Ceres2030
Sustainable Solutions to End Hunger

TECHNICAL NOTE

Integrating Gender and Climate Change in the SDG 2 Agenda:

A Ceres2030 Perspective

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Abstract	This technical note describes how gender and climate changes issues could be embedded in the SDG 2 roadmap and how Ceres2030 addresses them.

1 EXECUTIVE SUMMARY

Gender and climate change issues cannot be solved without attention to SDG 2. In least developed countries, 2 in 3 women are employed in the agricultural sector in least developed countries, but women face higher barriers to farming productivity than men. Women are more vulnerable to food insecurity and malnutrition than men. With respect to climate, agriculture accounts for a quarter of global greenhouse gas emissions, so expansion of agriculture to reach SDG 2 could be devastating if done without prioritization of the climate agenda.

Likewise, SDG 2 cannot be realized without attention to gender and climate change. Because women are both a large part of the agricultural sector and face high barriers to maximizing their productivity, they are crucial to reaching the SDG 2 agricultural productivity target. The end of hunger for all cannot be accomplished without the end of hunger for women. Climate change is already a key driver in food crises worldwide and is expected to have increasingly devastating effects if current trends continue; action on SDG 2 will have to integrate both climate-adaptive and climate-resilient interventions.

Ceres2030 is a roadmap for donors on how much to spend and how to spend it to achieve SDG 2, and it makes clear the importance of including gender and climate in SDG 2 plans. The gender and climate experts serving as co-authors on the project's evidence syntheses will provide critical perspectives in the identification of the most promising SDG 2 interventions. Natural language processing[1] tools will help locate evidence on SDG 2 interventions related to gender and climate. Ceres2030's state-of-the-art model will measure greenhouse gas emissions to provide intervention recommendations tailored to climate goals, allowing donors to leverage SDG 2 action in the climate agenda. The model will also be used in a partial analysis of gender effects at the household level and other aggregate levels.

Limited quantitative evidence is the greatest barrier to better inclusion of gender in Ceres2030. The absence of consistent, global individual-level data or better knowledge of intra-household allocation of food and other resources precludes modelling an individual's outcomes separately from their household's outcomes. The model therefore cannot, for example, account for how calories might be divvied up within a household or attribute a household's farming productivity to individual men or women in the household. There is, however, good qualitative evidence on these issues. Ceres2030's evidence synthesis will provide qualitative guidance to round out the model's quantitative depiction.

[1] Natural language processing is a field of computer science concerned with processing and analyzing large amounts of human language. In Ceres2030, a natural language processing program is used to search databases of research papers, then to map and analyze the research landscape related to SDG 2.

2 INTRODUCTION

Achievement of the UN Sustainable Development Goals (SDGs) requires interventions that simultaneously benefit economies, societies, and the environment. Understanding how such interventions affect the realization of SDG targets as well as the trade-offs they require is a complex task. Ceres2030, a joint project of Cornell University, the International Food Policy Research Institute (IFPRI), and the International Institute for Sustainable Development (IISD), will combine a state-of-the-art model with a synthesis of evidence on SDG 2 interventions to build a roadmap to achieving SDG 2, with a focus on SDG 2.1 (ending hunger), 2.3 (doubling smallholder food producers' productivity), and 2.4 (ensuring agricultural sustainability and resilience). The Ceres2030 roadmap will include a prediction of the cost of achieving SDG 2, recommendations for spending allocations by type of intervention, and the identification of high-impact interventions.

This technical note explores the relationship between SDG 2, gender, and climate change and describes how Ceres2030 will integrate gender and climate change considerations throughout the project.

Agriculture is a critical field for gender equality and women's empowerment. Women make up between 43 and 60 per cent of the agricultural workforce but have lower average productivity than their male counterparts. A variety of legal, social and economic obstacles constrain their access to resources and finance. Hunger issues also differ by gender, with women facing greater vulnerability to food insecurity and suffering higher rates of malnutrition than men.

Climate issues are just as crucial for the future of agriculture. As a generator of a quarter of global GHG emissions, the agricultural sector is central to climate mitigation strategies. Adaptation is also vital to maintain and expand food production in the face of rising temperatures and more frequent extreme weather events.

The economic model used in Ceres2030 will incorporate climate and gender analysis where reliable data exists to support it. On climate, for example, the Ceres2030 model will measure GHG emissions and land use changes and estimate the impact of changing rainfall patterns and temperatures on agricultural yields. The model will be able to generate rough analysis of the impacts of agricultural interventions by gender by combining household-level data, such as the number of women in the household and the sex of the household head, with data on gender patterns in farming and society more broadly. More precise measurement of outcomes by gender is limited by the absence of global individual-level data or better knowledge of intra-household allocation.

