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Exploring the Landscape of Gendered Geospatial Methods in Agri-Food Systems: A Scoping Review

By Arielle Rosenthal, Sophie Legros, Sze Vei Leong, Alessandra Zannier and Martina Sole

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ABOUT CGIAR GENDER IMPACT PLATFORM

Generating Evidence and New Directions for Equitable Results (GENDER) is CGIAR's impact platform designed to put equality and inclusion at the forefront of global agricultural research for development. The Platform will transform the way gender research is done, both within and beyond CGIAR, to kick-start a process of genuine change toward greater gender equality and better lives for smallholder farmers everywhere. gender.cgiar.org

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Executive Summary

Women play pivotal roles in agri-food systems and understanding the complex and multi-faceted nature of gender inequalities within agri-food systems is critical to continue empowering women in the agricultural sector. However, while women's unequal access to opportunities and resources in agri-food systems is well known, little is known about the spatial distribution of the challenges they face. In this context, Geographic Information System (GIS) can help in revealing gender dynamics in agri-food systems and generating actionable insights that could make policies and interventions gender-responsive and/or gender-transformative. However, the application of GIS and other geospatial techniques is an underexplored area within the women, rural and agri-food nexus.

To fill this gap, the CGIAR-GENDER Impact platform commissioned this scoping review to map and analyze the current landscape of how geospatial approaches and analyses are applied to gender and social research within rural development and agri-food systems and to identify opportunities for future research and development (R&D). This review applies a critical feminist lens to investigate what is missing in recent efforts to use GIS to study intersecting gender inequalities within agri-food systems, and how GIS technologies could be better employed to foster gender inclusion while enhancing women's empowerment.

Chapter 2 provides an overview of the methodologies used to conduct this scoping review. The review aimed to identify literature relevant to the overarching research questions:

- *What is the current state of research and opportunities for applying geospatial methods for gender research related to agri-food systems?*
- *Applying a critical feminist lens, what is missing in recent efforts using GIS and how could they be better used to ensure gender and social inclusion and women's empowerment?*

A total of 120 documents were retrieved and included in the literature matrix, comprising academic articles, research articles, books, working and briefing papers, and reports. A total of 75 documents were selected based on their relevance and included in an analytical framework that informed the content and trends analysis of the scoping review. The research team conducted a rigorous trends analysis to capture and explore the key topics in the literature related to gender and GIS in agri-food systems. To supplement the desk research, semi-structured key informant interviews (KII) were conducted with six stakeholders from the private sector, academia, research and NGOs. The interviews served to gather in-depth insights into the process of applying GIS methods in research, policymaking, international development assessments and interventions, and identify opportunities for future projects and collaborations for CGIAR.

In Chapter 3, the range of descriptive, inferential and predictive GIS applications are explored, highlighting key takeaways for potential applications to gender and agri-food systems research. Descriptive GIS applications focus on gathering, managing and visualizing spatial data to describe and represent phenomena studied. Inferential GIS applications, which employ spatial analysis to identify, estimate and graphically visualize statistical correlations between geo-referenced variables, provide an opportunity to link data from different databases, enabling gendered analysis of various phenomena. Finally, predictive GIS applications use models to forecast unknown conditions or future scenarios based on known spatial relations within geo-referenced data.

Some key takeaways for descriptive, inferential and predictive GIS applications in gender & agri-food systems research:

- Inferential GIS applications can be combined with qualitative methodologies, such as interviews, focus groups and ethnographic research to spatially visualize gendered lived experiences within specific geographical contexts.
- Descriptive GIS applications can be combined with qualitative methodologies such as interviews, focus groups and ethnographic research to spatially visualize gendered lived experiences manifested within specific geographical contexts; therefore, enhancing understanding of the localized structural drivers of intersecting inequalities.
- Predictive GIS applications provide an innovative methodology to select policy interventions based on their expected spatially specific gender outcomes.

Chapter 4 provides an overview of GIS and gender research in the context of agri-food systems, identifying key themes in the landscape**.** In particular, the chapter reviews how geospatial applications have been used to understand gender differences in land use and agricultural production, women's socio-economic experiences, and the division of labor between men and women in agri-food contexts.

Some key thematic takeaways for GIS applications in gender & agri-food systems research:

- There is a frequent use of GIS to understand differences in perceptions between men and women farmers of agriculture-related activities, such as soil quality or resource use.
- Geospatial approaches can be used to map vulnerabilities and inequalities in order to develop insights into the relationship between gender-based deprivations and other forms of inequality in agri-food contexts, including income, employment, education and access to infrastructure.
- GIS can help identify areas of vulnerability and need, which helps researchers, practitioners and policymakers target interventions and policies that can support and empower women within agri-food systems, through capacity building, training, skills development and programming.

Following this, Chapter 5 identifies and analyzes the challenges, gaps, opportunities and potential applications for gender and agri-food systems research in GIS. Some of the major challenges identified in the literature included the limited availability of reliable gender-specific data, power imbalances that can influence research outcomes, and gaps in technical expertise. Additionally, open access to data, while safeguarding the privacy of participants, is a frequent challenge. However, to address these challenges and gaps, the combination of spatial analysis with qualitative methods can enhance locally specific contexts, while interdisciplinary approaches can drive more systematic integration of GIS in research, particularly in the context of gender and agri-food systems.

Some key takeaways for challenges gaps, opportunities & potential applications for GIS in gender & agri-food systems research:

- Power dynamics are an important consideration in the use of GIS, presenting challenges that affect both research processes and outcomes. These dynamics often stem from the unequal relationship between the researcher and the researched, exacerbated by cultural, social, and institutional factors.

- There are critical gaps in knowledge, limited technical expertise and the perception of GIS as overly complex could limit its adoption, particularly for women and marginalized communities.
- GIS techniques are often inconsistently applied across disciplines, with insufficient innovation to capture gendered experiences and social constructs.
- By providing a spatial and gender-disaggregated view, there is an opportunity for GIS methods, particularly P-GIS, to inform policymaking and help in targeting interventions.

Chapter 6 presents the key recommendations derived from the scoping review of literature and the insights obtained from the expert interviews. The recommendations fall into three specific areas: research, collaborations and resources. With regard to areas for future research, key recommendations include:

- Testing geospatial approaches and techniques from other disciplines to apply them to gender and agri-food research;
- Ensuring there is a gender lens throughout geospatial research process in agri-food systems;
- Building a standardized framework for gender research using GIS;
- Improving technology accessibility through community-based GIS training, researcher education and the use of open-source data platforms;
- Leveraging participatory GIS in research that targets the micro level of analysis.

Collaborations are integral to study in the geospatial, gender and agri-food systems space, as this area is currently a small but emerging field. As such, it is important to connect with other organizations working within this field and others who have complementary capabilities that can help progress research, leverage research opportunities and mitigate data gaps that are presented in this review. The main opportunities for CGIAR are to:

- Work with private sector actors and governments to increase data accessibility;
- Collaborate with grassroots organizations to implement capacity building initiatives for women in rural agri-food settings;
- Create a network or platform to host discussions on the topic;
- Host a consultation of geospatial innovations and on data privacy solutions within geospatial research.

Finally, the interviews and literature analysis unveiled a number of key tools that are needed by researchers, practitioners and policymakers within this space. Among these are:

- Developing a database of best practice projects and case studies;
- Developing a report on the impact of GIS capacity-building initiatives;
- Developing a GIS guidebook, toolkit and training course for conducting gender-focused research in rural agri-food systems;
- Increasing accessibility to technical geospatial studies and knowledge production.

This scoping review serves as a resource for researchers and other stakeholders to understand the landscape of current research, to adopt and experiment with GIS approaches within gender and agri-food systems and to improve the understanding of how geo-spatial analyses can be better utilized for evidence-based policymaking; thus, opening possibilities for interdisciplinary collaborations in this emerging fields.

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1. INTRODUCTION

1.1. Background

Women play pivotal roles in agri-food systems and throughout all segments of the food value chain. From agricultural production to food provisioning within households, women shoulder the dual burdens of reproductive and productive work taking on unpaid domestic and care work, while simultaneously participating in global agri-food markets (Quisumbing et al., 2023). Closing gender gaps in agri-food systems does not only represent an intrinsically valuable goal to foster women's empowerment and socio-economic wellbeing; it is also an instrumental objective to enhance progress on ending poverty and creating a world free from hunger. Closing the gender gap in land productivity (which currently stands at 24% on farms) and the wage gap in agriculture (women earn 82 cents less for every dollar earned by men) could reduce global food insecurity by about 2%, raising the living standards of 45 million food-insecure people (FAO, 2023). Hence, achieving gender equality in agriculture is central to moving towards more equitable, sustainable, productive, and climate-resilient food systems.

Gender inequalities within agri-food systems are complex and multifaceted, encompassing unequal access to material resources and opportunities; marginalization and precarious working conditions; and unevenly distributed vulnerabilities in the form of unpaid work. These issues disproportionally affect food-insecurity and vulnerability to global socio-economic crises and natural disasters (Quisumbing, Doss, 2021). The greatest barrier, however, is discriminatory social norms affecting women and girls and their subsequent empowerment and agency, as they are difficult to change (FAO, 2023). Gender-based discrimination in socio-economic institutions varies by region, country, culture and rural-urban conditions, creating different types of power imbalances which can limit women's ability to participate in intra-household decision-making; to access and benefit from services, technologies and development policies; and to play a stronger role in the governance of agri-food value chains.

It is well acknowledged that women in agri-food systems have unequal access to opportunities and resources across different contexts, but little is known about the challenges they face in agri-food systems in a spatial dimension. It is indeed paramount to enhance our understanding of how locally contextualized social norms and institutions create structural conditions which perpetuate cycles of marginalization and intersecting inequalities (Vercillo et al., 2023). In such a scenario, spatial analysis and visualization of complex data can generate more targeted and actionable insights to help develop gender-responsive and/or gender-transformative policies and interventions (UN Women, 2018).

1.2. Rationale for this review

Geographic Information System (GIS) includes a wide range of tools and techniques for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which is spatially represented. GIS technologies are part of the broader family of geospatial approaches, which also include Remote Sensing, Global Positioning Systems and Global Navigation Satellite Systems. These techniques provide an innovative approach to study and visualize spatial relations. They can be applied to any field of study which would benefit from the investigation of geographical characteristics and their inter-relationships, of which is concerned with understanding geographical patterns and processes (Lindley, 2010).

By integrating spatial interfaces, satellite imagery and advanced data analytics, GIS approaches play a critical role in transforming agri-food systems. A primary application of GIS in agriculture is precision farming, where insights generated from the analysis of temporal and spatial variability enable farmers to make informed decisions and optimize their resources for improved outcomes (Neményi, 2003). Additionally, geospatial approaches are increasingly being used in agriculture research for crop monitoring and management, soil fertility assessment, pest and crop disease detection and management, mapping climate variability, water management, land use planning, and supply chain management (Mathenge et al., 2022).

Despite the transformative potential of geospatial approaches, their applicability in addressing gender and other social dimensions of agri-food systems has received relatively little attention. GIS technology has inherent structural characteristics that make it a powerful tool to produce gender knowledge by connecting different layers of spatial information to generate comprehensive insights into gender data, such as patterns, relationships and situations (Ozdenerol, 2021). However, the extent to which gender-disaggregated data is readily available for spatial analysis is a critical challenge that inhibits GIS's potential to foster progress in the understanding of how place-based characteristics are associated with gender inequalities (Resurrección at al., 2017). Recent research shows that overlaying new and innovative GIS data, such as qualitative and ethnographic data, with sex-disaggregated social and economic statistics can generate novel insights into spatial patterns of marginalization and disadvantage (ibid). Access to these insights provides an opportunity to identify the localized structural conditions which drive intersecting inequalities within agri-food systems (Azcona et al., 2021). GIS applications have been proven to generate beneficial insights on gender and agri-food systems, for example:

- Pockets of impoverished women farmers can be identified by modelling land-use change (Bosak et al., 2005).
- Crucial information on women's multi-dimensional vulnerabilities can be assessed by mapping climate–agriculture–gender inequality hotspots (Lecoutere et al., 2023).
- Variable challenges faced by men and women farmers related to irrigation demand management can be addressed by integrating GIS with smart irrigation technologies (Aeman, 2023).

More so, significant opportunities for advancing gender equality in agri-food systems can be identified by utilizing evolving geospatial approaches to creatively capture and leverage new data sources.

The objective of this scoping review is to map the current landscape of how geospatial approaches and analysis are applied to gender and social research within rural development and agri-food systems, highlight options for research and development (R&D) action and opportunities for future R&D. To do so, this review applies a critical feminist lens[1] to investigate what is missing in recent efforts to use GIS to study intersecting gender inequalities within agri-food systems; and how GIS technologies could be better employed to foster social

[1] A critical feminist lens refers to the application of the principles and ideology of feminism to analyze and critique the ways in which literature and research reinforces narratives of male domination or the systemic economic, social, political and psychological oppression of women.

and gender inclusion while enhancing women's empowerment. This scoping review serves as a resource for researchers and other stakeholders to understand the landscape of research, adopt and experiment with GIS approaches within gender and agri-food systems and to improve the understanding of how geo-spatial analyses can be better utilized for evidence-based policymaking; thus, opening possibilities for interdisciplinary collaborations in this emerging field.

