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Gender and Institutional Dimensions of Agricultural Technology Adoption: A Review of Literature and Synthesis of 35 Case Studies

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Abstract

This paper reviews and integrates findings from existing empirical studies and case studies received from 35 organizations in various countries to identify demand- and supply-side constraints and opportunities in access, adoption and impact of technological innovations. This review consistently finds that women have much slower observed rates of adoption of a wide range of technologies than men; and these are mainly due to differentiated access to complementary inputs and services. There are limited studies that looked at upstream stages including priority-setting and innovation processes, in which women continue to be underrepresented.

Keywords: gender, technology adoption, innovation, agricultural extension, research, institutions

1. Introduction

Two thirds of the world's poor live in rural areas and depend on agriculture and the food sector as their main source of livelihood. Increasing agricultural productivity, availability of rural employment and sustainable rural livelihoods are key to reducing poverty and decreasing the number of food insecure worldwide. Broad increases in agricultural and labor productivity will raise incomes of the rural poor and reduce food prices, which govern real incomes and poverty in urban areas and generate important spill-over effects to the rest of the economy. However, the growth in the agriculture and rural sectors in many developing countries is undermined by gender-related constraints and unequal access to productive resources and opportunities (World Bank, FAO and IFAD 2008; FAO 2011). The gender inequality in various sectors and in many developing countries imposes real costs on society in terms of untapped potential in achieving agricultural output, food security and economic growth. It is therefore high on the development agenda to devise and adopt strategies and approaches promoting gender equality in productivity and access to productive resources and economic opportunities. This will not only lead to the empowerment of rural women and men, but it is also important for agricultural and economic development as a whole.

This paper explores in detail the recent evidence on gender gaps in technology adoption and access to innovations resulting in gender differences in agricultural and labor productivity and access to employment and economic opportunities. This paper answers the two specific research questions: *“How can we improve the adoption of technologies by men and women farmers and what is their involvement in shaping the research agenda and innovation processes to make sure their needs are taken into consideration?”*

This paper adds value to existing literature on gender in agriculture and rural development (e.g., the Gender in Agriculture Sourcebook; Promising Approaches in Reaching Poor Women Farmers; Engendering Agricultural Research; and SOFA 2010-2011 on Women in Agriculture) by developing a framework that systematically looks at both supply and demand sides of technology and service provision and applies this framework to draw key messages and lessons from past development projects and programs using a gender lens. In particular, it looks at the organizations and institutions that link the demand and supply sides and explores how they could be more responsive and supportive of technology adoption among women and men farmers. It looks at the role of rural institutions (both formal and informal); emerging institutional arrangements (such as contract farming, public-private partnerships, innovation networks, and multistakeholder platforms); and the role of information and communication technologies (ICT) in increasing the flow of knowledge, productivity and incomes of poor women and men farmers.

Another added value of this paper is its focus and in-depth investigation of the continuum of technological development, adoption and impact. While technologies are intended to be productivity-enhancing, value-adding, and labor-, energy- or cost-saving, not all technologies are beneficial and responsive to the needs of poor women and men or their expected users. Available evaluation and impact assessment studies throughout this paper suggest that technologies do change the division of labor and can sometimes do more harm to poor women than good and this can also explain why technologies are adopted (or not) by men and women (for example, Fisher, Warner and Masters 2000; Venter and Mashiri 2007; Rao 2002; Maguzu et al. 2007; and World Bank, FAO and IFAD 2008). This paper also looks at examples of technology evaluation or impact assessment and identifies constraints that limit their intended outcomes and opportunities and the key elements that contributed to some technologies' successes. This paper is produced from the richness of existing literature; submissions of case studies from various organizations worldwide; and the experiences and observations of authors in past work in several developing countries.

Following this introduction, the definition, scope, data sources and conceptual framework are presented. Then, the review and analysis are organized as follows: (1) gender differences in technology access and adoption; (2) demand- and supply-side constraints in technology adoption, as

well as constraints in bridging institutions and policy environment from a gender lens; and (3) promising demand- and supply-side strategies and opportunities for increasing the adoption and impact of technologies on poor women and men producers and consumers. The paper ends with a discussion of lessons learned and conclusions.

1.1. Definitions and scope

In this paper, we define technologies as “practices or techniques, tools or equipment, know-how and skills, or combinations of the aforementioned components” (<http://teca.fao.org/technologies> accessed September 16, 2011) that are used to enhance productivity, reduce production and processing costs, and save on scarce resources or inputs, such as labor or energy. This paper looks at technologies along the continuum from farm to fork, with a particular focus on food chain stages where women are more involved (e.g., processing and home production). The type of technologies, improved practices and innovations it examines are as follows:

- Technologies for land preparation and cultivation (e.g., improved varieties, production or natural resource management practices, fertilizer, pesticides, knapsack sprayers, plows, irrigation, and other farm power)
- Harvesting technologies (e.g., hand tools, reapers)
- Post-harvest operations and processing technologies (e.g., solar drying equipment, threshers, improved marketing or processing practices)
- Labor-, time- and energy-saving technologies for household tasks (e.g., fuel-efficient stoves, key-hole gardens, technological and institutional innovations for greater access to water and energy)
- Rural transport (e.g., hand carts, bicycles, motorized transport)
- Information and communication technology – ICT (e.g., mobile phones, rural radio, internet, television, print media)

We can further group these technologies into (1) intangibles (knowledge-based or management practices); (2) tangibles or physical technologies; and (3) biological technologies incorporated in the seed or planting materials. This classification can highlight the complementarities among these technologies and may have different implications on the relative role of institutions and organizations, adoption decisions, and access of these technologies. For example, improved knowledge-based management practices, information and extension systems (intangibles), and ICT (intangibles and tangibles) can help facilitate adoption of the biological and physical technologies. Physical infrastructure, transport and distribution system (tangibles) can facilitate access and adoption of other tangible and biological technologies, and mobility of frontline professionals who deliver information and intangible technologies.

Rural institutions include both formal and informal structures. Following Uphoff (1986: 8-10, quoted in Uphoff 1997: 6), “*Institutions* are complexes of norms and behaviors that persist over time by serving some collectively valued purposes, while *organizations* are structures of recognized and accepted roles, formal or informal.” An institution may be embodied in an organization, but some institutions are sets of rules that persist without structured roles. Institutional and organizational arrangements are referred to in this paper to mean contractual and informal agreements between producers and/or other social and economic actors to achieve common objectives. This paper will focus on institutional and organizational arrangements that facilitate flow of information for technology development and adoption, including farmer-based or rural producer organizations, research committees, information networks, multistakeholder networks, innovation platforms, public-private partnerships, social networks, water-user associations, self-help groups, and formal outgrower contracting arrangements that engage small farmers with private firms mainly into high value agriculture.

1.3 Data source and methods

This paper is based on the review of literature from 2000 onwards on gender-sensitive projects and interventions on technological innovations. The literature reviewed includes peer-reviewed publications and selected grey literature that provides useful insights and value addition to the discussion of issues and opportunities for improving technology adoption and impact on the poor. This paper builds on existing reviews by Doss (1999; 2001), which focuses on Africa and agricultural production technologies, and by Peterman, Behrman and Quisumbing (2010), which review microeconomic papers on non-land agricultural production technologies from 1999 to 2009. In this paper, we review additional empirical papers and we examine other technologies (that is, post-harvest and processing; homestead food production systems; ICT and rural transport) to complement the findings of earlier reviews. A number of examples and analyses from these past reviews are still cited in this paper whenever they are most relevant in the discussion.

This review paper extensively looks at impact assessments and evaluation studies related to technologies that have gender-disaggregated data and analysis. However, our review highlights that gender is largely absent from impact assessments, particularly in the context of agriculture and natural resource management. In a meta-analysis of 81 country-specific impact assessments of agriculture- and rural-related projects worldwide by the World Bank's Independent Evaluation Group (IEG) (2011), only 6 studies have a discussion on gender. The only rare examples with gender discussion are on microfinance, land, and community-driven development (CDD) (Subramanian and Qaim 2008 on Bt technology; Datar, del Carpio and Hoffman (2009), Goldstein and Udry (2008) and Deininger, Ali and Alemu (2008) on land rights interventions; and Kaboski and Townsend (2005) and Khandker (2005) on microfinance).

With the aim of casting the net more widely, this literature review is complemented by a call for case studies that was widely disseminated through a range of networks, electronic channels and social platforms. These networks covered inter-governmental and other international organizations; civil society organizations (in particular producer organizations); research institutes; and non-governmental organizations (NGOs) that are working with and for farmers (following FAO's definition which includes agriculture, forestry, livestock and fishery), with an emphasis on the grassroots level. There were 35 case studies that were received from various countries, namely Burkina Faso, Burundi, Cameroon, Democratic Republic of Congo (DRC), Equatorial Guinea, Ethiopia, Malawi, Niger, Nigeria, Senegal, Tanzania, Uganda, and Zambia in Africa; Cambodia, China, India, Malaysia, Nepal, and Philippines in Asia; and Bolivia, Ecuador, Uruguay and the Andes and Latin America in general. Most of these are boutique cases with less than 100 beneficiaries and have not been adopted on a wider scale. There is also limited written or formal evaluation of them to validate results and outcomes of the case study write-ups. It is therefore difficult to consider them good practices, success stories, or innovative approaches due to their limited scale and lack of rigorous evaluation. Nevertheless, these case studies provide important insights and useful lessons for future interventions on activities that worked well and areas that need further improvement from the perspective of those involved in these projects. These lessons are referred to in the subsequent sections of this paper.

In this review paper, the overwhelming bulk of evidence is from studies in Sub-Saharan Africa, some in Asia, and a few studies on Latin America, Eastern Europe, North Africa, and Middle East. This may be a reflection of regional or cultural differences in households and farming practices. The issues of women's technology adoption are more prominent in Sub-Saharan Africa, where women are more likely to have independent farming responsibilities and where there are clearly demarcated men's and women's plots, as opposed to other regions, where there is more joint farming. In other regions, it is harder to measure differences in men's and women's inputs and outputs and consequently there is relatively little empirical evidence.