The evidence synthesis process in Ceres2030 will review and summarize published research to inform decision makers on the most promising interventions related to SDG 2. As scientific evidence increases in volume and simultaneously becomes more specialized, researchers need methods to create comprehensive yet succinct syntheses of published knowledge. Ceres2030 has developed a process using both natural language processing software and teams of experts to rapidly locate and evaluate the available qualitative and quantitative evidence. The reviews generated by the evidence synthesis will augment the integration of gender and climate issues in the Ceres2030 model, provide guidance on the types of interventions that have had the most success in improving gender and climate outcomes, and support additional model outputs that measure the impacts of gender and climate-sensitive

interventions. The reviews generated by the evidence synthesis process will be published in top-ranked science journals to establish credibility and build consensus among scientists, journalists, and policy makers on effective interventions for SDG 2.3 and 2.4.

SDG 2 addresses a complex series of issues that are deeply interrelated with the larger Sustainable Development Agenda. It thus requires a sophisticated policy roadmap. Ceres2030 will consider the costs and trade-offs for SDG 2 of the interrelated issues covered in the SDGs. Ceres2030 findings can help mitigate the risk of creating policy that exacerbates gender inequality and climate change and can ensure that gender and climate issues are prioritized in SDG 2 efforts.

3 RELEVANCE OF GENDER AND CLIMATE CHANGE TO SDG 2

This section examines how gender and climate change relate to the SDG 2 agenda. Table 1 provides a brief overview of how SDG 2 targets and indicators overlap with gender and climate issues. The rest of the section focuses on gender and climate intersections with SDG 2.1, 2.3, and 2.4, as these targets are the focus of Ceres2030.

Table 1: Gender and Climate Change in the SDG 2 Framework

	Relevance for Gender	Relevance for Climate
2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.	Food insecurity disproportionally affects women.[2]	Expansion of agricultural production will drastically increase greenhouse gas emissions if climate is not considered.[3]
2.2 By 2030, end all forms of malnutrition, including achieving, by 2025[…]	1 in 3 women of reproductive age suffers from anaemia.[4]	Climate change is a key driver in worsening food security and nutrition.[5]
2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers […]	Women in agriculture worldwide face high barriers to productivity.[6]	Climate-adaptive agricultural interventions are needed to combat climate change's negative impacts on productivity.[7]
2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, […]	Climate-smart agricultural interventions can worsen gender disparities.[8]	Interventions can boost producers' resilience and sustain the environment.[6]
2.5 by 2020 maintain genetic diversity of seeds […]	Seed diversity management is gendered in some places; for example, women may have more control over seed diversity of food crops.[9]	Diverse seed genetics can be used to find or create climate-adaptive crop varieties.

Source: Authors' own work.

[2] See Nagel (2016) and FAO et al. (2017).
[3] See Ciais & Gitz (2004).
[4] See FAO et al. (2018).
[5] See FAO et al. (2018).
[6] See O'Sullivan et al. (2014).
[7] See FAO et al., especially Section 2.4 (2018).
[8] See Beuchelt & Badstue (2013).
[9] See Amri & Kimaro (2010) and Pionetti (2006).

3.1 GENDER

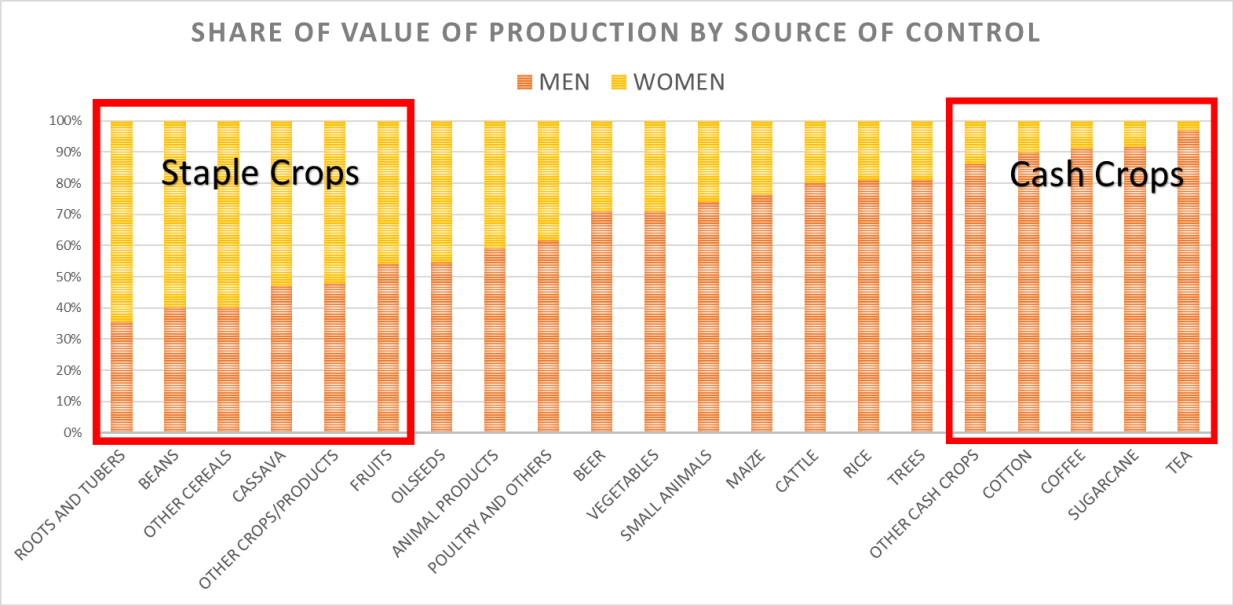
SDG 2 is a gendered challenge.[10] Women are especially vulnerable to food insecurity, and although agriculture is the largest sector for women's employment in Least Developed Countries, women face barriers in farming that men do not. Thus, SDG 2 should not be ignored in work to advance gender equality.