2. METHODOLOGY

2.1.1. Desk Research

The scoping review was guided by the following objectives:

1. *To understand how geo-spatial analyses can be better utilized for evidence-based policymaking related to gender in agri-food systems; and*
2. *To identify the possibilities for interdisciplinary collaborations in this emerging field.*

The review aimed to identify literature relevant to the overarching research questions:

- *What is the current state of research and opportunities for applying geospatial methods for gender research related to agri-food systems?*
- *Applying a critical feminist lens, what is missing in recent efforts using GIS and how could they be better used to ensure gender and social inclusion and women's empowerment?*

The guiding questions informed the formulation of primary and secondary questions *(Figure 1)*, the keywords *(Figure 2)* and inclusion and exclusion criteria *(Figure 3)* for the literature search. The data was gathered from a variety of sources, including peer-reviewed journals and grey literature comprising articles, reports and unpublished research material.

Figure 1: The primary and secondary questions formed from the guiding thesis question

<table>
<tr><th colspan="2">Guiding (Thesis) Question</th></tr>
<tr><td colspan="2">What is the current state of research and opportunities of applying geospatial methods for gender research related to agri-food systems? Applying a critical feminist lens, what is missing in recent efforts at using GIS and how could they be used better to ensure gender inclusion and women's empowerment?</td></tr>
<tr><th>Primary Questions</th><th>Secondary Questions</th></tr>
<tr><td>1. How are geospatial approaches and analysis being applied to gender and social research within rural development and agri-food systems?
    1. What approaches and types of analysis are being used?
    2. What aspects of gender and social research are covered?
    3. What aspects of rural development and agri-food systems are studied using existing approaches?
2. What are the opportunities for future research and development? (R&D)</td><td>1. Where is GIS being used, what is the geographical scope, and regions where there might be less research because of gaps in statistical or digital capabilities (related to unequal patterns of knowledge production)?
2. What gendered aspects of agri-food systems are more researched, and in which specific sectors (fisheries, smallholder farming, etc.)?
3. What aspects of gender relations are being considered e.g., participation or areas related to changing power relations and social structures?
4. What kind of population groups within agri-food systems are studied using GIS methods?</td></tr>
</table>

1. What are the challenges? 2. What are the opportunities? 3. What are the gaps? 4. What are the recommendations and areas for further research and application in development practice?	5. What might be missed by these methods, where do they need to be complemented by other methodologies and how could they complement other methodologies?

Figure 2: Boolean Keyword Search Logic

Description: Selected search terms and Boolean logic operators (AND, OR, NOT) used for search strings for the literature.

<u>Central</u>: Geospatial, GIS, Gender, women, agr*, food systems
<u>Complementary</u>: agr*, production systems, female, remote sensing, spatial analysis, rural development

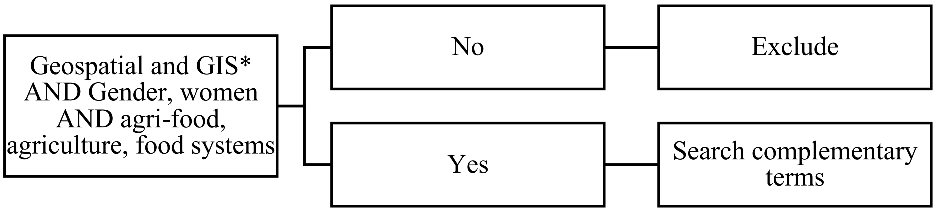

Figure 3: Inclusion/Exclusion Criteria

Category	Inclusion Criteria	Exclusion Criteria
Type of studies	Peer-reviewed journal and grey literature; Articles; Reports or other unpublished research material	Blogs, newspaper articles, documents without a clear methodology and sample selection criteria
Key words	Explicit mention of gender, gender/social research, agri-food systems, geospatial, GIS, remote sensing, spatial analysis, rural development	No mention of key words
Topic area	Geospatial approaches focusing on gender, agri-food systems, climate, sustainability and rural development	Documents about social inclusion where GIS is not mentioned or only tangential.
Geography	South Asia, Southeast Asia, Sub-Saharan Africa, MENA, Latin America & Caribbean, Global	N/A
Time period	Published between 2000-2024	Published before 2000
Language	Published in English	Published in languages other than English

A total of 120 documents were retrieved and included in the literature matrix, comprising academic articles, research articles, books, working and briefing papers, and reports *(Figure 4)*. The literature was mapped based on the documents' titles, keywords, and abstracts. In reviewing the documents, 75 sources were selected to be included in an analytical framework that informed the content and trends analysis of the scoping review. Articles to be analyzed were selected based on their relevance to the scoping review's aims: which addressed at least two out of the four general themes of the gender x climate x agri-food systems x rural development landscape, and had to use some form of geospatial approaches and techniques (e.g., remote sensing, satellite data, GIS, etc.) *(Figure 5)*.

Figure 4: Overview of screened literature

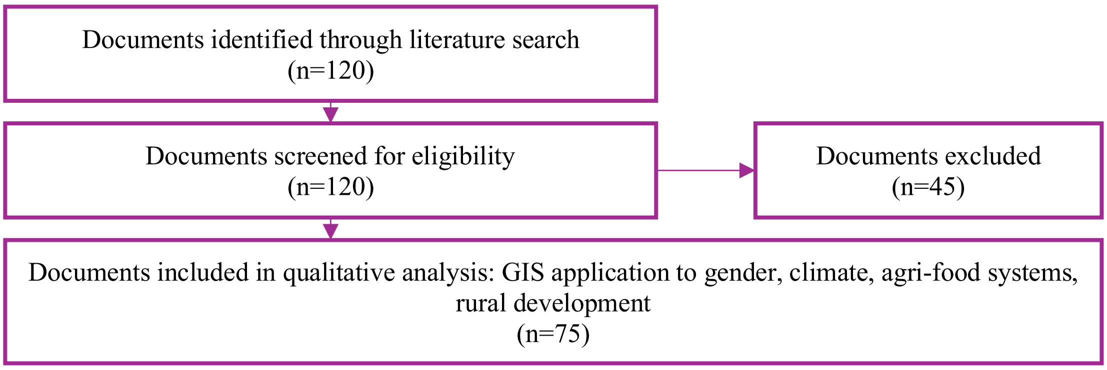

Figure 5: Keywords for the scoping review

Priority	Geospatial-related terms	Agriculture-related	Gender-related	Rural Development
• GIS • Geospatial • Women • Agriculture • Food Systems • Rural • Gender • Livelihoods • Climate	• Remote Sensing • Spatial Analysis • Spatial Data • Mapping • Land Use (Tenure) • Satellite Imagery	• Value Chain • Production • Processing • Aquaculture • Fisheries • Farming Systems • Crop (Production) • Livestock (Management) • Agroecology • Food • Agricultural Inputs (E.G., Seeds, Fertilizers, Tools) • Market Access	• Femini- (Feminism, Feminization) • Gender (+ Roles, Inequality, Differences, Dynamics, Access, Decision-making, Disparities) • Women's Empowerment • Agency • Intersectionality (With Race, Age, Etc.) • Participation/Participatory • Labor/Labour (Division) • Action (Collective)	• Sustainable Livelihoods • Subsistence (Consumption) • Agri-business • Smallholder • Farmer • Food Security • Nutrition • Transport • Infrastructure • Health • Education • Urban-rural Linkages • Poverty

2.2 Trends Analysis

The studies and documents selected for the in-depth analysis were closely reviewed within an analytical framework. Researchers examined the literature to identify recurring patterns and topics regarding gender and GIS in agri-food systems. The analytical framework captured the following areas:

- How geospatial methodologies and data sets are used;
- How the Geospatial method fits within the whole study;
- Level of geographic granularity and unit of analysis;
- Theoretical Framework/Lens/Approach;
- Population targeted;
- How the geospatial approach used data and mitigate the challenges around the data sets;
- Key themes with geospatial applications related to Gender, Agri-Food, Climate, and Rural Development;
- Findings and outcomes of the literature;
- Opportunities and potential of geospatial methods;

- Challenges and concerns of using geospatial approaches; and
- Gaps, recommendations, and future research (related to the use of geospatial approaches).

Researchers conducted a rigorous analysis to understand the context in which key topics appeared within the literature. The trends in the commonly mentioned GIS methods, contexts, and findings that related to the key topic were identified and analyzed.

2.3 Key Informant Interviews

To supplement the desk research, semi-structured key informant interviews (KII) were conducted. Interview participants were selected based on their expertise, professional role and experience with geospatial approaches in gender and agri-food contexts. A combination of desk research, including the reviewed literature, and snowball sampling was used to identify potential participants. The six interviewees included a mix of private sector (1), academia (2), research (1) and nongovernmental (2) actors *(see Table 1 for the distribution of interview profiles).* In preparation for the interviews, participants were provided with interview guides and consent forms *(Appendix 1).* Semi-structured interviews were then conducted over the course of one hour via the Microsoft Teams platform. The objectives of the interviews were as follows:

- To gather in-depth insights into the processes of applying GIS methods in research, policymaking, international development assessments and interventions; and
- To identify opportunities for future projects and collaborations for CGIAR.

The interviews were recorded with permission from the participants and transcribed for analysis. The insights from the interviews were then coded and analyzed via a thematic analysis to identify additional trends, gaps, challenges and opportunities for using geospatial approaches in gender and agri-food contexts. The insights have been used to supplement the desk research and develop the actionable recommendations for future R&D in the geospatial x gender x agri-food context for the CGIAR.

2.4 Limitations

The main objective of this scoping review is to provide comprehensive insights into the landscape of research production on geospatial approaches in agri-food systems, with a focus on gender. The scoping review provides a broader overview of the topic rather than in-depth analyses on the literature provided, limiting the level of detail that the findings can present on the mechanisms and applications of geospatial approaches within this context. Furthermore, the KIIs were conducted with the purpose of supplementing the research. The research team conducted six interviews, providing an indicative perspective of research on the topic, rather than a representative sample of the actors working within the geospatial, gender and agri-food system field. Furthermore, while the researchers employed a rigorous and structured methodology within the project, multiple researchers conducted multiple searches for literature, introducing a degree of bias and inconsistencies within the research. Despite these limitations, the research presents an overview of the key thematic areas and mechanisms by which geospatial approaches and techniques are applied in social science research on gender and agri-food systems.

3 'STATE OF PLAY' OF GEOSPATIAL RESEARCH ON GENDER AND AGRI-FOOD SYSTEMS: METHODS USED

Applications of GIS

For a long time, GIS has been conceptualized as a methodology for positivist, empiricist and quantitative research. Yet, developments in critical and feminist geography have demonstrated the value of applying GIS methods to explore questions related to gender, feminist epistemologies and social theory (Kwan, 2002). GIS represents a useful tool to study intersecting inequalities when embedded within feminist research approaches thanks to its ability to depict spatial patterns while connecting multiple layers of information. GIS can reveal patterns in socio-economic data at finer scales, such as at the district level, which would otherwise be missed by data aggregation by political or other larger units. Development in digital technologies have greatly broadened the type of information that can be gathered and processed through GIS beyond traditional quantitative or numerical data. Therefore, opening innovative possibilities to include primary qualitative and ethnographic data such as digital photographs, video and voice clips within spatial analyses through GIS (Zhang, 2021).

Consequently, most of the literature on gender and agri-food systems analyzed through this scoping review used mixed methods where GIS approaches were combined with other methods, rather than as a stand-alone research methodology. Within these fields, GIS tools are often used in combination with Remote Sensing (RS) techniques and Global Positioning System (GPS) technologies & data. A great portion of the literature reviewed also combined geo-referenced data gathered through GIS with secondary socio-economic data from nationally representative census or household surveys. Indeed, GIS serves as a powerful tool to link geo-referenced secondary data from different databases, thus enabling analyses which span across different analytical levels. Additionally, geospatial approaches were used to digitize and analyze primary quantitative and qualitative data collected through interviews, focus groups and ethnographic research. A particularly promising methodology within research on gender and agri-food systems is Participatory-GIS (P-GIS), an approach that combines GIS with community engagement for data collection, analysis and visualization, empowering local stakeholders by incorporating their knowledge and perceptions within research (Bosak et al., 2005). Different open-source free tools can be employed for carrying out P-GIS research including Open data Kit, Kobo Toolbox, QGIS, OpenStreetMap (OSM) and World Map.

Through this scoping review we have identified three main categories of GIS applications within the literature on gender, agri-food systems and rural development:

1. Descriptive GIS applications which focus on gathering, managing and visualizing spatial data to describe and represent phenomena studied.
2. Inferential GIS applications which employ spatial analysis to identify, estimate and graphically visualize statistical correlations between geo-referenced variables.
3. Predictive GIS applications which use models to forecast unknown conditions or future scenarios based on known spatial relations within geo-referenced data.