Nevertheless, there is a whole set of issues that are very relevant in any region. The definition of "agriculture" is very much production-focused and limited to the activities and inputs needed between

land preparation and harvest, which is a mostly male domain. This ignores postharvest processing and kitchen gardens (now called "homestead food production systems") that are often women's domains. Ironically, these areas do get recognition for research and innovation when they are taken over by men and get commercialized. A related issue is the perceived dichotomy between "male crops," which are often equated with lucrative cash and export crops, and "female crops," which are often equated as crops used for home consumption (Doss 1999; Kasante et al. 2001; World Bank and Malawi 2007). While in some societies, this dichotomy exists, a study using nationally representative data by Doss (2002) in Ghana finds little evidence of this. This issue is also relevant to Asia and Latin America regions and is discussed in this paper.

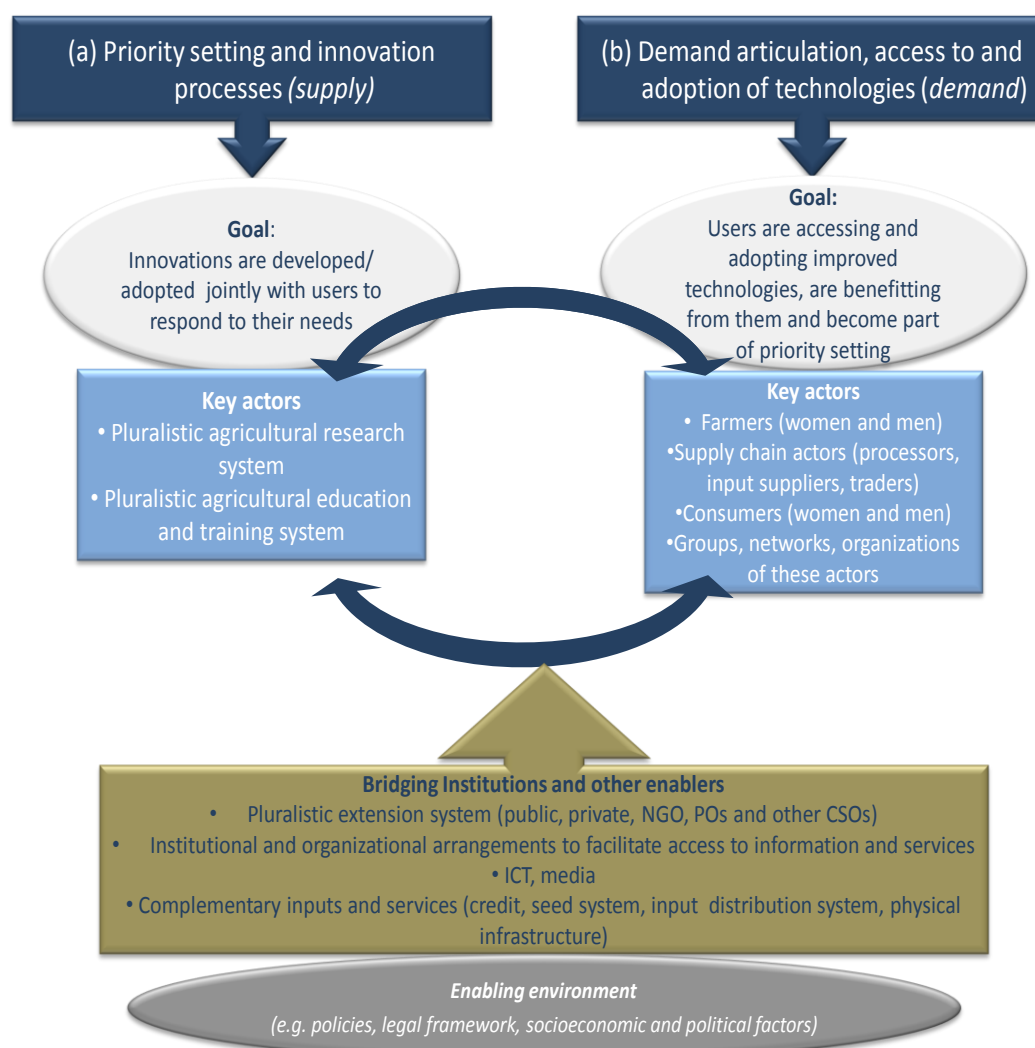
Another important issue is the definition of a farmer or plot operator since both women and men often have distinct roles within the production and marketing of agricultural products. Within Sub-Saharan Africa and Asian farming systems, men often perform more physically-intensive tasks of clearing and preparing the land, and women are often responsible for planting, weeding, harvesting, and postharvest processing (Guyer 1991; Kasante et al. 2001; Quisumbing and McClafferty 2006). However, in many communities, women are not considered "farmers" and therefore are sometimes not targeted in many agricultural and technology development and extension projects (World Bank and IFPRI 2009). The implications of the literature reviewed on this issue are discussed in the subsequent sections of this paper.

2. Conceptual framework and approach

Access to and adoption of technologies are analyzed in this paper by looking at both the supply and demand sides of technologies and related services (Figure 1). The demand side pertains to users of technologies and services, while supply side pertains to the developers of technology, input suppliers, and providers of services. The former includes different types of farmers and other supply chain actors who are the intended users of technologies and services. The latter includes the (1) research system (research institutes, academia, and think tanks either from public sector, private sector, non-governmental organizations, or other civil society organizations such as farmer organizations) that provide scientific and technical expertise and indigenous knowledge; and (2) education and extension systems (trainers, subject matter specialists, front-line field workers either from public sector, private sector, non-government organizations, or other civil society organizations) that provide training, education and advisory services on technologies, management practices and livelihood strategies. Between them are bridging institutions, organizations, and systems that link and integrate the two sides. This includes approaches for participatory priority-setting and feedback mechanism between the supply and demand actors. This also includes ICT that facilitate the flow of information, as well as physical infrastructure and efficient distribution system to enable flow of goods and services. The policy, legal and political environment are also enabling and conditioning factors that affect the supply and demand sides of technology development and service provision.

The distinction between supply and demand sides in this framework is useful in better identifying bottlenecks and constraints, as well as strategies, opportunities and approaches, in the development of technologies, access to, adoption, and impact of these technologies and services on poor women and men farmers. Demand-side constraints involve problems or impediments affecting the effective engagement of different social users and groups (e.g., gender roles, social hierarchies, incentives) in articulating demand and needs; limited ability and opportunity to shape the research agenda and innovation processes; limited capacity of these users to access technologies and services; and their limited information and complementary inputs to use these technologies. Thus, potential demand-side strategies that can address these issues include improving access to technologies and information about technologies; access to education and complementary inputs which will be important in the adoption of technologies; strengthening the ability of rural men and women to formulate and advocate for their needs in terms of technologies and services; and strengthening their capacity to be engaged in committees and institutions that would hold service providers and suppliers accountable to their needs and demands.

Figure 1. Conceptual framework in analyzing the demand and supply side of technological innovation while analyzing the role of rural institutions as catalysts and using a gender lens



Source: Authors.

Supply-side constraints pertain to the nature of the problems affecting the performance of technology developers and service providers (e.g., incentives, organizational and bureaucratic culture, and political capture). Thus, supply-side strategies include strengthening capacity and devising innovative ways of providing incentives and accountability of service providers to supply services efficiently and equitably while taking into account the needs of beneficiaries.

Looking into the supply and demand sides ties in with the principles of “agricultural innovation systems (AIS) perspective,” which is increasingly being used to analyze and guide investments in technological development and innovations. Within this perspective, connectivity of various actors along the market and food chain and within the system and an enabling environment are critical for developing innovations and ensuring positive social and economic impacts of innovations on poor men and women farmers and marginalized groups (World Bank 2008; 2011c). It highlights the linkages among research, education and extension systems; broader set of innovation actors; and the role of bridging institutions. It focuses on economic and social outcomes and impacts of innovations. It looks more comprehensively at capacity, incentives and behavior change in both supply and demand sides needed to come up with creative ideas and useful innovations. These elements have been well incorporated into the demand- and supply-side framework adopted in this paper. This paper

is structured by looking at supply- and demand-side constraints and opportunities of all key actors along the innovation cycle and food chain, paying close attention to the policy environment, role of institutions, incentive systems, and outcomes.

3. Gender differences in access to and adoption of technologies

There are numerous studies that look at gender differences in technology adoption. There is much variability among these studies in the inputs, crops, and locations analyzed, as well as in study designs, sampling, sample size, quality of data collection tools and analytical techniques, and in the indicator of gender used. Given this wide variability and the limited available empirical research for many types of technologies, it is hard to generalize and develop typologies and patterns about why gender differences are evident or not. However, there are some key insights and general lessons from these empirical studies reviewed and they are discussed below.

Gender indicator and definition of “women farmers” matter: Doss (1999, 2001); Quisumbing and Pandolfelli (2009); Peterman, Behrman and Quisumbing (2010); and many others have highlighted the heterogeneity of women farmers and have emphasized the need to collect different indicators of gender for a robust analysis or proper targeting of beneficiaries and end users. The issues that these authors raised are summarized as follows: (1) a majority of studies simply compares female- and male-headed households but this provides only limited information about a small segment of women producers in female-headed households and ignores the majority of women farmers in male-headed households; (2) the definition of female-headed households is often inconsistent or unclear (gender of household head versus household that does not have any adult male; *de facto* versus *de jure* female-headed households; and female household head versus female owner, manager or decisionmaker) but many studies continue to provide mis-informed comparisons and biased generalizations; (3) while most female-headed households are smaller in household size and more resource-poor than male-headed households, existing studies do not disentangle these relationship and it remains unclear as to what factors really affect technology adoption and productivity; and (4) a narrow comparison of women and men masks the differences and significance of a number of demographic characteristics (such as age, marital status, education level, and land holdings) and most studies continue to fail to look at the interaction of these factors. A number of studies have made an urgent call for future research agenda that addresses these methodological gaps as they may lead to ineffective targeting of interventions and misguided policy implications (Doss 1999, 2001; and Quisumbing and Pandolfelli 2009).