As consumers of food, women are up to 11 per cent more likely than men to report food insecurity (Nagel, 2016). Food insecurity is more prevalent for women not only at the global level but in every region of the world (FAO, IFAD, UNICEF, WFP, & WHO, 2017).

As producers of food, women also fare worse than men. Women are important contributors to agriculture, accounting on average for 43 per cent of the agricultural labour force worldwide (FAO, 2015); in some African countries, they make up as much as 60 per cent. Likewise, agriculture is an important sector for women, accounting for 66 per cent of women's employment in Least Developed Countries ("Employment in agriculture," 2018). However, female farmers' productivity in agriculture is lower on average than male farmers' productivity. This productivity gap, both in yield and monetary terms, is largely explained by the disadvantages that women face in relation to the factors of production, including access to and control of land; access to inputs such as high-quality seeds, fertilizer, and farm equipment; access to hired labour; inclusion in and appropriateness of agricultural extension programs; access to credit; and access to markets (O'Sullivan, Rao, Banerjee, Gulati, & Vinez, 2014). These access issues are largely driven by social and cultural norms (O'Sullivan et al., 2014) and may explain women farmer's tendency to specialize in low-value crops. Figure 1 illustrates this specialization pattern for Uganda, one of the focus countries for Ceres2030.

[10] In this technical note, we use the term 'gender' broadly, to refer to the socially determined roles of and relationships between men and women. The focus is on the role of women because they have been traditionally underrepresented or invisible in the research agenda.

Figure 1: Gendered Agricultural Specialization in Uganda



Source: Ceres2030 dataset based on LSMS survey.

Closing the gender gap in agricultural productivity could have enormous impact. The FAO estimates that if female farmers had the same access to productive resources as men, their productivity could increase by up to 30 per cent, reducing the number of hungry people in the world by 12 to 17 per cent (FAO, 2011). This would also contribute to the SDG 2.3 target of doubling smallholder productivity. Closing the gender gap in agricultural productivity is both important in its own right, to ensure the principle of gender equity and "no one left behind," and important as a crucial pathway to achieving SDG 2.

But closing this gender productivity gap is a nuanced challenge. Strong social and cultural norms around the roles of men and women may constrain interventions that aim to ameliorate access issues (O'Sullivan et al., 2014). Understanding norms and patterns in particular contexts is crucial to designing effective gender-sensitive SDG 2 interventions. Using Figure 1 data as an example, Uganda may decide to provide a new subsidy for coffee exports. This subsidy has no gender aim *ex-ante*, but because men produce almost all of Uganda's coffee, the subsidy will benefit male more than female farmers. Capturing the gender specificity of the populations affected by an intervention (whether directly or indirectly) is crucial to designing effect interventions to realize SDG 2.