3.1 Descriptive GIS applications

3.1.1 GIS as a data collection and management tool

The most basic application of GIS pertains to the collection, management, and storage of large quantities and types of data (see Table 1 for overview of applications). GIS tools can be directly employed to collect and analyze geo-spatial data at different scales through satellite images and remote sensing. RS technology acquires images from sensors positioned on different platforms including satellites, airborne remote sensing - drones - and ground-based equipment that is then processed to aid agricultural decision-making (García-Berná, 2020). GIS can be employed within agriculture research to understand the implications of farmers' differentiated access to livelihood capitals, resources, essential infrastructure and services existing in a locality (Mathenge et al., 2020). Data representing each of these variables can be deconstructed as nested spatial layers linked to specific geographic coordinates obtained through GPS technology and then processed and analyzed in a GIS system. For instance, in a study evaluating the effects of participatory forest management programs on land use and land cover change in southwest Ethiopia's Alle District, Masha et al. (2024) use GIS Landsat images from 1992, 2012 and 2022 obtained from Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+), and Operational Land Imager (OLI) to track changes in forest cover. By overlaying this data with primary data collected through a survey and analyzed using ArcGIS 10.5, ERDAS Imagine 2015, SPSS version 20, and Excel 2010, the authors found that over time, land ownership had a negative impact on forest management participation, while other factors including gender, access to credit and training had positive effects. Therefore, developing an integrated participatory approach actively involving all farmers in forest management programs was a priority to avoid wetland ecosystem deterioration and the consequent extinction of ecologically valuable species and loss of biodiversity in the area (Masha et al., 2024).

Additionally, we observed that GIS is used to support sample definition in primary data-collection through large-scale surveys and interviews. In this case, geographical study areas are defined through satellite images, then systemic random sampling and geographical distance measurement through GIS are employed to select interviewees or survey participants. The data collected is geo-referenced using manual GPS systems and then digitized and analyzed through GIS. This data-gathering methodology is applied by Honarvar et al. (2023) to study the socio-economic and geographical drivers of household food insecurity in the Golestan province, in the Northeast of Iran. The authors carried out a cross-sectional study collecting sociodemographic characteristics, including age, ethnicity, household size, education level, and occupation status through interviews. The sample was based on the local healthcare database, first randomly selecting 50 households and then selecting additional households at a fixed distance from the first. The geographical coordinates of each household were recorded using a Garmin 60 GPS. Finally, regression analysis, GIS and inverse distance weighting interpolation were employed to infer the association between food insecurity and socio-demographic characteristics and to estimate the severity of food insecurity in different areas by displaying the intensity in a graduated color map (Honarvar et al., 2023).

Moreover, secondary qualitative and quantitative data such as digital photos, voice clips, video clips and socio-economic data from nationally representative household or census surveys, can be incorporated into GIS through geo-referencing and digitization. Equally, ethnographic data such as subjects' diaries, hand-drawn maps, and other sketches can also be analyzed through GIS. For instance, Christie et al. (2016) examined men and women's local knowledge of soils in upland, smallholder farms in two villages in Mindanao, the Philippines, using focus group discussions, semi-structured household interviews, ethnographic field visits, GIS and soil testing. Their research demonstrated that men and women chose the same plots for what they considered their best soil, but differed on what they felt was their worst. Additionally, although soil fertility analyses showed that the women's chosen soils were similar to the men's, analyses of qualitative data showed that their knowledge of soils was different and based on a gendered division of labor. A multidisciplinary approach helped bridge the gap between sociocultural and soil research (Christie et al., 2016).

Furthermore, with relevance to gender, climate and rural development, Zang (2021) argued that the combination of spatial and qualitative analysis can enable a more contextual understanding of social and environmental injustice against female migrant workers in China as lived experiences, instead of just variables and regression models. The research combined GIS approaches with qualitative data from ethnographic fieldwork and online resources such as media reports and NGO briefs to spatially visualize participants' information, narratives, photos and the authors' field notes collected through walk-along tours. This analysis provided a deeper insight into how patriarchal practices and perceptions can result in worsened migration experiences for females, including limited access to education, increased vulnerability to environmental pollution, exploitative working conditions and exclusion from governance and decision-making processes (Zang, 2021).

Lastly, P-GIS can be used to capture context- and time-specific social and institutional dimensions by involving local stakeholders in the generation of information. P-GIS methods range from paper-based mapping exercises to sophisticated digital platforms, allowing diverse groups to contribute their spatial understanding and personal perceptions of an area. An example from the literature is a study on gender-based constraints and opportunities for the adoption of conservation agriculture production systems in a smallholder community in the Philippines. Harman et al. (2013) employed participatory community mapping methods to collect data by asking participants to draw on printed satellite maps their perceived best and worst soil locations. The geo-referenced data from interviews and focus groups was then digitized and analyzed using two geospatial software applications: Google Earth and Arcmap10. Findings indicated that men and women had different soil knowledge linked to topography, gender roles and access to resources, which can have implications for the adoption of conservation agriculture production systems.

3.1.2 GIS as a visualization tool

The second observed descriptive application of GIS is for visual representation of data arranged in a spatial manner (see Table 1 for overview of applications). This can be done using GIS as a standalone methodology, for instance, mapping data from satellite images or remote sensing, or to visually represent data gathered through different methods – i.e. surveys, interviews, ethnographic research. Lecoutere et al. (2023) provide a viable, cost-efficient and effective methodology to combine different data types and sources to obtain a reliable estimate of the spatial distribution of gender-related risk through the convergence of hazard and gender-differentiated exposure and vulnerability of agricultural involvement in relation to climate change. The result of their study is a map of climate-agriculture-gender inequality hotspots in low-and-medium-income countries across the globe.

Additionally, it is paramount to recognize the instrumental value that GIS as a visualization tool generates in driving positive social and ecological change through awareness raising campaigns. For example, Vizzuality, a private sector company which participated in the key informant interviews, employs GIS to create easily accessible visualizations, digital maps and interactive dashboards for NGOs, public and private sector clients (KII, Vizzuality, 2024). These representations are crucial to communicate complex information about social, environmental and economic phenomena to widespread audiences, raising awareness of the need for urgent action against the social and ecological problems of modernity.

3.1.3 Monitoring and evaluation

Many of the studies on gender and agri-food systems use GIS to monitor and visualize the spatial and temporal evolution of known statistical relationships between variables and the impact of defined interventions or phenomena (see Table 1 for overview of applications). For instance, Kross et al. (2022) develop a geospatial framework for the systematic assessment and monitoring of environmental impacts of agriculture practices using agri-environmental impact indicators and the environmental impact assessment (EIA) method. Geospatial approaches are identified and synthesized for four key phases of the EIA method: (1) screening; (2) scoping; (3) impact prediction & assessment; and (4) impact management, monitoring & follow up. The study shows the potential of remote sensing and geospatial methods such as mapping, geostatistical interpolation, spectral indices, image classification, multi-criteria decision analysis, and GIS watershed analysis for the different EIA phases. The study creates a framework can be used by farmers, women farmer groups and environmental agencies to design specific strategies for the implementation of sustainable agricultural practices (Kross et al., 2022).

Different types of geospatial approaches including Geospatial Impact Evaluations (GIEs), geospatial data, GIS, remote sensing, causal and spatial impact evaluations are employed by researchers at AidData's Gender Equity in Development Initiative. As highlighted during the key informant interview, the purpose of this is to improve the measurement of gender-related outcomes from policy interventions and to provide insights into the key issues facing women's empowerment (KII, AidData, 2024).

3.1.4 Development of indicators

The final observed descriptive application of GIS is its use to develop socio-economic or environmental indicators, indexes and estimates, and to visualize their geographical distribution and/or temporal evolution (see Table 1 for overview of applications). For instance, Hargreaves and Watmough (2021) use Satellite Earth Observation to complement traditional survey and census data to measure progress in achieving the Sustainable Development Goals, notably SDG1 and SDG2, in rural areas, especially in low-and-middle income countries. Earth Observations can deliver auxiliary data, in the form of high spatial and temporal resolution data to provide spatially explicit insights into socioeconomic conditions. These can be fused with conventional survey data and compared between regions and countries to proxy poverty and development during intercensal periods, where ground data is unavailable, or where data collection may be unfeasible (e.g. due to high costs or conflicts). Therefore, Earth Observations could be leveraged to deliver timely and cost-efficient statistical updates at finer scales of analysis that would otherwise be possible (Hargreaves, Watmough, 2021).

Table 1: Overview of descriptive applications of observed GIS methods

Type of descriptive application	Author(s)	Study	GIS Method
GIS as a data collection and management tool	Masha et al. (2024)	Evaluating the effects of participatory forest management programs on land use and land cover change in southwest Ethiopia's Alle District.	Use GIS Landsat images from 1992, 2012 and 2022 obtained from Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+), and Operational Land Imager (OLI) to track changes in forest cover, overlaying this data with primary data collected through a survey and analyzed using ArcGIS 10.5, ERDAS Imagine 2015, SPSS version 20, and Excel 2010.
	Honarvar et al. (2023)	Studying the socio-economic and geographical drivers of household food insecurity in the Golestan province, in the Northeast of Iran.	Geographical study areas are defined through satellite images, then systemic random sampling and geographical distance measurement through GIS are employed to select interviewees or survey participants. The data collected is geo-referenced using manual GPS systems and then digitized and analyzed in GIS.
	Christie et al. (2016)	Examining men and women's local knowledge of soils in upland, smallholder farms in two villages in Mindanao, the Philippines.	Incorporating secondary qualitative and quantitative data such as focus group discussions, semi-structured household interviews, and ethnographic field visits into GIS through geo-referencing and digitization to reveal local soil knowledge.
	Zang (2021)	Combining spatial and qualitative analysis to enable a more contextual understanding of social and environmental injustice against female migrant workers in China as lived experiences.	Combining GIS approaches with qualitative data from ethnographic fieldwork and online resources such as media reports and NGO briefs to spatially visualize participants' information, narratives, photos and the authors' field notes collected through walk-along tours.
	Harman et al. (2013)	Study on gender-based constraints and opportunities for the adoption of conservation agriculture production systems in a smallholder community in Northern Mindanao, in the Philippines.	Employing participatory community mapping methods to collect data by asking participants to draw their perceived best and worst soil locations on printed satellite maps. The geo-referenced data from interviews and focus groups is then digitized and analyzed using two geospatial software applications: Google Earth and Arcmap10.

GIS as a visualization tool	(Lecoutere et al., 2023)	Mapping climate-agriculture-gender inequality hotspots in low-and-medium-income countries across the globe.	Combining different data types and sources to estimate and visualize the spatial distribution of gender-related risk through the convergence of hazard and gender-differentiated exposure and vulnerability of agricultural involvement in relation to climate change.
Monitoring & evaluation	Kross et al. (2022)	Monitoring the environmental impacts of agriculture practices using agri-environmental impact indicators and the environmental impact assessment (EIA) method.	Developing a geospatial framework for the systematic assessment and monitoring of environmental impacts of agriculture practices using agri-environmental impact indicators and the EIA method. Geospatial approaches are identified and synthesized for four key phases of the EIA method: (1) screening; (2) scoping; (3) impact prediction & assessment; and (4) impact management, monitoring & follow up.
Development of indicators	Hargreaves and Watmough (2021)	Measuring progress in achieving the Sustainable Development Goals in rural areas, especially in low-and-middle income countries.	Using Satellite Earth Observation to complement traditional survey and census data to measure progress in achieving the Sustainable Development Goals in rural areas, especially in low-and-middle income countries.

Descriptive GIS applications – Key takeaways for gender & agri-food systems research:

- It is paramount to enhance efforts to collect gender-disaggregated data that can readily be analyzed and visualized through GIS.
- GIS can be combined with qualitative methodologies such as interviews, focus groups and ethnographic research to spatially visualize gendered lived experiences manifested within specific geographical contexts; therefore, enhancing understanding of the localized structural drivers of intersecting inequalities.
- Participatory GIS represents a powerful instrument for women's empowerment by providing a platform for women to map and visualize their unique spatial knowledge, experiences, and needs, thereby amplifying their voices in community decision-making processes and promoting gender-inclusive spatial planning and resource management.
- Monitoring and evaluation applications of GIS for agricultural management are the most widespread in programs supporting the empowerment of women in agri-food systems through capacity building and training activities.
- GIS can provide a cost-effective methodology to track progress in achieving SDGs by complementing traditional survey data, and by providing an alternative data source when ground data is unavailable.

3.2 *Inferential GIS applications*

3.2.1 Linking data at different analytical levels

GIS can be used to link data at different analytical levels, thereby allowing explicit modelling of micro, meso and macro levels of analysis (see Table 2 for overview of applications). This methodology can be applied to connect secondary data collected through various sources such as national censuses, household surveys, satellite images and primary data collected through surveys, interviews, focus groups and ethnography. Kilic et al. (2015) employ GIS to link household and plot level data to provide a nationally representative analysis of the gender gap in agricultural productivity in Malawi, decomposing it into (i) a portion driven by gender differences in levels of observable attributes (the endowment effect), and (ii) a portion driven by gender differences in returns to the same set of observables (the structure effect). The authors find that while female-managed plots are, on average, 25 percent less productive, 82 percent of this differential is explained by differences in endowments, mainly due to high-value crop cultivation and levels of household adult male labor inputs. The factors driving the structure effect include child dependency ratio and effectiveness of household adult male labor and inorganic fertilizer (Kilic et al., 2015).