There are two findings from this review that are critical to consider. First, there are significant differences in results and implications depending on what gender indicator is used. For instance, in Zimbabwe, Horrell and Krishnan (2007) find differences in output prices received and access to selling consortia between *de jure* and *de facto* female heads of households; and in the use of farm machinery between male and *de facto* female heads of household but not between male and *de jure* female heads. In Malawi, Uttaro (2002) finds that married women are more likely to access inorganic fertilizer than single household heads. In Ghana, Ethiopia and Karnataka, India, the World Bank and IFPRI (2010) study shows that differences in the likelihood of adopting improved management practices are correlated with differences in literacy level between women and men.

Second, there are significant variations in gender differences in technology adoption based on geographical location within and across countries, highlighting the importance of institutional and socioeconomic context in shaping constraints and opportunities. For example, the School of Oriental and African Studies (SOAS) et al.'s (2008) study finds varying results across different regions in Malawi in terms of gender differences in probability of household head receiving and accessing fertilizer coupons. In the central region, female-headed households are likely to receive fewer coupons than male-headed households if they do receive coupons (SOAS et al. 2008). In terms of mechanized tools, while in some Southeast Asian countries women drive tractors and other mechanized farm equipment, it is rare in East Asia and in Sub-Saharan Africa (Singh and Kotwaliwale 2011). These

findings suggest the need to pay close attention to the definition of gender indicator and take extra care in generalizing across various geographical contexts.

Access to complementary inputs and services is a key issue: Based on simple comparisons and observations, evidence consistently suggest that male-headed households adopt new agricultural production technologies faster than female-headed households across regions (Doss 2001; Tiruneh et al. 2001; Bourdillon et al. 2002; Phiri et al. 2004; Kakooza et al. 2005; Jagger and Pender 2006; Thapa 2009; the World Bank and IFPRI (2009) study on Ghana and India; Peterman, Behrman and Quisumbing 2010 to name a few). Many studies have also used cross-sectional regression analysis, which methodologically allows controlling for other factors at a given period; and the results of these studies suggest that the gender indicator/variable used was not a statistically significant factor in explaining technology adoption. Most common factors that appear to be statistically significant are education or literacy level, fertilizer, extension services, credit and size of plot, which are all statistically correlated to the gender of the farmer. That is, women farmers surveyed in these studies have lower levels of education or literacy, less access and application of fertilizer, less access to credit, and have smaller plots. These studies emphasize that while the gender of the farmer *per se* is not statistically significant, it is the differentiated lack of access to these technologies and complementary inputs and resources between women and men that mainly explain the observed slower adoption rate of technologies by women than men.

Doss's (2001) review paper concludes that men and women farmers do not necessarily make different adoption decisions in many African countries and it is mainly the differentiated access to complementary inputs that explains the observed difference in adoption decision between women and men. Similarly, Peterman, Behrman and Quisumbing (2010) articulate well that it is the "accessibility of inputs, not propensity to use inputs" that constitutes a major bottleneck for many women farmers. The World Bank's and Government of Malawi's (2007) poverty vulnerability analysis finds that women on average make half of the decisions on crops not requiring fertilizer compared to only 10 percent of the time with crops requiring fertilizer. They conclude that women and men differ in their adoption decision patterns, but do not explain the reasons for these differences. Again, the difference may likely be because women face less resources and inputs, which is consistent with Doss (2001) and Peterman, Behrman and Quisumbing (2010) findings. Nevertheless, there is an ongoing debate and lack of research that systematically looks at whether women and men fundamentally differ in their adoption decisions and whether the observed difference in adoption decision and actual adoption is due to their differentiated access to complementary inputs or resources.

There are also limited randomized control trials and experimental field research that rigorously evaluate causal relationships between access to inputs or other factors and technology adoption (although several studies are known to be ongoing research). One available experimental study in Malawi by Gilbert et al. (2002) shows that before the intervention, female maize farmers have lower fertilizer use than men. However, when women were provided with seed and fertilizer inputs, their farm management efforts and fertilizer use were equally as productive as the men. These types of studies will be useful to identify binding constraints and approaches that actually work.

Access to information about technologies and extension services have also been consistently mentioned as a key factor explaining observed gender difference in technology adoption. The limited available studies on new and more controversial technologies, such as genetically-modified organisms (GMOs), highlights the need for greater understanding of these new technologies and stresses the key role of extension agents or rural advisors in bringing this information to both men and women farmers and facilitating their adoption.

There is also a need to look at the heterogeneity of women in assessing differences in access to complementary inputs. For example, Doss (2001) find that women in male-headed households are better off and command more resources and better quality land holdings than women in female headed households. In Kenya, Potash (1981) study find that actively farming older women may have more resources to draw upon to better respond to extension messages than younger counterparts. These types of studies will be important in effective targeting of projects and programs.

Limited accessibility and adoption of labor- and energy-saving technologies and transport:

Although various labor-saving and energy-saving technologies could have huge potential to reduce considerable time burden of women and increase labor productivity in general, empirical studies show that their use and adoption among rural women has not always been high and usually much lower than men (Pender and Gebremedhin 2006; Horrell and Krishnan 2007; Oladele and Monkhei 2008; Babatunde et al. 2008; Carr and Hartl 2010). Three reasons are commonly highlighted as reasons for this gender difference: (1) culturally-appropriateness; (2) physically accessibility; and (3) affordability. For example, the reported value of farm tools owned between male-headed households and female-headed households (Horrell & Krishnan 2007 on Zimbabwe; Babatunde *et al.* 2008 on Nigeria) and difference in use and ownership of animal draft or animal tractor (Pender & Gebremedhin 2006 on Ethiopia; Oladele & Monkhei 2008 on Botswana) are likely attributed to the relative affordability of these technologies, coupled with women's less income and asset holdings and less access to credit than men. Similarly, affordability and access to financing can explain less access to and use of more advanced agro-processing equipment than men; and women often rely on less mechanized and more labor-intensive processing technologies and/or are employed as workers in large processing plants (Singh and Kotwaliwale 2011).

Several studies indicate that adoption of improved technologies have increased women's time burdens as additional and highly time-consuming tasks or processes are often required on the onset of these new technologies (Berio 1984; Suda 1996; Quisumbing and Pandolfelli 2008). For example, in Malawi and Zambia, women who were doing processing reported that adopting hybrid maize gave them more time-consuming tasks as the hybrids were more difficult to pound (Hirschmann and Vaughan 1984; Jha, Hojjati, and Vosti 1991).

Sometimes technologies are not physically accessible to both women and men. This is related to access to transport technologies and availability and quality of roads physical networks and connectivity. Women have fewer opportunities than men to use transport technologies to alleviate their heavier transporting time burden across regions (Fernando and Porter 2002; Starkey et al. 2002; World Bank 2004; Carr and Hartl 2010). For example, in Nepal, women were found to travel 10 to 180 minutes to reach the mills and wait for 30 minutes for their turn (Intermediate Technology Development Group 1986).

Women often lack cash to pay for fares or purchase transporting technologies. Rural transport services are often infrequent and expensive; and at times, harassment and safety are also a major concern for women traveling long distances alone (World Bank, FAO and IFAD 2008). In some cases, it is also reported that women are of less priority than men customers or those traveling a longer distance (World Bank, FAO and IFAD 2008). In some countries, restrictive cultural traditions (e.g., in Bangladesh) also have an effect on women's use of available transport facilities (Starkey et al. 2002). This often limits mobility of women to interact with other producers, input suppliers, and buyers; and to participate in meetings, trainings, extension services, that require travel. All these affect their decision and ability to adopt improved technologies and foster entrepreneurship. Across regions, gender-specific needs are very seldom considered when developing transport infrastructure or networks especially in rural areas (Carr and Hartl 2010). Most transport projects stress building major roads to promote connectivity of rural areas, while women often access the smaller local roads which are often not part of project considerations (World Bank 2004).

Limited access to advanced ICT: Distinctions or classifications of ICTs are useful in analyzing access to and implications of more advanced (internet, wireless) and more traditional technologies (radio, satellite radio, and television). Many developing countries, especially in rural areas, lag behind in the rates of connectivity in access to both internet and mobile phones. Liff and Shepherd (2004) argue that this digital divide is not only between rural and urban and between the rich and poor but is also closely associated with the gender divide. Due to unequal access to the factors that appear to enhance ICT access and use, such as income and education, women generally have less access to ICTs and this pattern increases as the technologies become more sophisticated and expensive.

A study by Gillwald, Milek, and Stork (2010), using empirical data across 17 African countries, finds statistically significant gender differences in access to and use of internet for all countries, except Cameroon. In most of these countries, men are more likely to claim to know more what the internet is, to use the Internet, and to have an email address than women. In terms of television, no clear pattern of TV usage can be drawn between women and men, although the process and method are quite different. In some countries (e.g., Botswana, Kenya, Namibia), significantly more men than women watch TV, but the opposite applies in other countries (e.g., Cameroon and Mozambique) (Gillwald, Milek and Stork 2010). Combined results for all countries show women are as likely as men to watch TV at friends', relatives' or neighbors' houses (Gillwald, Milek and Stork 2010).

There is a more promising pattern of rural women's access to radios, although men still are more likely to access and use them. In Ethiopia, 16 percent of women and 31 percent of men listen to radio at least once a week, implying that men were about twice more likely to have frequent access to radio than women (Ethiopian Society of Population Studies 2008). Across 17 African countries, average hours listened to the radio per day were higher for men than women (except in Namibia, South Africa and Kenya) (Gillwald, Milek and Stork 2010). Across various types of ICT, the majority of women in Ethiopia (54 percent) while a less proportion of men (33 percent) did not have access to any newspaper, magazine, radio or television (Ethiopian Society of Population Studies 2008).