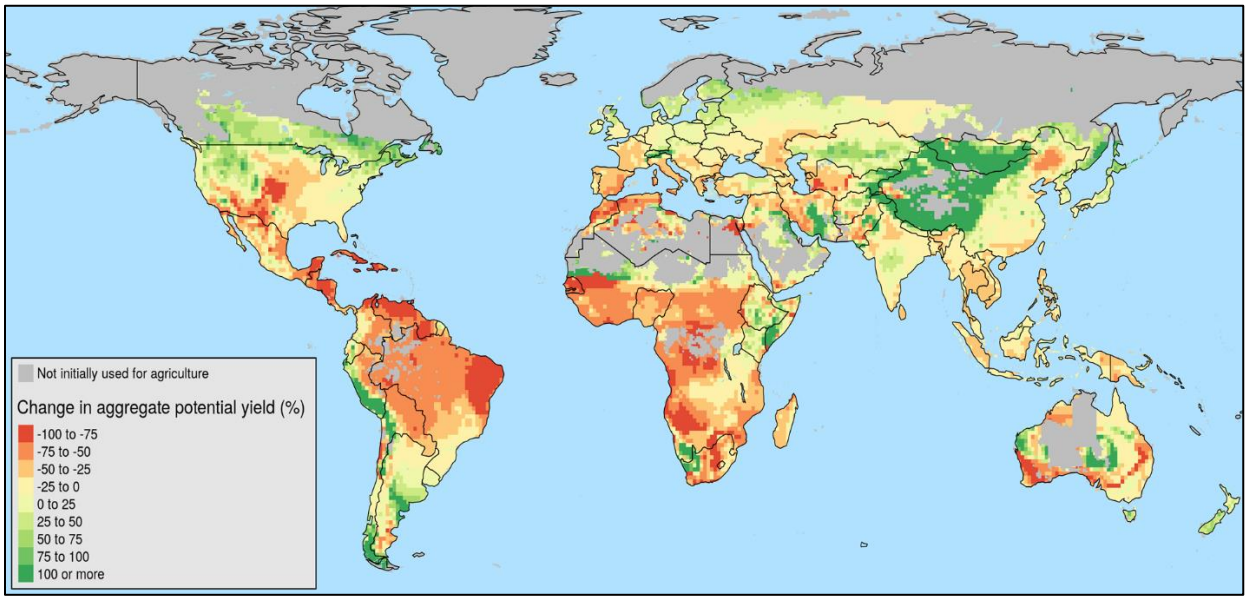
3.2 Climate Change

Climate change both affects and is affected by food production.

Climate change could undermine the achievement of SDG 2. The 2018 State of Food Security and Nutrition report highlights climate variability and extremes as a key driver of the recent reversal in progress towards SDG 2, and warns of increasing climate pressures in the coming decades (FAO, IFAD, UNICEF, WFP, & WHO, 2018). Changing rainfall patterns and increasing temperatures will have a negative impact on global agricultural yields (Gouel & Laborde, 2018). The increased frequency of extreme weather events and the predicted rise in sea levels could lead to major productivity losses (Dell,

Jones, & Olken, 2013). And climate change doesn't only affect plants and livestock: higher temperatures also reduce labour productivity for farm workers, especially in high humidity climates (Dell et al., 2013). So, climate change will reduce farmer productivity and incomes (SDG 2.3) and increase food prices, with a risk of deteriorating the state of food and nutrition security globally (SDG 2.1 and 2.2). The brunt of these costs will be borne by the most vulnerable and food insecure countries, as shown in Figure 2. SDG 2 efforts must consider means of adaptation and resilience, such as drip irrigation, heat-resistant varieties of traditional staple crops, or different crops that are more adapted to the future climate (target 2.4, and target 2.5).

Figure 2: Climate Change Impact on Crop Yields Highest in Food Insecure Countries



Source: Gouel & Laborde (2018). 2080 horizon

At the same time, the expansion of food production that is necessary to achieve SDG 2 could place a heavy burden on the climate, depending on how expansion is achieved. Agriculture is a substantial source of GHG emissions, accounting for about one quarter of emissions globally (IPCC, 2014, p. 816). Thus, achieving SDG 2 could imply a significant increase in GHG emissions. To mitigate the potential GHG increases, we must promote interventions that increase yields sustainably, considering factors such as increased emissions due to land use change (e.g. deforestation for farming), and the relative climate impacts of different kinds of foods (e.g. the high GHG cost of beef and other livestock) and farming practices (e.g. no-till farming and improved crop rotation for carbon sequestration). The challenge is to make sure that pro-climate policies do not put an unfair burden on the poor, or on smallholders.

3.3 SDG 2: A Nexus for Gender and Climate Issues

SDG 2 is a goal where climate change and gender issues meet. Understanding these interactions is essential to achieving SDG 2 in a way that minimizes climate change and supports gender equality.

Often, climate-sensitive interventions in the agricultural sector appear to be gender neutral but can unintentionally widen gaps between men and women (Beuchelt & Badstue, 2013). For example,

subsidizing fertilizers could be biased towards men in a context where intra-household decisions result in fertilizer being allocated primarily to farm plots operated by the men in the household. Similarly, pro-livestock policies, especially for cattle, would mainly benefit male farmers in countries where large animal assets are owned mostly by men.

Researchers have documented especially salient evidence on this climate-gender collision in climate-friendly ICT interventions. Wong explores how climate-friendly ICT interventions often fail to reach women and reinforce gendered power dynamics (2012). Currea questions the assumption of gender neutrality of the UN Clean Development Mechanism (CDM) under which emission-reduction projects in developing countries can earn certified emission reduction credits (2015). Technology transfers promoted by the CDM are mainly directed towards men (Wamukonya & Skutsch, 2002), reinforcing gendered access to and power over technology. Overall, trying to use ICTs to achieve environmental sustainability will require guaranteeing proper economic and cultural access of ICT technologies to women.