3.2.2 Geostatistics

Geostatistics is a class of statistics used to analyze and interpret the values associated with spatial or spatiotemporal phenomena. It incorporates geo-referenced data – spatial coordinates – within econometric analyses. A fundamental concept in geostatistics is spatial dependency, which posits that observations closer together in space are more likely to be related than those at longer distances. In the literature on gender and agri-food systems, GIS is employed to collect spatial data, statistically infer spatial patterns through econometric models and graphically visualize the statistical correlations existing between the considered variables. For instance, Liu et al. (2014) employ geostatistics in a study on employment location of rural migrant workers in mountainous and upland areas of Sichuan, China. GIS is used to collect data on natural environments which serves as an explanatory variable in a binary and multinomial logistic regression to model the decisions of rural workers migrating to each location. Employment location selection of rural migrant workers is found to be influenced by the travel time required to reach a town, the cultivated land area per capita of a worker's household, the worker's age, whether an employer provides housing or meals, and the RDLS (relief degree of land surface) of the worker's home village. Gender is found to affect the likelihood of laborers taking off-farm employment in their home villages but does not appear to influence movement to other migrant locations (Liu et al., 2014).

3.2.3 Spatial and locational analysis

Spatial and locational analysis involves the systematic assessment of locations, attributes and relationships between geographical variables collected through GIS. Within the literature, overlay and buffer analysis are the most frequently used methodologies to conduct spatial analysis through GIS. Overlay is a technique which involves layering multiple datasets to identify relationships between spatial variables. For instance, Lecoutere et al. (2023) identify climate-agriculture-gender inequality hotspots. These are defined as *"geographical areas where extreme climate hazards intersect with large concentrations of women participating in* *agri-food systems and in the agricultural labor force, and with high levels of gender inequalities; thus, resulting in high risk, high exposure, low adaptive capacities, and more vulnerability of women to adverse effects of climate change."* In order to do so, they overlay socio-economic data from publicly accessible databases with geospatial data on climate hazards and agricultural effects (Lecoutere et al., 2023).

Additionally, buffering is a technique which involves creating spatially defined zones around geographic data points to analyze proximity effects. Waler & Vajjhala (2009) explore how GIS technology can support integrated evaluations of the gender dimensions of transport using an innovative combination of community participatory mapping, new gender-disaggregated household-level Demographic and Health Surveys (DHS), and transport sector GIS data. They focus on Lesotho, Ethiopia and Ghana to map the links between the gendered dimension of spatial exclusion, transport access and Millennium Development Goals. They employ buffering to generate a jurisdiction-independent measure of transport access based on statistical analysis of GPS-referenced DHS data. Particularly, they plot 2-km, 5-km and 10-km radius buffers around each survey EA and calculate the total road length within each buffer to enable comparisons of road density by buffer at the cluster level as well as comparisons of buffer averages at the district and country levels. The outcome of the study is the identification of area "hotspots" of limited transport access and/or poor health service outcomes (Walker et al., 2009).

Table 2: Overview of inferential applications of observed GIS methods

Type of inferential GIS application	**Author(s)**	**Study**	**GIS Method**
Linking data at different analytical levels	Kilic et al (2015)	Analysing the gender gap in agricultural productivity in Malawi.	Employ GIS to link household and plot level data to provide a nationally representative analysis of the gender gap in agricultural productivity in Malawi, decomposing it into (i) a portion driven by gender differences in levels of observable attributes (the endowment effect), and (ii) a portion driven by gender differences in returns to the same set of observables (the structure effect).
Geostatistics	Liu et al (2014)	Studying employment location of rural migrant workers in mountainous and upland areas of Sichuan, China.	Geostatistics is used to collect data on natural environments which serves as an explanatory variable in a binary and multinomial logistic regression to model the decisions of rural workers migrating to each location.
Spatial and locational analysis	Lecoutere et al., 2023	Identifying climate-agriculture-gender inequality hotspots.	Overlay socio-economic data from publicly accessible databases with geospatial data on climate hazards and agricultural effects to identify climate-agriculture-gender inequality hotspots.
	Waler & Vajjhala (2009)	Mapping the links between the gendered dimension of spatial exclusion, transport access and Millenium Development Goals	Explore how GIS technology can support integrated evaluations of the gender dimensions of transport using an innovative combination of community participatory mapping, new gender-disaggregated household-level Demographic and Health Surveys (DHS), and transport sector GIS data.

		in Lesotho, Ethiopia and Ghana.	

Inferential applications – Key takeaways for gender & agri-food systems research:

- GIS provides an opportunity to link data from different databases at different analytical levels through geo-referencing and digitization, enabling gendered analyses of various phenomena.
- When conducting inferential analyses using GIS in research on gender and agri-food systems, it is paramount to avoid categorical thinking by adopting an intersectionality-driven research approach.

3.3 Predictive GIS applications

3.3.1 Integrated Assessment Models

GIS is used in the literature to develop and implement Integrated Assessment Models, which are used to study the interactions between human systems and the environment. Integrated Assessment Models provide a framework for analyzing complex systems by combining knowledge from economics, environmental and social sciences (see Table 3 for overview of applications). GIS enables the integration of multiple datasets, which is fundamental to represent physical, economic, and social dimensions of the systems being modelled. Additionally, GIS can be used in Integrated Assessment Models to carry out spatial analysis, model spatial relations and develop and visualize resulting scenarios. This technique is particularly useful to develop policy-recommendations for agricultural resource management and environmental impacts. For instance, Falchetta et al. (2022) employ GIS to create an Integrated Assessment Model of energy needs related to small-scale agriculture and water management in rural sub-Saharan Africa, as well as the technologies required to meet those needs. This enables the development of a framework for optimizing long-term, multi-scale energy-water-land system transformations, while achieving sustainable development goals. Additionally, this approach enables the creation of a framework to evaluate business models and policy interventions required to ensure implementation (Falchetta et al. 2022).

3.3.2 Interpolation

Interpolation is a GIS methodology which involves using mathematical algorithms to predict values at unsampled locations by analyzing the spatial relations among known data points (see Table 3 for overview of applications). Within the literature analyzed, the most frequently used interpolation techniques are Inverse Distance Weighting, which assign weights to data points that diminish with distance, and spatial autocorrelation, which spatially model and visualize data based on their underlying statistical properties. A summary of predictive GIS applications as a tool to conduct interpolation is provided in Table 3. Mathenge et al. (2020) conducted a study to identify, map and analyze spatial dependency and heterogeneity in factors that impede poor smallholders from participating in agribusiness markets in Nyando and Vihiga County, Western Kenya. They collected geo-referenced survey data and used three spatial geostatistics methods in GIS including Global Moran's I, Cluster and Outliers Analysis, and geographically weighted regression to carry out the analysis. They found that factors impeding smallholder farmers' participation exhibited local spatial autocorrelation linked to the local context.

Therefore, they identified and visualized distinct local spatial clusters in the form of hot spots and cold spots which were spatially and statistically significant. They concluded that, to improve poor smallholders' participation in agribusiness, policymakers should design spatially targeted interventions that are embedded in the local context and informed by locally expressed needs (Mathenge et al., 2020).

Table 3: Overview of predictive applications of observed GIS methods

Type of Predictive GIS application	**Author(s)**	**Study**	**GIS Method**
Integrated Assessment Models	Falchetta et al (2022)	Small-scale agriculture and water management in rural sub-Saharan Africa	Employ GIS to create an Integrated Assessment Model of energy needs related to small-scale agriculture and water management in rural sub-Saharan Africa, as well as the technologies required to meet those needs.
Interpolation	Mathenge et al (2020)	Analysing spatial dependency and heterogeneity in factors that impede poor smallholders from participating in agribusiness markets in Nyando and Vihiga County, Western Kenya.	Collect geo-referenced survey data and use three spatial geostatistics methods in GIS including Global Moran's I, Cluster and Outliers Analysis, and geographically weighted regression to carry out the analysis.

Predictive applications – Key takeaways for gender & agri-food systems research:

- GIS provides an innovative methodology to select policy interventions based on their expected spatially specific gender-outcomes.
- When conducting interpolation, it is paramount to identify the specific gendered local and temporal characteristics that affect the correlations studied to avoid reinforcing power and gender imbalances.

4. 'STATE OF PLAY' OF GEOSPATIAL RESEARCH ON GENDER AND AGRI-FOOD SYSTEMS: KEY THEMES COVERED

This section provides an overview of the recurrent trends that emerged within the scoping review of the literature. In particular, it reviews how geospatial applications were used to understand gender differences in land use and agricultural production, women's socio-economic experiences, and the division of labor between men and women within agri-food contexts.

4.1 Gendered perceptions of land use and agricultural production as it pertains to climate mitigation and adaptation

4.1.1 Perceptions

Throughout the literature, GIS is often used to investigate the perceived differences between men and women when researchers are seeking to understand agriculture in relation to climate change. Geospatial applications have been used to gauge to what extent men and women in households view the quality, use of resources and time constraints differently, ultimately impacting their agricultural production activities. Often, in these contexts, modelling and assessments are used to understand soil quality and the extent of participants' education and knowledge for how to manage the land i.e., through community soil maps. These GIS analyses draw on observations of individuals' knowledge of plant growth and soil quality indicators. Harman et al. (2013) conducted an assessment of soil quality in a Filipino village that assessed the differences in men and women's soil knowledge through participatory GIS and soil assessments. Their findings articulated that there were gendered perceptions of soil quality that depended on access to education and the subsequent division of labor on the household farm (Harman et al., 2013).

4.1.2 Capacity Building for Women Farmers

In other examples in the literature, GIS plays a vital role in building capacity among women farmers to mitigate climate change impacts on agri-food production and manage disaster risks and disaster reduction interventions. Capacity-building programs focused on equipping vulnerable women farmers with spatial skills to support their ability to manage natural resources like forests, agricultural land and water, and apply climate change mitigation strategies (Khatri-Chhetri et al., 2005).

The literature emphasized how geospatial technologies, including crop assessments and modelling, empower women farmers, enhancing the inclusion of gender justice considerations in agri-food systems, and supporting climate-smart agriculture. P-GIS and hotspot mapping help identify vulnerable areas and reveal how climate change impacts crops, food production and accessibility to resources (Bosak et al., 2005). Literature within this theme often focused on women's participation in climate change related projects in the contexts of forestry and land usage, often to understand women's perception of how climate change is affecting crops (Lecoutere, et al., 2023). It is also important to note that monitoring and evaluation applications of GIS are the most widespread in programs supporting the empowerment of women in agri-food systems through capacity building and training activities. The Women's Geospatial Technologies Rally is an initiative that empowers women in rural areas in Latin America by providing free training in different types of GIS technologies for agricultural water and soil monitoring & management and community empowerment (KII, Molina, 2024).

Technologies like satellite sensors and other digital technologies aid in pinpointing location-specific agro-ecological issues, enabling targeted interventions for climate-smart agricultural and natural resource management policies (Muralikrishnan et al., 2021). By involving women in decision-making and capacity building within GIS research, the scoping review showed that GIS research can help obtain first-hand information on farmers' needs, resource availability and location-specific problems linked to climate change. Several studies found that these tools facilitate public policy and planning efforts to improve food production and accessibility, promote conservation agriculture, and support sustainable resource management (Watmough et al., 2019).

4.2 *Gendered impacts within socio-economic development*

4.2.1 Geospatial approaches to map gender inequalities

Geospatial approaches can be used to map vulnerabilities and inequalities to develop insights on the relationship between gender-based deprivations and other forms of inequality in agri-food contexts (Hong, 2016). In several studies, GIS was used to map hotspots to illustrate how women have been affected by climate change, GBV, and poverty, disaster and conflicts. Further, it was also used to understand various socio-economic differences, including differences between urban-rural contexts (Sevier, 2014). One particular study used GIS to understand differential gendered impacts of rural outmigration on agricultural land use in Nepal (Maharajan et al., 2020). In integrating GIS (macroscale longitudinal geospatial analysis) with KIIs, focus group discussions and econometric analysis, the researchers explored the complexities of agricultural land abandonment. They found that a 1% increase of women's outmigration increased the chance of agricultural land abandonment by 36% compared to a 1% increase of men's outmigration decreasing the chance of agricultural land abandonment by 15%. The authors cite that women would take over the cultivation of land when men migrate, resulting in a feminization of agriculture patterns, whereas when women migrate, often older people are left behind who do not take over the agriculture responsibilities (Maharajan et al., 2020).

"GIS information can provide important insights on the relationship between gender-based deprivations and other forms of inequality related to geographic location and intersection of geography with other group-based inequality." (Azcona, Bhatt, 2021)

The study from which the above quote is taken mapped deprivations and inequalities in Pakistan and found that women from marginalized ethnic groups, living in poor rural households, fared worse in terms of well-being and empowerment compared to the richest women in Pakistan, while the latter group are more likely to be out of employment. Overarchingly, mapping hotspots can be used to identify gender inequalities and can contribute to identifying vulnerabilities, such as those based on differential access to resources. By layering GIS data on rural climate hazards with population data in rural and urban agri-food contexts, Koo et al. (2022) determined that hotspot mapping can contribute to risk management by identifying regions for either mitigating the risks of climate change or developing adaptation assistance by allocating scarce resources to populations at highest risk. Another study looking at energy found that access to electricity was inherently tied to the size of agricultural holdings. Geospatial research used to develop the methodology and data sources found that energy interventions must take into account the needs of stakeholders across the entire value chain and ensure that investments trickle downstream to smallholder farmers, in order to be financially sustainable and encourage local development.