The relative difference between men's and women's access to and usage of mobile phones is diminishing (Sorenson 2002). Zainudeen et al. (2008) find a wide gender gap in access to mobile phones in Pakistan and India; less in Sri Lanka; and none in the Philippines and Thailand, where mobiles are most pervasive. In 13 out of the 17 countries, more men than women own a mobile phone and mostly spend a greater amount of money using it (Gillwald, Milek and Stork 2010). After controlling for other factors, Chabossou et al. (2008) find that gender is mostly insignificant. What was interesting is that in rural areas, men are more likely to own and have access to phones than women. This could be attributed to a number of factors, including greater levels of illiteracy, cultural barriers, and less available cash faced by women compared to men in rural areas.

Adverse effects of adoption of technologies: While access and use of these labor- and energy-saving and productivity-enhancing technologies are desirable, second-generation issues sometimes occur. One such issue is the risk of shifting control over profit and assets from the female to the male domain. Fisher, Warner, and Masters (2000) find that the adoption of the stabling technique in rural Senegal improved milk production and profits but later on was taken over as an activity by men. Venter and Mashiri (2007) and Rao (2002) show that various intermediate means of transport (such as donkey carts or bicycles) often fall into the control of men or add more tasks, responsibilities and time burden for women compared to when they were less mobile. This risk often contributes to reluctance among women to adopt and use labor-saving technologies that increase profits or incomes if they themselves do not control these economic gains.

Another second-generation issue is the magnitude and equitable distribution of effects. Paris and Chi (2005) find that plastic drum seeders benefitted better-off households but have resulted in the loss of livelihoods for the many women from poorer and landless households who used to be hired to undertake these tasks. Maguzu and others (2007) and World Bank, FAO, IFAD (2008) analyze conservation or zero tillage agriculture and suggest while it has many benefits, it led to more women

in landless households receiving fewer opportunities to work in planting and seeding and to more liquidity constraints for poor women to purchase inputs up front and to purchase tools suitable for direct planting. Economic cost-benefit analysis and poverty and social analysis are important in order to know which type of farmers or segment of the population are adversely affected; to support the transition and adjustments needed by those affected; and to devise ways to protect those vulnerable and resource-poor who would be affected. Not much has been done in terms of economic, social, gendered, and poverty impact assessments of technologies, and this is a key knowledge gap and major research need in the future.

4. Constraints to technology access and adoption

There is a wide range of literature that looks at factors affecting the adoption of various kinds of technology; many of them include a variable on the gender of the farmer or household head. Common factors in these studies are attributed to both demand and supply sides of technologies and can be broadly grouped into: (1) accessibility; (2) liquidity; (3) profitability and suitability; and (4) sociocultural factors. Accessibility includes access to information or extension services about these technologies and access to the technology or mix of inputs and labor required. This also reflects access to transportation and infrastructure and efficiency in the distribution system. New technologies often require more investments and small farmers often face liquidity constraints in purchasing these required inputs. Profitability from or suitability of technology (or lack thereof) is a major factor in non-adoption of many new improved technologies and reflects both supply and demand side issues. Limited adoption can reflect a number of factors including the lack of feasibility studies, weak planning and research prioritization processes; lack of consultation among potential users/beneficiaries; weak demand articulation of small producers' needs and preferences, and/or sociocultural constraints encompassing the various gender norms and social barriers women face in accessing and adopting new technology. There is also a role that enabling environment and rural institutions play in facilitating information exchange; pooling and access to resources and opportunities; and bridging the supply and demand sides.

What is largely missing in the literature are studies that systematically understand whether the issue of low adoption, especially among women, is the inappropriateness of technology, the lack of complementary inputs to enable adoption, lack of credit to access these inputs, the lack of access to information about the technology or the lack of required knowledge and skills to adopt and implement them. All studies reviewed point to a mix of these factors but none has analyzed comprehensively the root causes, bottlenecks, and binding constraints of technology adoption and outcomes. This section will summarize the available evidence to date.

4.1. Demand-side constraints

4.1.1. Limited women's participation in priority setting and innovation process

The lack of engagement of key actors (women and men) in priority-setting and innovation processes are cited by some studies as a reason for the limited responsiveness to the needs and constraints of rural women and men, social acceptability, and cultural appropriateness of some technologies produced (Meinzen-Dick et al. 2010; FAO 2010). While women are becoming more involved through participatory research approaches and participatory rural analyses, relatively little attention has been given to gender issues in the upstream priority-setting and decisionmaking (Meinzen-Dick et al. 2010; FAO 2010). References in the literature to women as innovators are limited despite women's vital role in farming, home production and processing and as keepers of large amount of traditional knowledge and technology. Other actors beyond farmers, research and extension agents are also missing in most priority-setting and research planning processes. More engagement of the private sector, input suppliers, processors and consumers is often beneficial to ensure that greater

commercialization of technologies and ensure demand for the products and services coming out of the technologies.

From the demand-side perspective, there are several reasons cited on why women are less likely to participate in meetings, priority-setting and innovation processes. They often lack mobility, access to transport, and travel funds to enable them to participate. In many cases, social and cultural norms against women and greater time burden are hindrances to their mobility and participation. Women often lack capacity, education, self-confidence, and more limited opportunities to join in groups and organizations, which often serve as platforms and avenues for consultations and information-sharing with other actors including policymakers, researchers, and technical experts.

A number of demand-side initiatives have been implemented to promote greater and wider stakeholder engagement in priority-setting and innovation processes. Linkage institutions at various levels are set up to manage these processes and include representatives of farmers, extension services, the research system, as well as public administration, policymaking, private sector, and other actors of civil society. Both centralized and decentralized approaches are applied. Organizations at the district and zonal level, such as the Research Extension–Farmer–Input–Suppliers Linkage System (REFILS) in Nigeria or the Research and Extension Linkage Committees (RELCs) in Ghana, focus on consultation and receiving farmers' input on research results through regular face-to-face meetings. If gender-responsiveness is well integrated and properly implemented, these types of initiatives can create a good opportunity for increasing women's engagement into innovation and decisionmaking processes.

However, equal opportunities for participation by gender are not always guaranteed. While there are often quota systems for women's representation in these councils/committees, they are often not followed. For example in DRC, while guidelines for Agricultural and Rural Management Councils (CARGs acronym in French) indicate that one-third of management should be women, this quota is often not followed due to several demand- and supply-side constraints. Interviews conducted by Ragasa, Babu and Ulimwengu (2011) suggest that reasons are multifaceted including: (1) limited number of women who are leaders of producer organizations and public offices, who can be members of the CARG management; (2) inability of women leaders to attend CARG-related meetings due to lack of funds for travel; (3) severe time constraints by women; and (4) lack of confidence and capacity of many women for more active engagement in these consultative processes. These demand-side constraints will need to be addressed and be part of gender-sensitive targeting and programming in order to ensure that women play an active part and make vital contributions to priority-setting, decision-making and innovation processes.

Overall, there is limited impact assessment on these formal linkages committees and consultative processes in general and their gender dimension in particular. Some project reports and authors' experience suggest that a lack of operational funds limit the incentives for participation and ability to bring people together. Elite capture is potentially a major problem, especially if operating funds are not available to cover travel costs of the poor in the remote areas and explicit attention to equitable outcomes and inclusion are not made.

4.1.2. Limited access to information or low literacy rate to use information

A number of studies highlight the lack of access to information about the technology or the lack of required complementary knowledge and skills to use technologies as hindrances to a much improved and faster adoption of new technologies improved management practices (Doss et al. 2003 based on a meta-analysis of 22 case studies in Africa; Ogulana 2003; Lubwama 2008; World Bank and IFPRI 2009; Tiwari 2010 to name a few). These issues point to the demand-side and supply-side weaknesses of the extension systems and bridging institutions in providing education, training, skills development and knowledge to rural population to improve their productivity, increase their incomes, and improve

their welfare. Again, there is lack of studies that systematically looked at both supply- and demand-side constraints of extension service delivery.

Although impact evaluation of agricultural extension services is very limited, a consistent message from a rich literature on extension services is that remote rural areas and poor rural women tend to be underserved (World Bank and IFPRI 2009; Meinzen-Dick et al. 2010; Ragasa 2011). For example, in a meta-analysis of 22 case studies in Africa, Doss et al. (2003) find that lack of access to agricultural extension is the major constraint faced by farmers, especially women farmers, which limit their uptake of technological innovations. For those who have access, the quality of service and the appropriateness of information are often cited as issues. Moreover, resource-constrained farmers, particularly poor women farmers, often have limited land, cash, or labor time required to apply the new knowledge and information acquired.

From the demand-side perspective, there are several reasons why women are more likely to get less information or extension services or less likely to use or process the information received. Women often lack of mobility, access to transport, and funds for participation in meetings, training or demonstration plots. The relatively more limited access to education opportunities and lower access to mass media and other forms of ICT among women as compared to men are also factors contributing to gender gaps in adoption of new technologies. Women farmers generally have lower education levels which affect their understanding and adoption especially if the technology requires use of more technical and intensive knowledge. In many cases, social and cultural barriers and greater time burdens are major constraints by women in acquiring information, education and training. For example, Ogulana (2003) reported that women farmers in Nigeria complained that the seminars and talks given by extension agents in community centers or other restricted areas that were not accessible by them or at times which are not convenient for them. More restrained opportunities for participation and leadership in groups and organizations limit women's ability to use these platforms and avenues for consultations and information-sharing with other actors including extension agents and researchers.

Several demand-side initiatives have been pilot-tested and implemented. A mix of different approaches are including field visits, group meetings, model farmers, farmer field schools, demonstration plots, and ICT (use of radio and mobile phone) are being used to reach out to rural women and men, especially in more remote places. There is limited impact assessment of these approaches (although a number of randomized control trials and experimental studies are ongoing to assess impact of demonstrated plots and model farmers). The only exception is on FFS, and impact assessment studies show mixed results in terms of its effectiveness, sustainability and gender-equitable outcomes (Davis et al. 2010; Meinzen-Dick et al. 2010; Ragasa 2011). While several boutique cases are proven useful and effective, the issues of cost-effectiveness and sustainability of funding often limit the scaling up of these approaches. A lesson from years of implementation experiences is the need to combine various approaches to extend and bring information and technologies to widely-dispersed farmers. This is discussed further in the Opportunities section.