These documented climate-gender trade-offs signal the need to anticipate gender differences. Mitigation initiatives could benefit from explicitly capturing gender differences, and future SDG 2 efforts should consider interventions that may positively affect both climate and gender. Below are a few examples:

1. Agricultural extension programs on conservation agriculture that are inclusive of women could both help women adapt farming practices to the effects of climate change and contribute to carbon sequestration (Corbeels, Sakyi, Kühne, & Whitbread, 2014).
2. Improving women's access to seeds for climate-resilient staple crops could improve female farmer's yields in the face of changing climate conditions and improve their household food security status, all while reducing GHG emissions by ensuring that agricultural land remains arable and minimizing global deforestation to expand agriculture (Cairns et al., 2013).
3. Improving women's land tenure rights could provide them with the stability and incentive to increase their investment in the productivity of their land (Goldstein & Udry, 2008), including investing in climate-adaptive agricultural practices that could boost their resilience to the effects of climate change.

These are examples with partial evidence – the full implications of such interactions require more evidence and analysis as new interventions are designed and implemented. In addition, the biggest challenge continues to be the lack of sex-disaggregated data. Achieving triple win policy outcomes – zero hunger, gender equality, and climate action – with single interventions is impossible, but a process to help combine and balance interventions across different areas is largely achievable. The Tinbergen rule in economics, which states that "for each policy objective, at least one policy instrument is needed," encourages policy-makers to use a mix of instruments to achieve each distinct goal, using the instruments in concert.

4 INTEGRATION OF GENDER AND CLIMATE IN CERES2030

As Ceres2030 develops a map towards the achievement of SDG 2, the complex interactions among hunger, gender, and climate change raise a question: How can we include gender and climate considerations in our SDG 2 roadmap?

Ceres2030's primary goal is to identify interventions to achieve SDG 2.1, 2.3, and 2.4 and measure their costs. Gender and climate issues will be reflected in these interventions. SDG 2.3—doubling the productivity of smallholders—is the most relevant to gender-sensitive interventions. SDG 2.4—ensuring sustainable food production systems—is more relevant to climate-sensitive interventions. In addition, however, Ceres2030 will reach beyond these specific SDG targets to reflect gender and climate change considerations throughout the whole project.

The structure of the project shows where these considerations will be incorporated. Ceres2030 is based on two core complementary activities:

1. The Model: Creating an advanced modeling framework, based on the work of Laborde, Bizikova, Lallemant, & Smaller (2016), that measures the cost of ending hunger (SDG 2.1) while doubling the productivity of smallholders (SDG 2.3) and promoting environmental sustainability (2.4) and predicts the most efficient allocation of public funding by kind of intervention to achieve these goals with minimum cost, and
2. Evidence Synthesis: Consensus-building on the most effective set of interventions through protocol-based reviews with results released in a special journal issue and communicated through news and policy-relevant activities.

The flow of core activities can be thought of in three overlapping stages (see Figure 3):

First, modelling, activity 1, will build a quantitative framework to measure hunger, smallholder productivity, and environmental outcomes. Once the quantitative framework is in place, we can predict the cost of ending hunger and outcomes for smallholder productivity and environmental sustainability in a Business-as-Usual (BAU) simulation, that is, in a scenario where public funding is increased but its effectiveness remains unchanged.

Second, evidence synthesis, activity 2, which will draw on the quantitative framework of the model to guide some of the criteria used in the evidence synthesis review of SDG 2 interventions, while also using qualitative criteria that are not covered by the framework of the model.

Third, the model will use the most promising interventions identified by the evidence synthesis to generate a new predicted cost of ending hunger while achieving smallholder productivity and environmental sustainability goals. The practical output of this simulation for policymakers will be a roadmap of how to allocate spending on SDG 2 most effectively.

Figure 3: Flow of Ceres2030 Activities

The Ceres2030 analytical framework can evaluate interventions' effects on gender and climate outcomes. Gender and climate issues are embedded in the various components of the model and evidence synthesis. This section addresses how and the extent to which climate and gender issues are integrated into the modelling and evidence synthesis. A summary of the integration is provided in Table 2 below.

Table 2: Summary of Planned Integration of Gender and Climate into Ceres2030

	Integration in the Modelling Framework	Integration in the Evidence Synthesis
Gender	The model will be able to check for some gender effects using available household-level data, but the absence of globally available individual-level data prevent precise analysis. Results from the evidence synthesis may uncover new ways to analyze gender outcomes in the model.	Research on gender interventions will be explicitly searched for using natural language processing. Experts on gender will be integrated into systematic review groups and form a consultative gender team to provide a gender-sensitive perspective.
Climate	Greenhouse gas emissions targets can be set prior to simulation, and the model will adjust the cost projection and the recommendation of intervention spending allocation to meet the target.	Experts on climate will be part of the systematic review groups and form a consultative climate team to provide a climate-sensitive perspective.