4.2.2 Access to transport and infrastructure for women in agri-food settings

The literature highlighted the importance of transport infrastructure for poverty reduction and equitable resource access in rural agri-food communities. Participatory mapping revealed how women's access to and management of resources helped address their needs related to income, education and training, and influenced their access to roads and land. Studies illustrated that transport infrastructure was used to support mobility and access to services for poverty reduction.

"Transport infrastructure and services play a critical role in supporting mobility and access to basic services vital to achieving poverty reduction, gender equality, and sustainable development objectives." (Falchetta et al., 2022)

Spatial analysis can be used to make sense of how location-specific dimensions such as access to roads have an effect on women's workloads (Asad, 2014). A number of studies in this space show that women in agri-food systems face higher workloads than men in households that are closer to road networks. In these contexts, men would often need to find employment elsewhere to subsidize the familial income, as the size of their landholding was not sufficient for income-generating activities. As a result, there is a higher burden on the women to care for the house and the land as the men left to work. Brown (2003) found that women outworked men by almost four hours, with women living near the road working longer days. Within this study, further geospatial research revealed that these household experiences were located particularly where roads cut across the canyon divides, influencing employment opportunities, access to markets, and dependence on subsistence agricultural production for women and their households.

4.3 Understanding gender roles and division of labor in agri-food systems

As the literature demonstrates, GIS is a valuable tool for increasing awareness and understanding gender roles in rural agri-food systems by analyzing women's activities in agriculture and household dynamics. Through remote sensing and participatory mapping, GIS can capture gender-disaggregated indicators on well-being, dietary intake, and income, revealing household norms that typically assign men to agricultural roles and women to reproductive responsibilities (Ambikapathi, et al., 2021). De la Torre-Castro (2019) found that, in a coastal area, men used the whole seascape for their activities, while women remained in coastal forests and shallow areas collecting wood, invertebrates and farming seaweed.

Illustrating the broader gender inequalities that exist within the division of labor and food systems, this experience reinforces how women are more limited in the work they can pursue, being forced to balance productive and reproductive work. Ultimately, as one of the few aquaculture examples, this geospatial approach highlighted the importance of conducting more gender analyses in coastal environments.

Gender mapping offers an important step towards greater awareness of the diverse gender roles in agricultural farm management systems. An analysis of a mapping of gendered indicators (incl. literacy, agriculture-based occupations and birth rates) and using de-identified mobile phone data, resulted in maps illustrating the extent of women's engagement in farm-based livelihoods based on call detail record data and the spatial variation and temporal dynamics of gender inequality (Flowminder Foundation, 2019). This strengthens the researchers' understanding of traditional gender roles and norms within households in the rural agri-food context.

As discussed in the previous section, researchers also use GIS to map workload differences and highlight diverse gender roles in farm management to provide time-geographic insights into female labor-force participation and how women are able to manage their time within the agri-food context (Van Ham et al. 2005). One study highlighted that rice farming and transplanting is typically done by women throughout Asia, but floods can destroy rice fields, which increases women's workloads as they replant the fields (Resurrección et al., 2017). These findings indicate how the gendered division of labor influences the time and income of women in agri-food systems, as women not only have to invest time in replanting the fields, but have to forego the potential income from the failed harvest. Connecting to the previous thematic areas, this study illustrates the impact of adverse climate patterns on crop production and their effect on women's livelihoods. The literature illustrates the potential for GIS to inform practitioners, researchers and policymakers to target and empower women through agriculture and climate interventions, to ultimately address gender inequality within agri-food systems.

Thematic Analysis – Key takeaways for gender & agri-food systems research:

- GIS is frequently used in research to understand perceived differences of agricultural-related activities between men and women in agri-food systems.
- GIS is vital in building the capacities of women farmers, whether through training, skills development or other activities. Programs may focus on strengthening capacities for natural resource management, climate change mitigation, climate smart agriculture, monitoring and evaluation, and more.
- Geospatial approaches can be used to map vulnerabilities and inequalities to develop insights into the relationship between gender-based deprivations and other forms of inequality in agri-food contexts, including income, employment, education, access to infrastructure, etc.
- By analyzing women's activities in agriculture and household dynamics, GIS can help identify areas of vulnerability and need, which helps researchers, practitioners and policymakers target interventions and policies that can support and empower women within agri-food systems, ultimately working to address gender inequality.

5. CHALLENGES, GAPS, OPPORTUNITIES & POTENTIAL APPLICATIONS

The following section will explore the challenges, gaps and opportunities based on the literature included in the scoping review. The first sub-section provides an overview of the main challenges for GIS methods to be incorporated into research on gender and agri-food systems. Based on the gaps identified in the literature, the subsequent section examines the potential opportunities for GIS applications in the field of gender and agri-food systems and consequently, what is needed to overcome these challenges.

5.1 Challenges

5.1.1 Data availability and reliability as an observable challenge across and within various contexts

The lack of gender-specific data sources is the most important obstacle to developing gender-sensitive GIS. This is compounded by the lack of relevant underlying data, which makes GIS analysis challenging in specific national or local contexts. One of the reasons for this is due to the need to collect gender-disaggregated data early in the research process, as later integration is more difficult and less effective. One barrier to this is funding limitations. Due to restricted funding and short project time frames, studies tend to be focused on narrow concerns relating to specific aspects of agriculture, rather than comprehensive and longitudinal studies on agri-food systems as a whole. While some gender-disaggregated and GIS data can be sourced freely, integrating gender-disaggregated data with satellite imagery is still a relatively new practice. There is a need to establish a proof of concept and strong evidence base to justify its value and attract further funding for development (KII AidData, 2024).

Based on this challenge, there is a clear need to draw from a broad set of variables and data to effectively integrate gender in GIS modelling. Although most countries collect basic census data, gender-specific metrics are usually limited to indicators such as sex ratios, fertility rates and literacy rates (Bosak et al., 2005). One study found that aggregating large-scale survey data offered the potential for gathering accurate and reliable data, yet nationally representative surveys generally lack the nuanced information necessary to map gendered agricultural management systems. For example, data on gender inequalities in agriculture remain scarce across many countries, and there is minimal GIS-compatible and readily usable data that addresses the experiences of rural, local, and indigenous women (Twyman and; Acosta, 2022).

Additionally, identifying the location of study participants in remote geographical areas can present accessibility issues. A study in northern Iran used geographic coordinates of households to estimate the prevalence of food insecurity, its related factors and geographical distribution. However, the authors faced issues in locating the GPS of certain households, which they attempted to solve with a technical team (Honarvar et al., 2023). In addition, data storage issues can emerge due to a lack of internet connectivity. One interviewee recalled that, for a project involving farmers in Costa Rica, the lack of internet connectivity in remote rural areas required the use of alternative tools, including GPS, which do not need internet connection to function (KII, Molina, 2024). The interviewee explained that “our main focus is giving [farmers] tools that are easy to use – tools that don't need internet access… GPS you can install on your phone, and you don't need internet" (KII, Molina, 2024).

The quantity and quality of available data also varies considerably across countries, particularly at the household level and on socioeconomic data, making comparative analyses difficult. While this can depend on the type of analysis being conducted, the quality of data can impact the robustness of a study. One study found that expert consultations are the best process for producing reliable gender-disaggregated data for mapping, however, this may not be readily or easily accessible (GECS, 2019). Furthermore, based on our primary data collection, a challenge to reliability is the cost of data collection due to financial, time, and labor costs. This can act as a barrier for women's participation in research due to their care and domestic responsibilities, which can take up more of their time in comparison to men. Additionally, data collection can be compromised when mobile phone data is leveraged, as researchers must take into account women's ownership of the phone. These factors can introduce a measurement bias, as men are more likely to be available to participate in household surveys and other research activities (KII AidData, 2024). This can skew findings and fail to accurately reflect the perspectives, experiences, and needs of women, particularly in contexts where the gendered division of labor is more pronounced. Additionally, this could lead to implicit bias when using secondary data from large representative survey data, because the latter replicates gendered knowledge by only encompassing the perspectives of the heads of households, who are usually men.

Socioeconomic data rarely includes a spatial context, making geographic inequalities difficult to analyze. However, a key limitation of using secondary data is whether the data is suitable for the project scope. For example, the information is typically aggregated into census units, political boundaries or ecological units, which can obscure the spatial variability needed to examine gender inequalities (Brown, 2003). One KII highlighted that data collection was not sufficient or usable due to the use of enumerators who may not have been instructed or trained on how to conduct spatial or gender-disaggregated data collection, such as field plots. Incorporating capacity-building initiatives, such as training for female enumerators into the design of projects, could address these gaps while achieving the dual goals of capacity-building and meaningful data collection (KII, Mugiraneza, 2024). Additionally, the feasibility of gender-sensitive analysis depends on the availability of open-source global data across these contexts. For example, only 26% (14 of 54) of gender-specific SDG indicators can be reliably monitored globally.

The use of GIS technologies may create further complexities for data quality and reliability. The precision of results can be impacted by the resolution and accuracy of different types of GIS data, with one study referencing this in the use of Landsat images (GEGS, 2019). The authors outlined that the precision of results may be impacted by the resolution and accuracy limits associated with using Landsat images to detect changes in land cover.

5.1.2 Data ethics, privacy, and maintaining the anonymity of participants

When conducting GIS data collection and analysis, issues around data privacy and confidentiality can present challenges distinct from traditional methods of data collection such as interviews or surveys. Data privacy laws complicate access to disaggregated data due to the need to protect individuals' privacy. This can create barriers in data accessibility between the public and private sectors, often hindering research that could be beneficial to the public. There is a need for a nuanced understanding in the importance of these protective measures, recognizing the value of research for public welfare while protecting personal data. The social and logistical complexities of gathering gender-sensitive data is also a barrier to GIS in this field. Primary data collection using field surveys and interviews on sensitive topics, such as gender inequalities, may require local authority approval – a process that is time-consuming or could be denied altogether, creating a gap in the data needed to conduct research (CECAD, 2019).

Geospatial data could compromise the confidentiality of household information or inadvertently disclose the identities and locations of vulnerable individuals, putting them at risk. For example, in cases where GIS data could expose household locations within communities experiencing social tensions, participants may fear that their information may be misused, potentially exposing them to danger, increasing tensions, and escalating the risk of violence within a community (Chambers, 2006). This risk not only endangers individuals, but could undermine the trust in GIS studies, particularly among vulnerable groups.

Based on the need to protect the anonymity of participants in primary data collection, studies may randomize gender-, age- and ethnicity-disaggregated data within spatial boundaries to maintain privacy. However, this can create barriers to data interpretation and the robustness of the data analysis, as participants' locations cannot be pinpointed. For instance, in a study examining rural accessibility to transport, the location of participants was randomized within a radius of 1-2km. This meant researchers were unable to conduct the point-to-point analysis due to anonymization constraints, significantly limiting the depth of the findings (Walker et al., 2009). Open-source satellite imagery may be supplemented, providing valuable information on physical aspects like transport and infrastructure, enabling the mapping of roads and other public utilities (KII AidData, 2024). However, the restricted accuracy in pinpointing participants' locations can also obstruct researchers' capacity to provide detailed spatial insights that would otherwise enhance the study's impact.

Although there is an encouraging trend towards the collection of gender-disaggregated data, ensuring data openness and accessibility while preserving participant anonymity remains a critical challenge (KII Vizzuality, 2024). Addressing this need will require cross-collaboration between agencies and institutions, funding support for data integration, and a framework that protects both the fundamental rights of study participants and data accessibility. This should be complemented with additional data sources and alternative methodologies to strengthen data analysis and interpretation. A multi-faceted approach can help ensure that GIS analysis remains both ethically responsible and analytically robust.

5.1.3 Unequal Power Dynamics in the use of GIS

Power dynamics are an important consideration in the use of GIS, presenting challenges that affect both research processes and outcomes. These dynamics often stem from the unequal relationship between the researcher and the researched, exacerbated by cultural, social, and institutional factors. GIS is not just a neutral tool for mapping spatial data. It reflects and can perpetuate existing power structures, raising ethical, methodological, and practical concerns. For example, cultural understanding and nuances are integrated in GIS, with power asymmetry existing between the technology user and the participant (Schuurman, Pratt, 2002). This is especially the case when secondary data is used, making it difficult to avoid the inherent inequalities between those conducting research and the communities being studied.

GIS has been criticized for its masculinist leanings, supporting power structures associated with surveillance and control (Hong, 2016). In the context of agri-food systems, this criticism particularly resonates given that GIS is increasingly employed by corporate entities such as insurance companies and banks, which could influence access to financing. For example, women in agriculture, particularly smallholder farmers, often face systemic barriers to accessing credit and financial services (Ricker-Gilbert et al., 2014). These pre-existing inequities are magnified when financing bodies rely on GIS data, which can place women at a disadvantage when accessing loans and insurance coverage. While the private sector can drive this imbalance, Rabobank is an example of a pioneer in agricultural impact, promoting greater collaboration and ethical practices. The Acorn project is a Rabobank program that provides financial incentives for smallholder farmers adopting climate-smart practices and transitioning to agroforestry systems. With 80% of revenue reaching farmers directly, the project seeks to provide a new revenue stream while supporting climate-resilient farming (Solidaridad, 2021).