4.1.3. Limited access to complementary inputs and services

One of the major constraints the literature points out is a lack of access to complementary inputs and services, which restricts the number of women farmers adopting improved technologies (Ani et al. 2004; Drechesl et al. 2005; Shiferaw et al. 2008; Tiwari 2010; Meinzen-Dick et al. 2010; www.genderafforum.org, accessed on September 10 2011). In a number of studies reviewed, it is observed that even when women farmers are aware of an improved technology or are very satisfied with the information and training provided, they do not always readily adopt it (Ani et al. 2004 in Nigeria; World Bank and IFPRI 2009 Meinzen-Dick et al. 2010 in Ethiopia). Across all studies reviewed, the most commonly cited binding constraints in technology adoption are the lack of complementary labor; access to land or insecurity of tenure; education level and access to credit (e.g.,

Doss and Morris 2001; Goldstein and Udry 2005 on land tenure insecurity in Ghana; Holden and Bezabih 2007).

Land: Insecure land tenure is an important binding constraint affecting men's and women's expected returns; adoption decision of technologies; exposure to risk and access to credit. Membership in water user associations and producer organizations is often limited to land owners, effectively excluding most women. Moreover, women's access to and use of extension services and technologies is often associated with the access to land or to other collateral with which to obtain credit. Agarwal (1994); Lastarria-Cornhiel (1997); Kevane (2004); Meinzen-Dick et al. (2010) find that women are often disadvantaged in both statutory and customary land tenure systems and they face greater land insecurity. Even where legislation exists that protects women's rights, the lack of legal awareness and/or weak implementation of these legislation may limit women's ability to exercise these rights (Peterman, Behrman and Quisumbing 2010).

Water: Associated with land tenure, right to use water is also a concern to many poor households, especially women. Meinzen-Dick et al. (2009) finds that in Sub-Saharan Africa, women are often excluded from irrigation projects or lose their use rights to land and property when new irrigation systems are set-up. They also conclude the poorest members of the community and women are more likely to be excluded from accessing irrigated water and less likely to be members of water user associations (Meinzen-Dick et al. 2009). This membership is often related to land owners and/or heads of households (Meinzen-Dick et al. 2009), which is often assumed to be men. Moreover, "the pricing of water resources is often calculated using affordability studies based upon men's incomes" (Meinzen-Dick et al. 2009).

The lack of access to irrigation is also often associated with much lower quality of landholding, less likely adoption of modern seed technologies, and lower yields. Since women's land holdings are often small and of lower quality, applying these technologies becomes costly or does not yield requisite results. Access to water is important for women not only for irrigating field crops, but also for domestic use, including not only drinking, washing, and bathing, but also watering gardens and livestock at the homestead. Women and children generally bear the greatest burden of time and effort to fetch water for domestic uses and for caring for family members who are ill because of lack of sufficient clean water.

Labor: Women often face constraints or shortages of hired male labor to work in the fields. Doss (2001) finds that in customary systems in most countries in Africa, men have control over women's labor, but not vice versa. These have implications to the adoption patterns of labor-intensive management practices by women. Quisumbing and Pandolfelli (2009) and World Bank, FAO and IFAD (2008) describe management practices [such as integrated pest management (IPM); biological nitrogen fixation technologies; and conservation (zero) tillage practices] that often require more time and labor to adopt and thus increasing women's time burden. This greater time requirement can hinder women's ability and incentive to adopt these management practices.

4.1.4. Availability and affordability of technologies and liquidity constraints

The availability and affordability of tangible technologies (improved seeds, planting materials, fertilizer, ICT applications, agro-processing technologies, or transporting technologies) have also been cited as major constraints by farmers (Doss 2001; World Bank, FAO, and IFAD 2008; among others). These issues of lack of availability and not affordable technologies reflect both supply- and demand-side constraints. The issue of availability is a consequence of combined effects of the nature and effectiveness of input distribution systems and physical infrastructure, as well as the geographical location and remoteness of the rural people to be reached and the presence of social networks or organizations that can help facilitate their access to these technologies. The issue of affordability reflects either the profitability of adopting the technology and the activity (that is, relationship of perceived income vis-a-vis cost of acquiring the technology) or liquidity constraints (that is,

technologies and activities might appear to be profitable but farmers may not have the cash available to purchase the needed inputs).

Liquidity constraints are very much associated with the availability of credit for women and men engaged in agricultural activities and the effectiveness of the rural credit and financial systems more generally. Access to credit or finance is considered as a major constraint in adopting almost all types of technologies (Tiwari 2010, Olaleye 2005, Doss et al. 2003 on production technologies; Wickramasinghe 2009, White 1999, Okorley et al. 2001 on agroprocessing; Olwande et al. 2009 and Gladwin 1992 on fertilizer adoption; Maguzu and others 2007 and World Bank, FAO and IFAD 2008 on management practices such as conservation [zero] tillage agriculture). For fertilizer, the key constraints limiting access are its affordability and farmer's liquidity constraints. In Malawi, Gladwin (1992) finds that although female heads of households uniformly apply less fertilizer than males, when farmer characteristics are controlled for in regression analysis, the critical factors that significantly limit fertilizer application are lack of access to credit and cash, not the gender of the farmer. Even for access to ICT (particularly internet and phone), financial constraints is a deciding factor in whether a woman can afford a phone or pay for internet access.

From demand-side and gender perspectives, women and men may find different profitability and technology feasibility due to different level of risk aversion, preferences, and availability of resources and opportunities. The greater risk aversion of women in rural areas in many countries (for example China and the Philippines) is related to their observed reluctance in borrowing from financial institutions and pledging their assets and land as collateral. Despite having expected positive profitability, some activities and technologies do not get initiated due to reluctance of taking up loans to finance these ventures. There are knowledge gaps in better understanding this risk aversion and reluctance to take up loans in various contexts. Taking into account these differences between women and men and inclusion of both women and men in priority-setting, feasibility studies, and research process are important starting point in effective targeting of interventions.

Moreover, rural women's access to financial services remains heavily dependent on microfinance. Women generally receive smaller loans than men, even for the same activities and are vastly underrepresented in programs that finance larger loans. In some societies such as DRC, women are not allowed to apply for credit without husband's permission. These bottlenecks will need to be addressed for women to take on bigger and more profitable ventures.

4.1.5. Sociocultural constraints

Most of the constraints on technology adoption cited above are related to social and cultural biases against women that persisted over time. Customs, traditions, religious beliefs, and social norms widely vary across countries, regions, and villages and have restrictions placed on women's activities both on and off farm and their ability to access to use new technologies and information. Due to gender norms and insecure tenure system, a technology or activity that becomes commercially profitable is often expropriated by male members of the household [examples are the adoption of the stabling technique in rural Senegal (Fisher, Warner, and Masters 2000) and control over intermediate means of transport (Venter and Mashiri 2007 and Rao 2002)]. In Nigeria, Ogulana (2003) finds that a majority of women have limited access and use of land or plot through the customary tenure system. Another study in Nigeria shows that a pedal-operated, bicycle-mounted rice thresher was rejected by female processors because using the thresher exposed women's thighs, and wearing trousers was not a culturally appropriate alternative in the region (UNIFEM 1993).

In Ethiopia, Pender and Gebremedhin (2006) show that strong cultural norms prevent women from plowing fields, thus disadvantaging women without adolescent or adult sons, who must hire additional labor to plow the fields. In Benin, Kinkingninoun-Médagbé's et al. (2008) study of 45 rice farmers finds significant gender differences in women farmers' access to farm equipment. "While women's groups got the tractor, they did not get a driver. They had to wait until the men's fields were ploughed

before the driver could start working on their fields. This caused a delay of about a week within the women's group" (Kinkingninhou-Médagbé et al. 2008, p. 62).

Across many countries, World Bank, FAO and IFAD (2008) suggest that women's control of household cash and intermediate means of transport, coupled with social and cultural constraints on women's mobility limit women's access to transport opportunities. Culturally in many countries women, especially rural women, are not permitted or feel comfortable to visit the public locations like an internet kiosks, or community halls to watch TV shows (GenARDIS 2010). In addition, perceptions that women are not "real" farmers may also reduce their opportunities for accessing credit, extension, and land (Doss 2001; World Bank and IFPRI 2009).

4.1.6. Gender gaps in rural institutions

Rural institutions such as farmer-based organizations, community-based organizations, cooperatives, water user associations, self-help groups, informal networks and various forms of collective action for agricultural and rural activities offer a potential in increasing the poor's bargaining power and in enabling them to pool extremely scarce resources together. Uphoff and Buck (2006) find that pooling resources and efforts makes it cheaper and more profitable for people to invest in activities which will produce more income and employment in rural areas.

Peterman, Behrman and Quisumbing (2010); Meinzen and Pandolfelli (2008); and Doss et al. (2003) have enumerated a number of studies that find significant role of local producer organizations in promoting improved technology use. In particular, women are often less likely to be served by conventional extension services, and as Katungi, Emeades and Smale (2008) suggest, group-based dissemination systems may be important in increasing adoption to technologies. Participation of women in mixed groups and leadership positions has been proven to be important in accessing resources and information, establishing contacts, and obtaining help and support from male members in case it is needed (Gotschi, Njuki, and Delve 2008; Acharya and Gentle 2008; Agarwal 2009; Apesteguia et al. 2010; Sun, Mwangi and Meinzen-Dick 2011). However, evidence suggests the presence of considerable gender differences in participation in membership and leadership in mixed-group cooperatives, associations and organizations, with women being less likely to participate and hold management positions (for example, World Bank and IFPRI 2009 on Ghana, Ethiopia and India; Gotschi, Njuki and Delve 2008 on Mozambique; and EADD 2008 on East Africa in general).