4.1 The Modeling Framework

The economic model is a dynamic computable general equilibrium, multi-country, and multi-sector model that uses household surveys for an innovate bottom-up approach.[11] The model simulates national and international markets, taking into account production, demand, and prices, and integrates this economic simulation with an analysis of biophysical and socioeconomic trends (Laborde, Robichaud, & Tokgoz, 2013). The model integrates the key economic factors that affect agriculture, thereby providing

[11] Household surveys from the World Bank and national governments are used.

a robust quantitative framework for estimating costs. At the same time, it tracks household-level consumption and production of major food items as well as other sources of income. This means that the model can target interventions based on the precise characteristics of hungry households rather than national averages, which is the more common method. Better targeting increases efficiencies and reduces spending, therefore reducing the overall costs of achieving SDG 2.

4.1.1 Integrating gender

Gender is the most challenging dimension to integrate into the model because the model is limited by what gender data already exists. To truly capture outcomes by gender, the model would need data at the level of the individual so as to simulate intra-household decisions. Global individual-level data does not exist. Our model pushes new boundaries by using available household-level data, but household-level data still masks intra-household allocation of food and other resources. A household might not be undernourished on aggregate, but a woman or girl in the household still could be.

This challenging data limitation is even reflected in official SDG indicators. Just one of SDG 2's thirteen indicators has an explicit, measurable gender dimension: Indicator 2.3.2, Average Income of Small-Scale Food Producers, by Sex and Indigenous Status (Inter-Agency and Expert Group on SDG Indicators, 2018). Even for this indicator, data availability remains hypothetical at this stage. The lack of good data on gender is a problem beyond just SDG 2: of the 54 gender-specific indicators across the 17 SDG goals, less than 20 per cent are classified as Tier 1 (best rating) and nearly the same amount falls into Tier 3 (worst rating) (Inter-Agency and Expert Group on SDG Indicators, 2018) (UN Women, 2018).

The model's innovative use of household data does enable Ceres2030 to explore gender in a few ways. We can track the behavior and performance of households that are female-headed, households that have a large share of female members, and households by proportion of women of working age.[12] The model could also estimate some gender impacts using data on sectoral or crop specialization by gender (see Section 3.1). For example, removal of sector-heterogenous taxation and protection (SDG 2, Instrument 2.b) would have differentiated impacts between male and female producers due to gender differences by sector. In other words, applying what we know about gender differences within the agricultural sector can inform estimates of how a given intervention might affect women and men differently (as where men are dominant in cash crop versus household food production, for example).

Nonetheless, gender analysis using these proxies – gender of the household head, share of household members who are female, and share of producers who are female – should not be considered complete. Indeed, analysis with these proxies may not even yield results that show gender differences in outcomes. For example, research in the last 20 years has shown that poverty may not differ significantly between male- and female-headed households for the very poor. Generic statements pointing to over-representation of female headed households among the poor are not supported by systematic statistical tests (Quisumbing, Haddad, & Peña, 1995). Our own dataset confirms the absence of a clear pattern, and we do not expect to see strong differentiated outcomes between male- and female-headed

[12] Currently, we do not emphasize this dimension in the cluster analysis used to define our typology of households, but this could be added to our analysis.

households overall. This does not mean that gendered differences do not exist – it simply means that they may not be visible without data that is more granular than the household level.

4.1.2 Integrating climate

To incorporate the potential implications of achieving SDG 2 on the climate, the model directly incorporates GHG emissions. As the model simulates agricultural expansion, it can include a maximum limit on how much GHG the agricultural sector can emit. The model can run different scenarios with different GHG targets, each time generating a different recommended mix of interventions depending on the GHG target desired. To help find the most appropriate path for policymakers, these targets should be consistent with national targets. For example, with a tighter GHG target, the model may recommend a greater portion of climate-friendly interventions from the set of options provided by the evidence synthesis, such as solar panels for powering farm equipment and ICT with extension services for sustainable farm practices.

The effect of the climate on the difficulty of achieving SDG 2 presents a different challenge for the Ceres2030 model. The model will use existing consensus on the effects of climate and other factors to predict yield from now through 2030. However, existing assessments show that the impacts of climate change are expected to be limited in this timeframe (Havlík et al., 2015), with larger impacts expected after 2050. In addition, due to the lagged effect of GHG emissions on climate, feedback effects of GHG emissions changes are not included in the model. Nevertheless, it will be possible to experiment with different climate change assumptions and include corresponding climate resilience interventions in the model.

Limitations: There are two key limitations to integrating more complex climate issues. First, spatial representation of households and production sectors is not available. The modeling framework does not use country-level GIS information to capture the spatially heterogenous impacts of climate change or local sustainability constraints and feedbacks. This could be addressed but would require significant additional resources.

Second, the modeling framework is non-stochastic by nature: in other words, the households in the model do not face, and do not cope with, risk. Therefore, our capacity to analyze the relationship between the additional risk farmers face due to climate variability and the impact of climate-resilience interventions can only be partial. An important research area in collaboration with the evidence synthesis findings will be how best to incorporate the long-term productivity impacts of climate resilience interventions into the model.