There are also other ethical issues, including taking up participants' time, whether participants have informed consent, whether the information being extracted benefits the individuals and the communities, and cultural and linguistic barriers. P-GIS is designed to empower communities through their involvement in data collection and analysis, yet it can be time-consuming for participants and unclear in how their data will be used and protected (Piñon et al., 2014). This raises significant ethical concerns about whether participants can provide free and informed consent. Additionally, one study also found that time was a practical barrier. Due to the restriction of time resources, it was not possible to teach the participants to digitalize the mapped information using the Quantum GIS software and functionalities, leaving them left out of the decision-making and participation within the research itself (De Carvalho et al., 2021).

5.1.4 Conducting Gender and GIS Qualitative Analysis as a Challenge

"Understanding GIS merely as a quantitative/empiricist method and placing it at the polar opposite to critical geographies or qualitative methods forecloses many opportunities for feminist geographers to critically engage GIS" (Kwan, 2022).

The process of conducting GIS analysis can present a significant challenge, particularly when incorporating gender perspectives. Feminist geographers have critiqued GIS due to the lack of standard procedure when representing gendered bodies or the social construction of space (Kwan, 2022). This could risk oversimplifying or entirely missing the diverse and complex realities of women's daily lives. GIS may fail to capture the ways in which gendered experiences intersect with spatial and social dimensions, limiting its potential as a tool for feminist inquiry.

A primary challenge to this is the complexity of data harmonization. Conducting accurate and effective GIS analysis often necessitates combining various modelling tools with different spatial-temporal resolutions, which requires alignment to scale the results (Falchetta et al., 2022). Additionally, consistency of input data is required, so care is needed to ensure homogenous assumptions and reliable results for robustness. Furthermore, attempts at cross-country uniformity of GIS methods does not always consider local realities in the construction of its concepts, survey questions or variables.

5.2 Gaps

The scoping review identified critical gaps in knowledge, methodology and data that could impact the effective integration of GIS in agri-food systems. Limited technical expertise and the perception of GIS as overly complex could limit its adoption, particularly amongst women and marginalized communities. In terms of methodology, GIS techniques are inconsistently applied across disciplines, with insufficient innovation to capture gendered experiences and social constructs. This fragmentation is exacerbated by data gaps, as traditional systems fail to capture spatial and gender-specific dimensions, while aggregated socio-economic data mask local inequalities.

5.2.1. Gaps in Knowledge

One significant gap identified in the use and application of GIS methods is the knowledge barrier, which often restricts effective engagement with these tools, particularly in the context of gender and agri-food systems. This complexity is compounded by the diversity of GIS instruments available, some of which are highly technical and require specialized knowledge to operate. These challenges can create an environment in which GIS is perceived to be difficult and overly technical, further deterring its integration into studies and projects (KII AidData, 2024). This knowledge barrier can exacerbate existing inequities, as women often face systemic disadvantages in accessing education, training, and technology.

The perceived technical expertise required to use GIS can be a substantial obstacle, especially for non-specialists and for initiatives aiming to empower marginalized groups, such as women farmers, to participate in data collection and analysis actively. This perception can also lead to an overestimation of the expertise required for relatively straightforward tasks, such as using mobile phone data or installing an app to gather GPS data (UN Women, 2018). In many cases, this perceived complexity discourages researchers from engaging with GIS tools altogether, particularly those from a social sciences background working on issues of gender inequalities and in contexts where simpler applications could yield valuable insights without requiring advanced technical training.

Moreover, GIS data can sometimes lack accuracy due to demographic factors affecting survey participation and response quality. For example, in data drawn from the Living Standards Measurement Study (LSMS), there is often uncertainty about who within a household is responding to survey questions. In some cases, male household members predominantly respond, which can skew data outcomes. One study conducted in Ghana revealed that women are more likely to report accurate outcomes regarding agricultural plots than their male counterparts (KII AidData, 2024). In terms of targeted participants, it has been observed that not much of the literature actively targeted young girls or older women as participants in GIS projects, indicating an opportunity for more specific targeting across demographics. This highlights the importance of capturing diverse information across different demographic groups to improve data reliability.

Similarly, when using Demographic and Health Survey (DHS) data to assess wealth distribution, estimates are often based on men's reporting and male-headed households. This approach can overlook significant differences in wealth distribution when female-headed households are included. One KII noted that wealth indicators vary when women's perspectives and circumstances are separately evaluated, revealing inequalities that would otherwise be missed. Another study highlighted that the relational theory of gender can be combined with DHS data, by drawing on existing literature to provide historical context to contextualize rates and means, and thus highlight variation within categories (Sochas, 2021).

An additional gap in knowledge is due to the types of GIS data collection. A key problem is that when it comes to linkages between environment and gender, sex-disaggregated and gender-disaggregated data is usually only collected as part of disaster risk assessment and not under regular data collection protocols. Particularly during times of crisis, there is a significant time lag in obtaining responses to surveys and generating the necessary data for geospatial analysis (ODW, 2022). This is also a problem in cases where GIS is used in retrospective evaluations, i.e., if the data has not been collected prior, a gender-sensitive evaluation cannot be conducted since proxies cannot be used. An example given by one of the KIIs was of a project to examine crop phenotyping in Afghanistan, which required additional ground truth data. However, when the government fell, the research team was unable to go back to complete the evaluation and the project was abandoned because there were no alternative measures put into place for data collection (KII AidData, 2024).

In terms of thematic knowledge, much of the literature focuses on specific areas or sub-topics of GIS application on crops and livestock. A gap in the literature was identified for fisheries research and the adaptability of GIS to the challenges that fisheries face. One reason for the slower uptake of GIS in this area could be due to the complex nature of GIS applications in the marine domain (Meaden, 2000). The variable nature of movement in water, quantifying it and conducting an analysis based on this can be difficult. This is particularly the case for studies examining a smaller area where movement is pronounced in contrast to larger scale projects, where movements are usually more predictable and quantifiable movements are relatively smaller in scale (Meaden, 2000).

While progress has been made, there remains considerable scope for improving GIS applications by addressing these technical, perceptual, and demographic challenges. Increasing accessibility, correcting misconceptions, and ensuring diverse data representation are essential for leveraging the full potential of GIS in gender and agri-food systems.

5.2.2. Gaps in Methodology

The gaps in GIS methodology highlight the need for a more systematic, interdisciplinary approach to integrating mapping techniques and spatial analysis. Currently, GIS methods and mapping practices are not uniformly applied across disciplines, with limited uptake in critical areas such as development programs, where mapping gender remains underutilized. Despite the strengths of qualitative approaches, such as ethnography, in analyzing complex social processes within specific contexts, these methods are often undervalued in GIS-related research. There is a critical need to grant qualitative methods equal prominence in studies, whether used independently or as part of mixed methods approaches that combine spatial and non-spatial data to inform public policy and research.

P-GIS approaches are often highlighted in climate-smart agriculture, particularly for their role in educating and engaging local farmers. However, these methods remain underused in other contexts, including gender-focused research. Some studies have called for P-GIS to inform better resource management policies by integrating local knowledge with regional policymaking efforts. Yet, the application of such approaches requires careful attention to methodological rigor. For instance, comparative analyses and triangulation across multiple methods must be approached with extreme caution to ensure validity and reliability when measuring categories at different levels of analysis (Sochas, 2021).

The incorporation of qualitative methods, particularly ethnography, into GIS frameworks is another area requiring attention. The strength of incorporating ethnographic data alongside GIS is rooted in its ability to capture the complexity of social processes within specific contexts. For example, feminist geographers have proposed re-envisioning GIS practices to align with feminist epistemologies and politics, incorporating qualitative data alongside GIS methods to generate contextualized cartographic narratives (Kwan, 2002). This approach challenges the traditional dualism between visual images, words, and numbers, instead using these elements to construct meaningful geographical discourses (Kwan, 2002).

A key limitation in GIS methodology is the reliance on summary statistics, such as national averages, which obscure disparities within sub-groups and spatial variation. Researchers stress the importance of moving beyond these aggregate measures by employing advanced statistical methodologies to uncover hidden inequalities. Moreover, creative methodological innovations, such as "performing the cyborg,"[2] advocate for feminist GIS researchers to engage in transformative practices that rethink traditional GIS applications (Kwan, 2002). Drawing from Haraway's conceptualization of the cyborg, GIS is a means of participation through a flexible form of data analysis, feminist GIS can contribute to a deeper understanding of lived experiences. In this way, public participation GIS can emerge as a "*set of anticorporatist, post-colonial and community-based GIS practices that align with a feminist GIS*," rather than its use as another system of representation similar to statistics (Pavlovskaya and St. Martin, 2007). Efforts should also focus on ensuring gender data is open, easily accessible, and geotagged to facilitate integration with geospatial analyses. Encouraging the building and accessibility of more permanent infrastructure to generate regular gender-disaggregated demographic data is critical to enabling more robust and inclusive GIS research.

To address these methodological gaps, a more integrative approach is needed. This includes combining primary data collection with multiple GIS methods to improve the possibilities of GIS for the representation of local communities. Furthermore, triangulating variables, particularly in mixed-methods research, enhances the validity of findings and provides a comprehensive lens through which to analyze complex social dynamics (Sochas, 2021).

5.2.3. Gaps in Data

Traditional data systems often fail to capture and visualize the nuanced status of women and girls, leaving significant gaps in understanding their lived realities. GIS, coupled with high-resolution satellite imagery, offers transformative potential by producing data that reveals geospatial correlations not discernible through traditional data systems (Vaitla, 2017). However, short-term study durations and inconsistencies in population samples—such as variations in education and social status between FGDs and household interviews—can further

[2] The cyborg refers to Donna Haraway's work "A Cyborg Manifesto", where the cyborg is symbolic of the fragmented body and the use of technology that is reflective of the modern human experience. In this context, technology (or more specifically GIS) is not a tool of patriarchal oppression, but instead can be used or "performed" to uphold feminist principles and the liberation of women.

affect the reliability and depth of insights. Data collection, such as household surveys, are typically filled out by male household members, which can overshadow other perspectives and compromise the validity of the findings. In contrast, household interviews may allow participants to express their opinions more freely (Christie et al., 2016).

The creation and management of large, cross-country datasets is critical for leveraging GIS to understand gender dynamics on a global scale. One KII noted that fragmentation across agencies working with GIS can make it challenging to synthesize data from many sources and limits the overall effectiveness of GIS analysis (KII, Mugiraneza, 2024). By integrating geospatial data and mobile phone information across countries, GIS has the capacity to store, analyze, and manage vast datasets, enabling cross-national comparisons and insights, that can illustrate patterns of gender inequality. In a similar vein, the expansion of publicly available high-resolution satellite imagery further enhances this capability, providing researchers with open access to detailed geospatial information (Vaitla, 2017). This can provide researchers with detailed geospatial information on the spatial dimensions of gender disparities, such as access to resources, services, and opportunities.

These advancements provide opportunities to tackle limitations such as response bias and social desirability bias, which often affect the reliability of survey data collected through questionnaires and interviews. Future research must address these biases to achieve a more comprehensive understanding of complex social and environmental dynamics, such as the intersection between participatory forest management (PFM) initiatives and the preservation of Ethiopian forests (Vaitla, 2017). Moreover, GIS methodologies can be re-envisioned through feminist epistemologies, using both qualitative and quantitative primary data to develop methods that are inclusive and reflective of diverse experiences (Kwan, 2002).

5.3 Opportunities

The use of GIS presents significant opportunities to address persistent data gaps, particularly in understanding gender disparities. Through advancements in high-resolution satellite imagery and integrating spatial analysis with traditional and qualitative methods, GIS enables researchers to uncover nuanced insights into women's roles, workloads, and access to resources. This section explores how GIS can enhance data collection and analysis, highlight inequalities, and provide targeted solutions to inform policymaking through its capacity for integration, data layering, and visualization.

5.3.1 P-GIS and spatial analysis

There is an opportunity for participatory GIS and spatial analysis to be used alongside qualitative data methods/analysis to provide additional contextual information. When it comes to spatial analysis, there is an opportunity for greater exploration of the use and application of spatial analysis to existing qualitative data (e.g., analyzing life histories spatially) or through participatory approaches. *"By placing 'people on the map,' GIS can present the actual and potential gender-differentiated impacts and implications"* (Resurrección, 2017). This, in combination with P-GIS, can allow for the visual assessment of landscapes, environmental services and land use, capturing the spatially explicit perceptions of these indicators according to gender. This method can be applied to additional contexts, fields, and case studies, to support the integration of a gendered approach to existing research.

Several studies highlight the opportunity for P-GIS in capacity building, analyzing, and understanding of the gaps in capacities for women in order to develop dedicated capacity-building programmes. GIS offers a means to visualize inequalities and socio-economic deprivation to understand the drivers and differences between urban and rural contexts, and how geospatial approaches can be integrated in resource-constrained settings. GIS can be used for education and engagement in landscape management plans. For example, helping participants to obtain a better understanding of the spatial distribution of their land and pinpoint locations related to their livelihoods and vulnerability. The training helped participants recognize where their forest, land and water resources are on the map; and monitor their territories for threats like climate change, illegal mining, and deforestation (Twyman and; Acosta, 2022).