Evidence also suggests that women participation in mixed groups can affect group effectiveness. Arcand and Bassole (2007) find that increasing the number of females on committees is likely to raise the number of completed projects in a Community Driven Development Program in Senegal. Westermann et al. (2005) find that female participation increases solidarity within the group and increases the group's conflict management capabilities. Agarwal, Yadama and Bhattacharya (2005) find that female participation significantly increases the probability of controlling illicit grazing and felling activities, and increases regeneration of allotted forest. Agarwal (2009) finds that forest management institutions in which women constitute a substantial fraction of the executive committees demonstrate better forest conservation outcomes in India and Nepal. Quisumbing and Pandolfelli (2009) suggests that increasing the participation of both women and men in fishery management groups in Bangladesh increased fish protection through increased efficiency of the controlling activities.

Despite these sets of evidence on the importance of women participation in collective action, they continue to be underrepresented due to various reasons. They often lack mobility, access to transport, and travel funds to enable them to participate. In many cases, social and cultural norms against women and greater time burden are hindrances to their mobility and participation. While legislation regarding membership in rural producer organizations or associations may not overtly exclude

women, it is the implicit or explicit conditions that many women cannot fulfill. As illustrated in studies on water user associations, membership is often based on access to and control a key asset such as land, which women are much less likely than men to control (Meinzen-Dick and Pandolfelli 2008); Meinzen-Dick et al. 2010; World Bank, FAO and IFAD 2008). Another requirement that may disadvantage many women is that a business enterprise must be a certain minimum size to be recognized as cooperatives or federations (such as the case in Madagascar [World Bank, FAO and IFAD 2008]). Many women-managed small business enterprises are often excluded from the benefits of these officially-recognized associations (World Bank, FAO and IFAD 2008).

4.2. Supply-side constraints

4.2.1. Supply-side constraints in equitable and inclusive priority-setting

Gender issues in priority-setting and research planning processes come in two forms: asymmetry in decision-making power and lack of mechanisms to that take into account the needs and priorities of women and men producers and consumers. And, these relate to how agriculture and research are historically defined. “Conventional definitions have been gender biased, focusing on the production of field crops, which are more likely to be male activities, and relatively neglecting homestead gardens, postharvest processing, supply chains, and consumption and nutrition outcomes, which are often of greater salience to women” (Meinzen-Dick et al. 2010, p. 9). There is a historical bias¹ toward agricultural production (from land preparation to harvest) in traditional priority-setting, research and education in agriculture rather than looking at the “food” sector in a holistic way and a systems-perspective. Because of this, engagement of women in priority-setting and innovation processes has been historically weak and it is only recently that institutions and approaches are in place to understand better needs and priorities of the food sector and value chains in a more holistic way.

There is also associated gender segregation in occupation and training for decades, with limited number of women entering into and getting training and education on agriculture fields. While a number of initiatives are already being implemented to address this (discussed in the Opportunities section), they need to be scaled up. There should be stronger focus on “food” in a holistic way, value chain approach, and a systems-perspective in priority setting, research, education, extension, and monitoring and evaluation. Curriculum development and adjustments are needed to encourage more women and youth in agriculture sector careers. Affirmative action will be required to promote increased number of women in agriculture, science, and professional fields and minimize the gender-segregation in training and profession (which is further discussed in the section on opportunities).

Another supply-side constraint is the lack of incentive and accountability among researchers, managers, and policymakers to respond to the problems and issues presented by farmers during meetings and consultations. The lack of follow-up actions and impacts of these participatory and consultative processes are often cited as disincentives for farmers to participate (for example RELCs in Ghana and CARGs in DRC discussed above), and thus perpetuating a situation of isolation and ineffectiveness of research and innovation systems. This lack of follow-up activities or projects that address the specific problems and needs identified during meetings may be due to deficient funding, poor implementation capacity, or lack of accountability and incentives faced by researchers and extension agents. However, no study is available that isolates and systematically analyzes what the

¹ Mead (1976) highlights the tendency national systems and international development community to attribute the concern with agricultural production (land preparation to harvest) to men and to attribute the concern with food after harvest to women, which has led to the occupational segregation branding scientific agriculture as a male field and food knowledge and preparation as a female field. This dichotomy is often used to characterize capacity strengthening efforts by developed countries and donors in setting-up technical agricultural schools for males and home economics schools for females in developing countries. Mead (1976) articulates well the dangers of this type of segregated occupation and training and strongly suggested that it should be recognized and corrected.

binding constraint is. This remains as a major knowledge gap in understanding gendered participation and impacts of technologies.

4.2.2 Gender gaps in extension systems

Gender-responsive extension system requires that: (1) women and men extension agents are aware and respond to the needs and priorities of women and men farmers; (2) women and men farmers have the same opportunity in access to extension services and in receiving trainings; (3) extension delivery approaches provide equal opportunity for demand articulation and access to extension services between women and men; and (4) training and recruiting of women extension agents to increase the likelihood that women farmers are reached, especially in areas that have cultural taboos restricting male extension agents' interaction with women farmers. Studies on agricultural extension have painted a quite different reality from this ideal gender-responsive system just described. First, similar to Mead's (1976) concern on gender-segregation in occupation and training, the perception bias that "women are not farmers" persists even though women are engaged in a wide range of agricultural activities. A recent report by World Bank and IFPRI (2009) in Ethiopia finds strong evidence of a cultural perception bias that "women don't farm." In Ethiopia, extension agents preferred to work with the household decisionmakers, who in a husband-wife household were always perceived to be the male (World Bank and IFPRI 2009).

Second, as already emphasized above, women farmers usually have more limited access to conventional extension service delivery and men are often the ones being called for in training and meetings related to new technology or management practices. There is also a perception that if extension services are given to a member of the family, the knowledge will pass on to other household members, including female members. However, men do not necessarily discuss production decisions with their wives or transfer extension knowledge to them. Moreover, if the extension information is tailored to men's crops or priorities, the information may not be beneficial to women.

The relatively lower provision of extension services to women is a reflection of the policies, or lack thereof, for example, staff gender policy. Women continue to be underrepresented as extension agents and field workers. A 1993 FAO study of 24 extension programs in Africa, Asia, and Latin America suggests that the presence of female extension agents was an important factor for the participation of female farmers in extension activities. World Bank and IFPRI (2009) find that female extension workers serve a higher proportion of female farmers than male agents (the average ratio of women to men farmers is 1.3 for female agents and 0.53 for male agents). This may suggest that extension services from female extension agents are better targeted to female farmers. In Tanzania, Due, Magayane and Temu (1997), 40 percent of women farmers preferred to work with female extension agents (compared to 26 percent who preferred male extension agents; the remaining 34 percent had no preference). These authors also find that female farmers stated that they preferred female extension agents as they were freer to discuss problems with them; and female agents were better able to accommodate their time preferences for meetings than male agents.

In Ghana, a World Bank and IFPRI (2009) study shows that of the 70 agricultural extension agents surveyed, only 10 were female. In Ethiopia, extension agents were overwhelmingly male, and cultural taboos restricted their interaction with women farmers (World Bank and IFPRI 2009). In Karnataka, India, a survey of front-line professionals responsible for extension service provision shows a limited number of women (no females among 41 agricultural extension workers, 1 female out of 41 junior engineers, and 4 females out of 40 veterinary assistants) (World Bank and IFPRI 2009). Moreover, opportunities for mid-career agricultural extension staff are also more limiting for female extension agents, due to various reasons including (1) perception bias—the community's low perception of women's talents and potentials and perception of agriculture as a domain of men; (2) limited access to information about opportunities for further education; (3) limited opportunities that target professional women; (4) family concerns and time constraints; and (5) other social, cultural, and religious barriers (Akeredolu 2009). Recruitment, incentivizing, and more opportunities for mid-career training for

more female extension agents is therefore crucial, but this should be coupled with gender-awareness and gender training for male and female extension agents making sure that all extension agents are aware and respond to the needs and priorities of both women and men farmers (more detailed discussion in Opportunities section).

4.2.3. Gender imbalance in research organizations

The gender issues in the research organizations pertain to both gender balanced staffing and application of gender-sensitive approaches to respond to the needs and problems of both women and men farmers.

The overwhelming underrepresentation of women as scientists, educators, graduates, managers and extension agents persists to date, despite a number of initiatives to increase women's representation. The fact that women play a central role in food production and post-harvesting activities in most developing countries stands in stark contrast to the fact that, for example, in Sub-Saharan Africa, only one in four agricultural researchers is female, or one in three in Latin America (Beintema and Di Marcantonio 2009). Also, women hold lower degrees on average than men, and have higher attrition rates (Stads and Beintema 2009). The lack of gender balance among agricultural scientists means that women's voices are less heard in critical and often male-dominated policy debates and decisionmaking processes, resulting in biased decisionmaking. Various authors have shown that gender-balanced groups in membership and/or leadership outperform male-only or female-only teams (Acharya and Gentle 2008; Agarwal 2009; Apesteguia et al. 2010; Sun, Mwangi and Meinzen-Dick 2011). Agarwal (2009) finds that group's gender composition affect women's effective participation. Her study's results support the popularly-emphasized proportions of one-quarter to one-third women participation, along with women's economic class and other factors.

The glaring gender disparities in agricultural research and development are largely attributable to a range of multifaceted challenges women routinely face. The fundamental cause is the often lack of opportunities for girls or social norms that prevent them from going to school. Moreover, historical gender segregation of training and occupation has limited the number of girls entering sciences and technical fields and pursuing more advanced degrees and career development. As a result, the supply of women graduates and professionals in the field of agriculture and sciences is limited in many societies. Meinzen-Dick et al. (2010) articulate various other challenges including the lack of balanced gender representation in recruitment and promotion committees; covert gender discrimination in organizations and societal attitudes toward the female professional; and work-life balance challenges owing to the prevailing perception of a woman's role as a mother and of the family as her domain, which adds to their time poverty and limited mobility. These factors severely constrain their advancement in research organizations and achievement of more advanced degrees. Quota systems and reservation policies implemented in the past have limited positive outcomes due to the lack of complementary capacity strengthening for women and inability to address these sociocultural and gender norms that limit women's engagement in higher degrees and more advanced careers.