4.2 In The Evidence Synthesis process

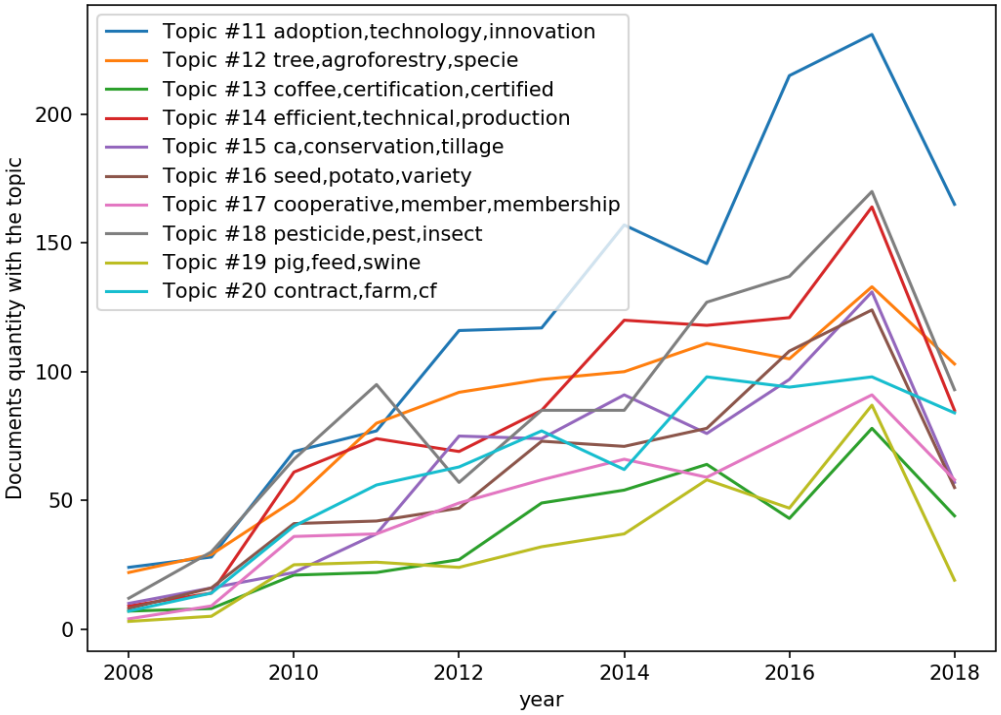
Science research has increased exponentially in the past twenty years to the point where we have a new scientific article published every seven second. At the same time, the scientific community has become increasingly specialized and fragmented. SDG 2 research is not immune – research to inform how to achieve the goal and its potential impacts on gender and climate is dispersed, making a comprehensive picture elusive.

The Ceres2030 evidence synthesis process was conceived to address this problem of fragmented and dispersed evidence. With the help of gender and climate experts, the process is designed to include a broad range of climate and gender analysis and to provide a clear and nuanced synthesis of the evidence.

Inclusion: The first step of an evidence synthesis is to survey the broad landscape across which agricultural and environmental evidence is scattered. We found more than 17,000 journals and 70 agency providers of grey literature. Using data from these sources, we developed an integrated database and an analytics dashboard. Within the dashboard, Ceres2030 uses an innovative natural language model that, given a term such as "women and agriculture," reads abstracts and titles for all literature matching the term and assigns up to three topical clusters, each comprised of five keywords per article. Next, the model aggregates the confidence intervals and assigns them to a "topic cluster." Subtopic analysis within the topic clusters can then be conducted to see more granularity. Figure 4 below gives an example of this process from preliminary analysis, which examined all English-language, peer and grey research that mentions the word "smallholder" between 2008-2018 (45,000 articles).

With this approach we solve a few pervasive issues with the overwhelming amount of evidence available. We aggregate and index literature from multiple sources in one environment to generate comprehensive analytics and filtering. Natural language processing helps quickly and accurately tag by country, crop, intervention, and more. It also 'listens' to the science to apply keywords and build topic clusters, normally a task performed by highly subjective human curators (often without deep subject knowledge). Our approach bypasses these traditional processes and in doing so we increase the likelihood of finding related information—even if the information is not 'similar.' For instance, gender responsive research used for one crop (like cassava) is likely to be unknown to wheat researchers, yet they are likely grappling with similar constraints in terms of intra household power dynamics over allocation of resources (just as an example). Our approach stands a higher probability of success of finding gender and climate change evidence to include in the evidence synthesis. In addition, the process helps to identify possible gender and climate change experts who might serve as co-authors.

Figure 4: Topic Clustering Example from the Ceres2030 Evidence Synthesis



Synthesis: Importantly, interventions must be succinctly evaluated without losing important scientific nuance in a policy-relevant framework. To ensure proper interpretation and representation of gender and climate change, Ceres2030 evidence synthesis teams will include interdisciplinary experts on these two issues. Where applicable, we will invite authors from our gender and climate consultative groups to join a review team.