P-GIS methods can be used to build the capacity of participants, such as women farmers, for instance through its use in irrigation demand management and to increase spatial understanding to improve forest land and water management (Aeman, 2023; CECAD, 2019). Developing an integrated participatory approach requires rapid attention, and stakeholders must be actively involved in the process. However, education, training and capacity building can help fill the knowledge gap. For example, a study in Pakistan examining gender-responsive approaches to challenges in irrigation looked at providing training for women farmers in GIS. In the authors' assessment of the training, an 80% improvement in farmers' knowledge was observed and participants expressed satisfaction with the opportunity to use the new technology (Aeman, 2023). In these approaches, there are also opportunities to shape the use of GIS in a constructive manner from an epistemological and ontological perspective. Moreover, integrating gender-responsive training into GIS allows for a rethinking of how the technology is applied, from both epistemological and ontological perspectives, which can help uncover gender biases in conventional quantitative methods (Kwan, 2002). By critically examining practices that reinforce traditional power dynamics, GIS can be reshaped as a tool that supports inclusivity and gender equity, rather than perpetuating exclusion. This allows for the identification of particular practices and operations that reinforce traditional power dynamics and further the inclusion of women in agri-food systems.

5.3.2 Informing policymaking

There is an opportunity for GIS methods, particularly P-GIS, to inform policymaking and help in targeting interventions, such as development, aid, disaster response, access to transport, health and social policies, agricultural policy, and more. For example, providing a spatial and gender-disaggregated view of resources and resource access can enable the identification of management gaps and biases to be addressed, and can ultimately further gender-positive policy agendas through visualization. *"GIS information can provide important insights on the relationship between gender-based deprivations and other forms of inequality related to geographic location and intersection of geography with other group-based inequality"* (Azcona, Bhatt, 2021*).* This highlights the value of using cluster-level data, based on women's economic lifestyles to categorize individuals with distinct social and economic needs into groups, allowing policymakers to identify areas of need and support more precisely with the planning and targeting of interventions (Vaitla, 2017). Thus, GIS can support policymakers to make informed decisions across several spatial and socio-economic indicators, with a view to addressing inequalities.

In the long-term, geospatial modelling and analysis can serve as a tool to facilitate cross-sectoral and multi-stakeholder collaboration and communication on issues such as health and education access. Another opportunity regarding policymaking is the potential for advocacy, influence or lobbying for policy. This scoping review identified that many solutions are context-specific, however, due to the diversity of contexts that this work can engage with, there is the opportunity to identify and scale effective solutions that work while being cautious of over-generalizing and relying on one-size-fits-all explanations.

GIS is valuable in identifying areas of opportunity and where resources exist within a particular landscape. This can help with mapping resources, how to access resources for projects and where best to place resources, supporting project implementation, interventions and/or policymaking. In the agri-food context, GIS can help stakeholders consider the differences in access to agricultural land and uneven impacts of natural disasters on women and girls, as well as more accurate links between individual households and the parcels of land which they use (Watmough et al., 2019). Some of the additional ways GIS can inform policymaking include:

- Geospatial data to augment data collected through household surveys to better identify gender-differentiated risks and opportunities;
- Highlight areas of need for women, such as access to health facilities or help record land tenure rights for women;
- Used to circumvent the issue of scarcity of administrative data and the lag of survey responses; and
- During times of crisis as an alternative data source including the use of smartphone technology to create gender disaggregated displacement maps following natural disasters (ODW, 2022).

Challenges surrounding GIS adoption often stem from limited access to technology, a lack of political will, and institutional bottlenecks, as noted by interview participants (KII, Solis, 2024). These factors collectively hinder its effective implementation and integration into decision-making processes. A significant hurdle is the ability to effectively communicate the complexities of GIS to policymakers, as this often involves translating technical details into actionable insights. When presenting maps or GIS outputs to decision-makers, it is crucial to provide clear explanations of how conclusions were reached and what assumptions underpinned the analysis. Without this, the value of the data can be lost, and its impact diminished. Bridging this communication gap requires not only technical expertise but also the ability to simplify complex topics and make them relevant to policy priorities, which can be a challenging and time-intensive process (KII, Solis, 2024).

5.3.3. Filling data gaps

GIS can help to fill some of the numerous data gaps created by traditional data methods, such as the data collection and monitoring of women's division of labor and workload. The recent availability of public high-resolution satellite imagery has enhanced the data landscape, allowing for detailed spatial analysis that can reveal geospatial correlations in many countries where traditional data systems cannot capture the status of women and girls (Vaitla, 2017). By leveraging GIS, researchers can capture dimensions of spatial analysis that can be used to make sense of location dimensions like proximity to roads, women's workloads and the division of labor within communities or households.

GIS allows researchers to use open-access satellite imagery data to explore geospatial correlations at different aggregated levels including the household-, community-, and village-level scales. This capability can be used to go beyond summary statistics such as the national average to uncover sub-groups and differentiate between groups, such as mapping deprivation and inequalities. For example, using the geographic coordinates of the DHS survey clusters, which can be matched with the individual, household, or cluster-level outcomes using GIS platforms such as ArcGIS, QGIS, and/or Tableau to map household-level access to resources (Azcona, Bhatt, 2021). Additionally, using available geo-referenced household and agricultural plot locations to create synergies with GIS system data to incorporate relevant geospatial variables into the modelling efforts and understand the gender gap in agricultural productivity (Kilic et al., 2015).

The ability for GIS to be combined and integrated into other methods can reveal insights that may not be visible through traditional methods. For example, qualitative data such as digital photos, voice clips, and video clips can be linked or incorporated into a GIS. In studies using qualitative methods, subjects' handwriting, hand-drawn maps, and other sketches collected through ethnographic methods can also be incorporated into a GIS methodology (Kwan, 2002). Additionally, layering data can be utilized to reveal spatial contexts and gender-based insights that are not available via traditional methods or if data availability is a constraint. For example, a study to conduct hotspot mapping based on publicly available data could not identify computable indicators of women's exposure to specific crops and livestock across countries (Koo, 2022). As the availability of data representative at country or first administrative subnational levels was a constraint, rural climate hazard GIS data was layered with population data and urban/rural data to identify climate–agriculture–gender inequality hotspots. Furthermore, the use of multiple GIS methods within one study can provide additional insights.

GIS is advantageous in its visualization and accessibility, offering spatially disaggregated insights that can be accessible and easy to interpret. This capability can be particularly useful in addressing large-scale disasters, such as climate change and natural disasters, where GIS mapping can be used to visualize risks like flood zones, and enhance disaster preparation (KII, AidData, 2024). In particular, due to the potential to reach the most marginalized groups, and those most vulnerable to these risks, GIS can facilitate better-informed decision-making at different administrative levels.

Case study: Leveraging Big Data for Women in Agricultural Development

Satellite imagery is a Big Data tool that could be employed to map women's land ownership across a region and to produce a meta-analysis that overlays land ownership data with large existing datasets for important health and social indicators. Remote sensing imagery data from satellites and unmanned aerial vehicles (UAVs) are being used to map the boundary of farm fields and their characteristics, such as crop types and production yield. By linking with sex-disaggregated household-level data, this farm-level geospatial data can provide objective, timely, and rich contextual information across multiple domains.

This could provide data across different critical intersections between women's land ownership, agricultural productivity, and broader socioeconomic outcomes like access to healthcare, education and financial resources. Through this granular and spatial evidence of gender disparities, the methodology can support targeted interventions to provide more equitable access to resources, strengthen women's land rights and enhance their participation in agricultural value chains. This demonstrates the potential for advancing women's empowerment alongside agricultural development.

Source: Brennan, E., (2018). Leveraging Big Data for Women in Agricultural Development. Foodtank.

5.3.4. Adoption of GIS in additional areas of research

GIS has increasingly found applications in diverse research areas that intersect with gender issues, demonstrating its potential to address complex socio-spatial challenges. By integrating GIS with other methods, these studies have expanded its utility beyond traditional applications, shedding light on nuanced gender dynamics in fields such as health, urban planning, and environmental resource management.

Below are some illustrative examples of its broader use:

- **Health inequalities in Zambia:** This study explored health inequalities by employing mixed methods and geo-referenced data to conduct a meso-level intersectional analysis. This approach moved beyond individual-level variables such as age or education to consider the influence of health system environments on disparities. The integration of spatial data provided fresh insights, reinforcing the argument that systemic factors, such as healthcare accessibility and geographic distribution of resources, play a critical role in perpetuating or alleviating inequalities. This study exemplifies how GIS can shift the focus from individual determinants to broader systemic drivers of inequality (Sochas, 2021).
- **Land dispossession in Vietnam:** In Northern Vietnam, participatory GIS was used to examine gender-sensitive issues related to land dispossession, livelihoods, and vulnerability among Thai and Khmu ethnic minority groups in Dien Bien Province. The study, which incorporated field surveys alongside GIS mapping, highlighted how land dispossession in rubber plantation communities affected women's control and access to forest and water resources. Importantly, participatory GIS enhanced local women's capabilities by helping them better understand the spatial distribution of their resources. This approach not only informed research outcomes but also empowered participants to advocate for their rights and manage resources more effectively (CECAD, 2019).
- **Transport and gender in Lesotho, Ethiopia, and Ghana:** A study integrating demographic and health data with transport GIS data combined participatory mapping to conduct a rural, micro-level comparison between Lesotho, Ethiopia, and Ghana. The research highlighted privacy challenges in GIS applications, such as maintaining confidentiality when using randomized data points within a 1-2 km radius. The study also faced data gaps, as road network data in Ghana was unavailable. Nevertheless, Ghana served as an example of what could be achieved with limited data availability. This demonstrates how GIS can still produce meaningful insights, even in constrained research environments, while offering lessons for navigating data limitations ethically and methodologically (Walker, 2009).
- **Monitoring of territories in the Amazon:** In the Amazon, GIS and satellite data were integrated with qualitative and quantitative methods to help communities monitor their territories. This study explored how geospatial services could address challenges such as land encroachment while examining how project interventions might alter gender

roles and living conditions for women and men. For example, GIS mapping allowed for the visualization of resource access and territorial changes, enabling communities to better advocate for their rights. The research also considered the gendered implications of these tools, noting that such interventions can shift power dynamics and redefine responsibilities within households and communities (Twyman, Acosta, 2022).

- **Gendered distribution of environmental pollution:** Zhang (2021) reviewed the environmentally vulnerable status of female migrant workers at the largest e-waste recycling city in the world - Guiyu town at Guangdong Province, China. The study utilized ArcGIS Story maps to spatialize qualitative research including census data, ethnographic observations and lived experiences from women. The results illustrated a maldistribution of environmental pollution and exclusion of women from education, and ultimately empowerment for their life outcomes due to their status of women and migrants (Zhang, 2021).

Within the aforementioned examples, the recurrent themes of inequalities and power dynamics support the review's key findings for how geospatial approaches can be leveraged to understand systemic and current issues within agri-food systems. GIS is used both as a diagnostic and solution tool to identify areas of vulnerability for women and to help design policies and interventions to address these vulnerabilities. These studies have utilized the same methodologies seen within the agri-food systems context, such as satellite data, GIS mapping, meso-level analyses, and ArcGIS maps to understand their own gendered contexts. Thus, these studies can be applied to understand different dimensions of gender and agri-food systems in the following manners:

- GIS can be applied to agri-food systems to understand access to social services, such as the distribution of healthcare facilities and their proximity to women farmers, or to understand food and nutritional experiences and outcomes.
- With transport and land dispossession, researchers can explore other elements of resource access. Both land ownership and transportation are important in understanding how they influence and affect women's ability to participate in the agri-food value chain, how women move between rural and urban areas, and how environmental changes challenge women's participation in agri-food activities.
- GIS can also enable the visualization of land use and land ownership over time, which can be used to monitor the impact of policies and interventions for women's resource access within the agri-food system.

Challenges, Gaps, Opportunities & Potential Applications - Key takeaways for gender & agri-food systems research:

- Data availability and reliability, especially of gender-specific data sources, is a key challenge both across and within contexts. There is a clear need to draw from a broad set of variables and data to effectively capture gender sensitivity in GIS modelling.
- Ensuring data openness and accessibility while preserving participant anonymity remains a critical challenge. Addressing this will require cross-collaboration between agencies and institutions, funding support for data integration, and a framework that protects the fundamental rights of study participants and data accessibility.
- Power dynamics are an important consideration in the use of GIS, presenting challenges that affect both research processes and outcomes. These dynamics often stem from the unequal relationship between the researcher and the researched, exacerbated by cultural, social, and institutional factors.
- Critical gaps in knowledge, limited technical expertise and the perception of GIS as overly complex could limit its adoption, particularly for women and marginalized

communities. Increasing accessibility, correcting misconceptions, and ensuring diverse data representation will be essential for leveraging the full potential of GIS in gender and agri-food systems.

- GIS techniques are often inconsistently applied across disciplines, with insufficient innovation to capture gendered experiences and social constructs. There is a need for a more systematic, interdisciplinary approach to integrating mapping techniques and spatial analysis.
- Data gaps emerge as traditional systems fail to capture spatial and gender-specific dimensions, while aggregated socio-economic data masks local inequalities. The creation and management of large, cross-country datasets is critical for leveraging GIS to understand gender dynamics on a global scale.
- GIS can help to fill some of the numerous data gaps created by traditional data methods, with the recent availability of public high-resolution satellite imagery having enhanced the data landscape and allowed for detailed spatial analysis.
- There is an opportunity for participatory GIS and spatial analysis to be used alongside qualitative data methods/analysis to provide additional contextual information.
- By providing a spatial and gender-disaggregated view, there is an opportunity for GIS methods, particularly P-GIS, to inform policymaking and help in targeting interventions, such as development, aid, disaster response, access to transport, health and social policies, agricultural policy, and more.