Greater attention to increasing gender balance in staff should also be coupled with gender-awareness and gender training for male researchers to ensure that all researchers are aware and respond to the needs and priorities of both women and men farmers.

4.3. Policy and regulatory constraints

There is a broad range of actors and processes in the enabling environment that are involved in making innovations work or not work. Much discussion of these actors and processes are in World Bank, FAO and IFAD (2008) and some key points are summarized as follows. A combination of gender-blind legislation and policies and gendered norms often causes men to benefit more than women from market opportunities or public programs and directly or indirectly influence technology

adoption decisions. For example, women in Kuwait and Yemen are not permitted to work at night. In Zimbabwe, married women need permission from their husbands to register land; while in the DRC, women need their husbands' consent to start a business. Such norms restrict women's mobility or decisionmaking and limit their opportunities and sources of livelihoods and thus the technologies to be adopted.

Even more important is the need for greater enforcement of policies and regulations that explicitly protect against gender discrimination. Moreover, many cases of discrimination against women are largely indirect and unintended, rather than through formal legislation. This has been illustrated in requiring land ownership or business size in membership of organizations or association, which limits the ability of women, especially the marginalized and resource-poor ones, to be excluded from the benefits of such collective action.

Aside from policies and specific conditions at organizational levels, regulatory barriers and bureaucratic processes often present greater obstacles for women's entrepreneurship and innovation than for men. For example, based on the Uganda Regulatory Cost Survey Report in 2004, World Bank, FAO and IFAD (2008) find that 25 percent of all enterprises, but 43 percent of women-headed enterprises reported that government officials had interfered with their business and threatening to close it or asking for bribes; while. In the same book, results suggest that 40 percent of microenterprises headed by women felt that the total burden of regulation was "heavy" or "severe" (as compared with 35 percent for those headed by men). This may be due to social and cultural norms that restrict women's access to credit and other services for businesses and greater discrimination faced by women in dealing with officials, filing documents or requirements needed to start or run an enterprise.

One consistent message in the literature reviewed is the lack of participation and influence by women not only in the research and innovation systems but in the broader policy, legislative, and public investment processes (World Bank, FAO and IFAD 2008; World Bank and IFPRI 2009). World Bank (2005); Zuckerman (2002); and World Bank, FAO and IFAD (2008) highlight that representation by women and the incorporation of gender issues in the Poverty Reduction Strategy Paper (PRSP) processes remain a challenge. One strategy that has been promoted is the gender-responsive budgeting, but Schneider (2007) noted that gender budgeting work in many countries was partial in scope, not suitable for the respective national budget system, was not institutionalized, and was not linked with recent reforms in many countries' public finance systems. Other strategies increasingly being promoted are the reservation policies or quota systems to promote women's participation in organizations, consultative and policymaking processes. While reservation policies clearly have a strong impact on women's representation, they do not necessarily have an impact on policy decisions and actual outcomes (Horowitz 2009). Chattopadhyay and Duflo (2004) highlight the causal effect of women's representation on actual policy decisions and service provision as a huge knowledge gap.

To sum up, the most recurring constraints to technology adoption, especially among women farmers, are time and labor constraints; cost of technology and the associated lack of access to funds and credit; lack of information, knowledge and capacity; limited capacity and opportunity in participation in innovation and decisionmaking processes; and limited access to accompanying inputs and services. These are influenced by weak design or implementation of legislation that protect rights and promote equal playing field and by the persistence of social biases and cultural norms limiting equal access and opportunities for women and men. The next section will look at approaches and strategies that have been used to address these constraints in participation, information, time and labor, cost of technology, profitability, and credit, as well as in legislation, institutions and organizations that potentially support women and men producers.

5. Opportunities for increased technology adoption and outcomes

Various organizational arrangements for greater inclusion have been piloted, tested and implemented in various contexts. For technology development and dissemination, rural institutions and emerging institutional and organizational arrangements play a role in linking the supply and demand of technologies and advisory services. There are several promising institutional and organizational arrangements that offer opportunities for inclusion of both women and men farmers and other supply chain actors in innovation processes and in ensuring that they benefit from technologies produced. However, the actual implementation of activities and projects reveals that inclusion and equitable outcomes are not automatic and that gender and equity issues must be explicitly and consciously part of their design, implementation and evaluation to have an effect.

5.1. Demand-side opportunities

5.1.1. Participatory approaches coupled with explicit attention to gender

In order for women's needs and specific constraints to be incorporated into technology development, they should be engaged from the priority-setting and research stages to extension and evaluation, as scientists, managers, researchers, producers, processors, traders, and consumers. Participatory approaches, codesign, and innovation platforms are some of promising approaches to foster participation of stakeholders (discussed in detail in Spielman, Ragasa, and Rajalahti 2011). One of the participatory approaches being promoted is participatory plant breeding (PPB), which has been cited by many studies as successful in terms of faster adoption and higher yield and taking into account women's and men's preferences and needs (Sperling 1993 on improved varieties in Rwanda; Ashby and Lilja 2004 and Ceccarelli and Grando 2007 on various participatory plant breeding; Bourdillon et al. 2007 on developing high-yielding varieties of maize Zimbabwe; and Bellón et al. 2007 on drought, pest and disease resistance in grain varieties in Mexico). However, the quality of participation and representation, elite capture, and limited gender impact has been also noted as limitations of PPB by a number of studies.

Participatory rural analysis is a participatory learning approach which offers a potential for gender inclusion, enabling unheard voices to be heard and creating a space for new rules for engagement, but it does not automatically incorporate gender issues. Moreover, it is sometimes used by facilitators who lack a concern with process, power and difference, and thus exacerbate exclusion and cement existing relations of inequality (Cornwall 2003). Redd Barna Uganda (RBU) provides a good example of effective participatory development project (Cornwall 2003). Key elements include (1) good facilitator; (2) provision of spaces in which gender- and generation-specific issues could be tackled within a broader participatory planning process; and (3) high-level institutional commitment enabled RBU to work with an approach that made gender and age differences explicit (Mukasa 2000) and emphasized women's subordination directly.

Another example of a participatory action research approach with explicit gender-responsive activity is the Enabling Rural Innovation (ERI) initiative implemented in Uganda and Malawi, which are showing some promise in terms of women's empowerment. Key factors include an explicit gender strategy at the start of the project, rather than as an afterthought; participatory approach that enabled joint identification of problems and implementation of solutions involving both women and men; and emphasis on linking small women and men to markets.

Codesign approaches seek better articulation between the supply and demand of research and technology and their core principles include joint planning, implementation, and decision making related to all activities that foster innovation; close coordination among stakeholders at all strategic and operational levels; and combining scientific, technical, and local knowledge and other resources (Spielman, Ragasa and Rajalahti 2011). The Papa Andina program implemented in Bolivia, Ecuador, and Peru adopts a codesign approach as well as innovation platforms. Although there are no gender-disaggregated impact assessments, a number of reports have indicated that poor women make up a

majority of the participants and that they benefited from the program (see Spielman, Ragasa, and Rajalahti 2011 for more details).

5.1.2. Access to information through appropriate ICT

Information and communication technologies (ICT), by enabling broad information sharing, has been shown to play a key role in empowering women and strengthening men and women's knowledge base. ICT has been increasingly used to disseminate information about technologies, markets, and management practices. The ability to operate a computer or own a mobile phone has been shown to have a direct effect on the self-confidence of women and girls (Omari and Ribak 2008). Developing content targeted to women's needs would help to increase women's use of this medium. Several organizations in developing countries are actively working to increase women's understanding and usage of various ICT for agriculture and related activities.

Radio is almost universally owned by households, even in developing countries, and is a low cost medium to reach the rural poor, who may not have the infrastructure to access any other technologies (Bates 2000). Community radios provide new opportunities for dissemination information about technologies and educating rural population in remote areas. The content of radio programs is also easy and cheap to create and to consume. This is especially important in countries with high illiteracy rates and where many rural people speak primarily local, indigenous languages. SEWA uses radio to disseminate information about agricultural calendar and about crops. Despite radio's advantages, the medium has some limitations. The information needs to be complemented with more hands-on training and even demonstration plots in some cases. People can learn only so much from radio without physical demonstration. Moreover, radio is a one-way medium and needs to be complemented by some other forms of ICT to ensure maximum two-way learning. Radio, therefore, is best used to complement rather than substitute for agricultural extension workers.

Mixing tools and media are more effective and efficient way of delivering information to rural populations. Community radio can be used along with newer forms of ICT to provide agricultural knowledge and information to rural women (Giles 2004). Both Wambui (2002) and Hafkin and Odame (2002) discuss how digital radio can be used to deliver local language programs through links with the internet and mobile phones. Radio broadcasts can also be used in distance education to air both formal and informal learning content for rural women (Maskow 2000). Similarly, the radio was used in rural Ghana to conduct panel discussions featuring women who could talk on a variety of topics affecting women on local FM. While training the rural women to serve as panelists, the project also increased their capacity and knowledge in these areas. The Dimitra project, which uses rural radio and listeners' club, is a promising example of mixing different tools of communication, such as the cases implemented in Niger and Democratic Republic of Congo. The Feminist Interactive Radio Endeavour (FIRE), the web-based feminist radio station in Latin America, received Peace Builders Award during the IV World Encounter on Non-Violence for their marathon 25-hour program in 2000 on the International Day for the Elimination of Violence against Women. They contacted women across the world for input in programming and linked with radio stations worldwide for simultaneous programming (WomenAction 2000).