Limitations: The evidence synthesis can only include the evidence that exists. Due to the bias towards quantitative studies, there may not be enough of the qualitative research that is necessary to elucidate the causal chains between interventions and gender outcomes. Furthermore, the nuanced, qualitative, and highly contextual interaction of gender with interventions is often by nature not generalizable.

To illustrate the nuanced role of gender in evaluating climate-sensitive agriculture interventions, take the example of cassava, a major staple crop across Africa. Because of cassava's wide use, varieties bred to resist severe climate conditions offer the potential to create a stronger food supply for hundreds of millions (FAO, 2016). Yet farmers' adoption of these improved varieties is lower than expected. This has puzzled scientists – why would farmers not select a larger-yield, more reliable product?

Gender research shines a light. Women and men play distinct roles in cassava planting, processing and selling. While men prefer agronomic characteristics like weed suppression, women have a statistically significant preference for cooking and processing traits such as dry matter content, swelling, color, and marketability (Teeken et al., 2018), traits that were low in scientists' breeding priorities. Investment in such traits will help deliver a product that is gender-sensitive, is climate-sensitive, and is something women smallholder farmers want to sell and eat.

The takeaway from this anecdote is that, in addition to the importance of incorporating gender considerations into the SDG 2 roadmap, gender must also consistently be considered from high level planning all the way to the ground level of implementation, where women affected by the interventions can and should be consulted.

In the modelling framework: The evidence synthesis can support additional model outputs that measuring the impacts of gender- and climate-sensitive interventions.

Beyond SDG 2: Reaching beyond SDG 2, Ceres2030 aims to build capacity for interdisciplinary evidence synthesis across SDGs as a normative research practice, something that is currently lacking in the space. We will implement this in part with our publishing partner *Nature*, which plans to implement a new technical article type for evidence synthesis once the Ceres2030 tools, including a protocol and a risk of bias assessment, have been validated. This would mean that any researcher in any discipline – including gender and climate experts – could contribute a full systematic or scoping review to any of their journals. This does not currently exist at *Nature* or *Springer*, major publishers of scientific literature, and is an important step to encourage leading experts to contribute interdisciplinary evidence on the SDGs to mainstream scientific publications.

5 Options for Ceres2030 Extensions on Climate and Gender

As discussed above, the Ceres2030 analytical framework is relevant and capable of designing and testing policies and interventions for gender and climate issues. However, external constraints, mainly around available data, limit the depth and precision of analysis of climate and gender issues. To address knowledge gaps in these areas would require significant additional efforts above the current activities.

On gender, the following potential extensions could be considered:

- Introduce intra-household processes in the modeling component to improve analysis of outcomes by gender, which requires modeling innovation and data. It would be possible to make a pilot study for 1 or 2 of our focus countries.
- Track explicitly female labour market dynamics versus male labour dynamics.
- Strengthen the nutrition dimension of Ceres2030 (SDG 2.2) to capture the specific gender aspects of this target, such as iron consumption.

On climate issues, the following potential extensions could be considered:

- Create more detailed climate change scenarios or alternative climate scenarios, especially for the focus countries, based on stakeholder feedback.
- Consider the local dimension of climate change, including local deforestation and changes in local rainfall patterns, with feedback effects. This would require inclusion of spatial dimensions in the analysis, i.e. using geolocation of households to track spatially heterogenous productivity and climate impacts.
- Build the resilience dimension more explicitly into the modeling framework to better understand the value of climate-resilience interventions in the face of rising temperatures and more frequent extreme weather events.

6 CONCLUSIONS

Ceres2030 embeds gender and climate issues throughout the various stages of the economic modeling and the evidence synthesis processes.

The model includes GHG emissions as indicators and allows GHG emissions to be set to different maximum limits in simulations. While climate impacts on agricultural yields by 2030 will be negligible, the model will allow for different scenarios to assess the importance of climate-resilience interventions.

Integrating gender in the model is more challenging. A full consideration of gender and climate issues related to SDG 2 would require an improvement in available data, significant additional resources for Ceres2030, and new model parameters, including a longer time frame to account for climate impacts beyond 2030. Nonetheless, the model does distinguish between female- and male-headed households as well as the number of females in a household, which will allow some limited gender analysis.

The evidence synthesis will uncover the qualitative and quantitative data available to further integrate gender and climate issues in the model, the types of interventions needed to improve gender and climate outcomes, and additional model outputs that can measure the impacts of gender and climate-sensitive interventions. Both natural language processing and experts in gender and climate change will help elucidate and integrate these important topics in Ceres2030.

Ceres2030 is working to overcome data and time constraints to create as robust a view as possible of the evidence to support effective public interventions to end hunger that take account of gender equity and climate change, two of the major challenges—and opportunities—on the road to end hunger for all.

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