% of the potential adopters.	Yes
Birachi et al. (2020)	The adoption of CGIAR co-developed CIS over a 10-year R4D investment has been measured between 20–40%.	Yes

Dayamba et al. (2018) Giraldo et al. (2020) Rios et al. (2018)		
Drewry et al. (2019)	Uptake of digital technologies such as mobile apps, market information for farm management in the USA is 20-30%. Uptake of weather and climate information is as high as 71%	No
Janssen and Swinnen (2019)	Loan access and use in India is 3% (Punjab and Andhra Pradesh)	No

Annex 2 – Planned geographic and topical synergies with other One CGIAR initiatives for the 2022-2024 period

Taken from Ramirez-Villegas et al. (2021)

Initiative	Countries and geographic synergies	Topical synergies
ClimBer	Guatemala, Kenya, Senegal	– Climate services and insurance design – Climate security observatory and programmatic recommendations
SAPLING	Kenya, Tanzania, Ethiopia, Mali	– Technologies, practices for sustainable production – Equity and social inclusion – Digital tools for markets and value chains – Trade-off analysis and policies that account for social, environmental, and economic outcomes
U2 (ESA RII)	Ethiopia, Kenya, Tanzania	– Scaling hubs – Sustainable intensification – De-risking mixed systems through advisory services, and early warning – Empower and engage women and youth – Ag-Tech partnerships and incubators
LACResiliente (LAC RII)	Guatemala, Honduras, Colombia	– Climate risk management services, ICT development, and data hubs – Scaling platforms (InnovaHubs)
Data Harnessing	Guatemala, Kenya	– Data hubs, ICT development, advisory services, and modelling methods and infrastructure – Ag-Tech partnerships, – Digital inclusion approaches
OneHealth	Kenya, Ethiopia, Uganda	– Surveillance and modeling of zoonoses – Development of advisory services for livestock health management and early warning – Capacity building for partners and producers
Mitigate+	Kenya, Ethiopia, Colombia	– Financing and technologies for emissions reductions in value chains