6. WAYS FORWARD

6.1 Key Learnings

Despite growing interest in geospatial approaches, the comprehensive literature search yielded a limited number of studies applying geospatial methods to study gender and social inequalities in agri-food systems. The preliminary screening of the literature revealed that many studies using GIS methods for agricultural and climate research are gender-blind, not taking gender into consideration when investigating topics related to decision-making and sustainability in agricultural production and natural resource management. Nevertheless, the in-depth analysis of studies and projects that have leveraged GIS methodologies to address gender concerns in agricultural communities and agri-food systems highlighted the many avenues GIS offers to answer questions that conventional research methods have not been able to answer, and to inform policymaking in more direct and transformative ways for women's empowerment and social inclusion.

In the context of the research, the added benefit of spatial visualization allows researchers to better understand the role that gender plays within agri-food systems. Geospatial approaches help to understand gender differences in perceptions and patterns in agricultural production and land usage. Another facet of this is the understanding of the role of GIS methods in the context of climate change. It also provides more context to the division of labor between men and women and the gendered experiences of vulnerabilities, specifically in relation to access to land use resources in agri-food systems.

The use of multiple GIS methods, including qualitative and quantitative, can help researchers overcome some of the limitations of traditional data methods and allows for more comprehensive and insightful data collection and analysis in the context of agri-food systems. GIS can also be re-envisioned and re-applied to support feminist studies and gender research on agri-food systems and help researchers, practitioners, and policymakers represent gendered spaces. Existing challenges for applying geospatial approaches within this field identified in this scoping review, including the accessibility, availability, and privacy of data, illustrate a need for further research to overcome these challenges. The findings presented here raise further questions as to how researchers can extend and deepen their engagement with geospatial data and analysis to foster transformative change for inclusive, equitable, and resilient food systems.

6.2 Recommendations for CGIAR

Based on the scoping review of literature and suggestions received from the experts through interviews, the following recommendations can be made in three specific areas including research, collaborations and resources.

6.2.1 Further Research

One of the key objectives of this scoping review is to identify key areas for future research to fill in data and research gaps within the gender and agri-food space. It includes:

- **Broadening GIS research** beyond crop research. The majority of the studies within this review focused on crop production, with a limited number focused on fisheries, aquaculture, livestock and pastoralism. In this sense, further research is needed to understand how geospatial technology can be applied in aquaculture, fisheries, livestock and pastoralism to understand the gender nuances and impacts within these areas. This includes climate change mitigation and adaptation techniques, the gendered division of labor, and the socio-economic vulnerabilities that women experience in these contexts.
- **Test geospatial approaches** and techniques from other disciplines to apply them to gender and agri-food research. The researchers identified other thematic areas, particularly relating to health inequalities and land ownership, where geospatial methodologies (such as ArcGIS, GIS inequalities mapping, and the use of mobile and road network data) can be applied to understand the experience of inequalities and power dynamics. Developing a multi-disciplinary research approach that identifies and engages with these other thematic areas to apply their findings and learnings to the agri-food context can leverage the opportunity for geospatial techniques and approaches within the gender and agri-food systems context. Key areas for researchers to review include the effect and impact on access to social services, resource ownership, skills knowledge and development, and gendered experiences of climate change.
- **Enhance capacity building activities for women in GIS,** not just through targeted beneficiaries, but also for example, through the training of enumerators on gender-responsive GIS data collection. The targeted demographic should also include older women (above the age of 64) and young people. Most of the literature included studies where women between 18-64 were the target demographic, however there is an opportunity to train older women, who serve as community leaders and knowledge-holders, who can then transfer the knowledge to the younger generation.
- Ensure there is a **gender lens throughout the entire geospatial research process** in agri-food systems to avoid inherent power dynamics and marginalization of women. Researchers, study participants, policymakers and others should be made aware of the importance of integrating a gendered approach to GIS research in agri-food systems.
- **Build a standardized GIS framework for gender research that leverages GIS**, to ensure that pre-existing power dynamics are not exacerbated within the project creation, data collection and data analyses phases.
- **Improve technology accessibility** through community-based GIS training, researcher education, and use of open-source data platforms. These tools will help researchers consider power dynamics within the research development process and accessibility of geospatial approaches to the local community.
- **Leverage participatory GIS** in research that targets the micro level of analysis, encouraging local communities and actors to become key stakeholders and decision-makers within the GIS research process.

6.2.2 Collaborate with other organizations[3]

Collaborations are integral to study in the geospatial, gender and agri-food systems space, as this area is currently a small but emerging field. As such, it is important to connect with other organizations working within this field and others who have complementary capabilities that

[3] Please see Appendix 8.3 for suggested partners for collaboration.

can help progress research, leverage research opportunities and mitigate data gaps that are presented in this review.

- **Work with private sector actors and governments** to increase data accessibility, particularly demographic and census data.
- **Collaborate with grassroots organizations** that serve to train and equip women in rural agri-food settings to understand the impact of their projects in the local community.
- **Create a network or platform** that hosts discussions to exchange ideas amongst researchers and practitioners on this topic. It is important to ensure that the platform is multi-stakeholder in nature for the inclusion of a diversity of perspectives (e.g., from statisticians to geographers to social researchers).
- **Host meetings on future geospatial innovations** within the gender and agri-food field so that geospatial approaches can be leveraged (such as machine learning and artificial intelligence) in research.
- **Host a consultation on data privacy solutions within geospatial research,** as this appears to be a general challenge within this field. It is important to understand how to overcome this challenge, while respecting the data privacy of local communities to progress this research.

6.2.3 Develop Resources

The interviews and literature analysis unveiled a number of key tools that are needed by researchers, practitioners and policymakers within this space. The below list outlines the top activities the CGIAR GENDER Impact Platform can engage in (based on existing activities within the Platform):

- **Develop a database** of projects and case studies to illustrate best practice in this space and identify potential partners.
- **Develop a report** on the impact of GIS capacity-building initiatives on women and other vulnerable populations within communities through primary and secondary research.
- **Develop a GIS guidebook, toolkit and training course** for conducting gender-focused research in rural agri-food systems for researchers and practitioners. The guidebook and toolkit could support the creation and implementation of a dedicated training course on GIS gender-focused research in agri-food systems.
- **Translate technical geospatial studies and knowledge production in an accessible manner**. Given the expertise often needed for geospatial analyses, researchers can increase accessibility to the information and make it more understandable for communities, policymakers and other actors not familiar with the geospatial field. This may include the creation of briefing materials, summary documents and other communications materials to communicate the findings of geospatial analyses to policymakers and other audiences in an accessible manner.

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8. APPENDIX

8.1 Interview Consent Form

CGIAR Gender Impact Platform – Scoping Review

Application of Geospatial Approaches and Analysis for Gender and Social Research in Agri-Food Systems

Information and Purpose: The CGIAR Generating Evidence and New Directions for Equitable Results (GENDER) Platform aims to catalyze research on gender in agriculture and food systems to achieve more equitable, sustainable, productive and climate-resilient food systems. The Evidence Module of the Platform, led by the International Rice Research Institute (IRRI), is designed to focus on synthesizing and sharing robust evidence, identifying and closing evidence gaps in the area of gender in agriculture and food systems. Currently, the CGIAR/IRRI team is collaborating with Shared Planet on a scoping review to map and analyse the current landscape of how geospatial approaches and analysis are applied to gender and social research within rural development and agri-food systems and to identify opportunities for future research and development (R&D). The project involves conducting a comprehensive mapping and analysis of existing literature on these topics. The current phase of the research involves conducting stakeholder interviews with academics and practitioners who have experience on using geospatial approaches and analyses for gender and social research in agri-food systems.

Your Participation: As part of this research project, you are invited to participate in a semi-structured interview lasting approximately 30-60 minutes. During the interview, you will be asked a series of questions regarding the application of geospatial approaches in gender research related to agri-food systems, the challenges and opportunities in conducting gender research using these methodologies/approaches, and your own specific research and experience. It is important to note that you are not obligated to answer all questions and are free to opt out of the interview and the project at any time.

Benefits and Risks: Your participation in this project is valuable as it contributes crucial insights to the CGIAR Gender Impact Platform's research. This information will be used to produce a technical report exploring how geo-spatial analyses can be better utilized for evidence-based policymaking related to gender in AFS and the possibilities for interdisciplinary collaborations in this emerging field. We do not anticipate any risks associated with your participation in this project.

Confidentiality: With your agreement/consent, this interview will be recorded for transcription and internal use. Your name and identifying information (excluding your profession and sector of activity) will not be associated with any part of the written deliverables. If we wish to use direct quotations from the interview in our report, we will first seek your approval then confirm your preferred affiliation. The recording and transcriptions will be stored on a secure drive and will only be used for the purpose of this research project.

Should you have any questions or concerns, please contact Arielle Rosenthal at arielle.rosenthal@sharedplanet.co.uk.

By signing below, I acknowledge that I have read and understand the above information and consent to the interview (please tick as appropriate).

☐ I agree to participate in an interview**.** I understand that I am free to withdraw my consent at any time without giving a reason.

☐ I agree to the interview being recorded.

☐ I agree that the information I provide as part of this interview may be used in a final report. This information may be presented anonymously, so that I will not be personally identified, unless I consent in a follow up discussion for the use of identifiable information.

☐ I understand that any personal data I provide for this project will only be used for research purposes. .

Signature: ____ Date: _______________

8.2 Interview Guide

Semi-Structured Interview Guide

Interview Guide	
Theme	Proposed questions and topics
Introduction	• Welcome interviewee and thank them for their time. • Can you briefly describe your background and current role? • Could you explain why and how you use GIS in your work?
Evolution of the field of GIS in agriculture, food systems and gender	• Could you discuss how, in your view, the field of GIS and its applications to studies of agriculture and rural development has evolved in the past decades? • In what ways gender considerations have affected the development and application of GIS methodologies within agri-food systems research? • What about the evolution of GIS in gender research and agri-food systems more specifically?

Studies and projects related to GIS	• Could you give us an overview of some of the studies/projects using GIS methods that you have been involved in?
	• What were the research/projects' aims and specific methods and data used?
	• What were some of the key challenges and opportunities that you encountered?
	  ○ Were there any specific challenges relating to data access and methods?
	  ○ How did you overcome these challenges?
	  ○ Related to the study/project's ability to foster transformational change for greater inclusion, equity, and resilience in food systems?
	  ○ How did you address these challenges?
	• [If their project/research is not gender related] How could similar studies/projects could be adapted for gender research and interventions?

Challenges and gaps in GIS applications today	• In your view, what are the biggest challenges for GIS applications in gender and agri-food systems as the field currently stands? • What gaps could be addressed and how?
Opportunities	• What are some of the biggest advantages of using geospatial analysis compared to other methods? • How can GIS methods be used to support women's empowerment and to foster transformational change for inclusive and equitable food systems within planetary boundaries?
Prospects and Recommendations	• What future trends do you see in the application of GIS methods for gender research (in agri-food systems)? • Are there any projects, ongoing research studies or experts that we should take note of for the scoping review?
Summary and conclusion	• Thank the interviewee for their time and valuable insights. • Explain the next steps in the project and how their contributions will be used.

	• There will be a webinar about our preliminary findings on X date, would you like to be involved as a potential discussant?

8.3 List of Interviewees

Interviewee(s)	Type of Stakeholder	Organisation
María José Molina	NGO	Women GeoSpatial Technologies Rallies (IICA)
Theodomir Mugiraneza	NGO	Cadasta
Francis Gassert and Susana Romero	Private Sector	Vizzuality
Patricia Solis	Academic	USAID YouthMappers
Sophie Ayling	Academic	University College London, Centre for Advanced Spatial Analysis
Jessica Wells, Katherine Nolan, and Rachel Sayers	Research Institute	AidData

8.4 List of Potential Partners

AidData	Femquant (feminist approaches to quantitative social science)	SERVIR / Women GeoSpatial Technologies Rallies	Vizzuality
Cadasta	HERE Technologies	SUMERNET	
Central Institute for Natural Resources and Environmental Studies (CRES)	ROOTS Project Gambia	USAID YouthMappers	
ESRI	Open Data for Resilience Initiative – World Bank	Wageningen University and Research - The PIP approach: building a foundation for sustainable change	

GENDER Impact Platform

Generating Evidence and New Directions for Equitable Results (GENDER) is CGIAR's impact platform designedto put equality and inclusion at the forefront of global agricultural research for development. The Platformis transforming the way gender research is done, bothwithin and beyond CGIAR, to kick-start a process of genuine change toward greater gender equality and better lives for smallholder farmers everywhere.

gender.cgiar.org

CGIAR is a global research partnership for a food-secure future dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources.

cgiar.org

Shared Planet is a global research and stakeholder engagement consultancy based in London, UK, dedicated to help solving systemic social and environmental issues.

sharedplanet.co.uk