Mobile phones also offer great opportunities for women and men, especially in remote areas, to be connected with information relevant for their livelihoods and social welfare. The Grameen Phone project (2005) that specifically targeted women in Bangladesh is a good example of the successful use of mobile phones in agricultural extension. Learning modules related to sheep and goat enterprises delivered to women through their mobile phones while they tended to the animals overcame the barrier imposed by time constraints (Balasubramanian 2010). Five hundred one-minute audio messages on topics like buying goats, feed, disease and health management and marketing management were sent as voicemails. The project not only increased women's confidence from the information sharing, it also linked them to information sources. The flow of communication within

the self-help groups, relatives and friends enabled the women to learn to use the phones as well as benefit from the information shared. It also enhanced their self-respect and status within the family. However, there are numerous types of information that cannot be delivered and shared through mobile phones. Similar to radio, people can learn only so much from mobile phones, and that they should be complemented with other forms of ICT, training, and traditional extension service delivery, especially in areas of new varieties or improvement production and conservation management practices. As demonstrated by the Grameen project, the information and knowledge shared through mobile phones were followed up with weekly group meetings to share experiences and recall information. In many instances, agricultural management practices can be delivered initiated by mobile phones and radios but hands-on training and demonstration plots will be required for effective learning by farmers.

The internet is of course the most modern form of ICT and has the capacity to be both a one-way and an interactive learning medium. The SISSI project in Uvira, Congo created a support group of women accessing agricultural information. The information center not only provided internet access to the 60 women farmers involved in the project, but also matched them with mentors from other local communities to reinforce their support networks (GenARDIS 2010). In another project in Uvira, 48 women and 18 men from 9 different women's groups received information on production and disease management for cassava crops. They were also provided with mobile phones to contact their potential buyers. A radio show was also created on topics related to gender and agriculture. Similarly, the Ndola resource center in Zambia trained 115 women in open source software (GenARDIS 2010). This again demonstrates the need to combine different tools and approaches to disseminate information and technologies among the rural population. Combining different ICT tools can overcome constraints in mobility, time, and formal education, which women have less access to. ICTs can even address the high costs of certain ICT technology and liquidity constraints by women since they are able to use ICT tools owned by others.

The Asian Women's Resource Exchange (AWORC) has responded to the challenge of women's need to access ICT and encourage their participation in development policies. They work with women's organizations in Korea, Malaysia, Philippines and other Asian countries to educate and train women to use ICT for social action (Plou 2003). Similar women's resource center has been set up in Papua New Guinea at the national and local levels, where women and men farmers can access and share information on various areas including agricultural technologies, improved management practices, market information, among others. Similar trainings were also given by the Association for Progressive Communications (APC) in South Africa to train women and share skills of communication using ICT channels (Farrell and Isaacs 2007). These resource centers and training for women will need to be supported at the start and should be able to re-train other women. Community information and resources centers that are led and managed by women's organizations and hosted at the research institutes have been proven to be effective in linking women and men farmers with researchers and extension agents, such as in the case of Papua New Guinea and Kenya.

The outcomes of these projects illustrate that ICTs have the capacity to empower women and overcome the socially constructed digital divide that placed such technologies only in men's domain. Given proper training, women have been successfully using various forms of communication technologies, even if both the use and social meaning of the technology varies between men and women. While most projects find that the ownership and control of costlier communication technologies like mobile phones or computers still lie with men, women control the usage of devices, especially mobile phones, in the house. Using these technologies as a form of e-learning, women have increased their knowledge of agricultural production and animal husbandry. At the same time, they have increased their social status within the family and community.

5.1.3. Knowledge and capacity strengthening

In addition to the use of ICT, there is a need for more tailored and specific training and capacity strengthening among the rural producers, especially poor women. Examples are presented in World Bank, FAO and IFAD (2008) and are summarized below.

Literacy and numeracy training: Understanding the literary and skill level of producers is important in packaging the information and technology dissemination and education to them. For the very poor, a good starting point will be to address generalized constraints such as illiteracy, innumeracy, low access to information, and limited levels of awareness of both constraints and economic opportunities. In many cases, training on leadership and management will be very important in building confidence and capacity of women and their organizations. An assessment of the norms and values of the target clients and indigenous service providers will be useful to understand what information is need and what the best delivery method is, such as educational focus or the promotion of awareness campaigns through the use of mass media.

Demand-driven and market-oriented specialized training: Training and extension should not only be on production technologies but should also cover new improve marketing and processing management processes to help rural population increase their incomes. Capacity development needs to be very specific to the situation faced by the women and not general training. It should include practical guidance on how to approach and resolve the issues and needs of the farmers and entrepreneurs, with explicit attention to women. Marketing extension education tool is a promising approach that is proven to help poor women producers increase their incomes in Bangladesh and other countries (World Bank, FAO and IFAD 2008). It starts with joint identification of the agroecological and economic potential of the area and current skills sets and livelihoods of people to determine opportunities for improving livelihoods and incomes. In addition to opportunities, identifying constraints and bottlenecks that would hinder successful development and marketing of products and services is also a key step. The market demand for the product or service options is then assessed, which is the basis for delivering a business plan for the area. Extension services and training in production and marketing techniques as well as business and financial managements. Key elements include: good and dedicated facilitator, engagement of rural population from the identification of opportunities and constraints to market studies, business plan development, and joint learning.

Agro-processing, seed multiplication and high-value agriculture are among the commonly-cited productive ventures for women. Again, the suitability of these enterprises to the households and their members and communities will depend on the specific local context. Important considerations in designing these projects are the: (1) security of asset and income among women from husbands or male relatives; (2) effect on labor and time burden of women; and (3) health effects in certain factories or processing plants and in the use pesticides or chemicals for production. Intensive training on good agriculture and aquaculture practices, food safety certification, and quality and biosafety systems will be needed so that poor women and men can participate in successful food processing and value addition ventures.

More women-friendly training design and delivery: Training programs with a flexible time schedule, covering also evenings, weekends, part time, and child care are often successful and effective for both women trainees and trainers. Moreover, removing constraints hindering women trainers' ability to travel are also important (Farnworth and Jiggins 2006). In many regions, women trainers and extension workers may be more appropriate because of cultural restrictions that limit interactions between women and men who are strangers or not part of the same family (World Bank, FAO and IFAD 2008).

Gender sensitization for both women and men: In some areas, female extension workers may not be respected by women farmers, in which case male extension workers trained in gender analysis may be more appropriate (World Bank, FAO and IFAD 2008). In Vietnam, while new opportunities for women may be a result of interventions, there are reported cases of greater violence against the wife due to jealousy or ego of the husband (Adthe et al. 2010). The risk of men taking over a productive venture from women has been reported in numerous cases (Ashby et al. 2008). It is crucial to involve gender sensitization for both men and women and to work with both to minimize adverse effects on gender relations.

Three examples from World Bank, FAO and IFAD (2008) can be cited where training initiatives targeted at women can be very successful when they involve working with both men and women. In Zimbabwe, a World Food Programme (WFP) project enrolled men as trainers for women to run the milling activities in the Kala and Mwange refugee camp. In Tanzania, another WFP project provided male landowners with incentives to provide women refugees to do homestead production. In Bangladesh, although women are the direct beneficiaries the Food Security for Vulnerable Group Development Women and Their Dependents (FSVGD) project, men's support groups have been formed (World Bank, FAO and IFAD 2008).

Continuity of trainers: Training-of-trainers approaches or training members of a household can help to continue developing and sustaining capacities. Several examples from World Bank, FAO and IFAD (2008) and case studies received can be cited here. In China and LAO PDR, strategies for offering training in weaving have a built-in multiplying effect, in which trainees are required to impart their new knowledge and skills others. WFP has begun a program in which training focuses on all family members so that critical skills are not lost and a business can carry on if a family member should die and this is especially useful for all remaining family members especially orphans in areas with high HIV prevalence. Training family members is also an important consideration used by SEWA approach in strengthening capacity of various groups and associations in all aspects of work including organizational management, financial management, and specific livelihoods being promoted in the specific local context.

Simple yet effective training and extension services: It is important to formulate extension messages and training courses that are easy to understand. Follow-up interaction with farmers will be required to ensure that the knowledge gained is applied. In areas where women have lower literacy or schooling rates than men, it is critical to adapt simple training materials that are easily understood. For example, in Bangladesh, the use of notebooks with illustrations was effective in imparting information on fishpond management and aquaculture among illiterate women (Quisumbing and Pandolfelli 2009). Education videos have also been proven to be effective in disseminating technologies, especially food processing techniques (Zossou et al. 2009; Van Mele, Wanvoeke, and Zossou 2010; Juma 2011). These educational videos provide a powerful, low-cost medium to extension services and disseminating new ideas and practices to most especially in food processing. In central Benin, women showed better understanding and adoption of rice processing techniques from educational videos than training workshops; but impact is maximized if education videos and training workshops are combined (Zossou et al. 2009).

5.1.4. Addressing time burden

Technologies that reduce women's labor burden, increase their labor productivity and provide greater control over the outputs and incomes from their labor, will have the considerable impact on the well-being of women farmers (Doss 2001). The need for labor-saving technologies is even more acute in households affected by HIV/AIDS, since women often bear the double burden of producing food and caring for the sick. There are numerous examples of such technologies including improved and fuel-efficient cook stoves that save women's drudgery by reducing time spent cooking and also their health (Paris et al. 2001; Carr and Hartl 2010). In Sri Lanka, Carr and Sandhu (1987) show that cooking time on the improved fuel stoves went from 77 minutes to 62 minutes for a meal. The more advanced stoves also reduce indoor air pollution thereby reducing respiratory illnesses among the women and children (Carr and Hartl 2010). The Kenyan Ceramic Jiko stove has seen a household penetration of 17 percent in Kenya alone, covering some 78,000 rural household (Walubengo 1995 in Carr and Hartl 2010). Post-harvest machinery for processing can reduce drudgery from hand pounding, increasing the volume of rice processed and allowing women to use their time more flexibly (Paris, Feldstein and Duron 2001). Women also need access to complementary resources in order to benefit from new technologies. When fuel-efficient stoves were introduced in the 1980s to reduce women's energy

burdens, conserve fuel, and decrease pollutants, women were slow to adopt them because they often lacked funds to buy the stoves.

Multifunctional platforms (MFP) are increasingly popular technology promoted through projects in Mali, Burkina Faso, Senegal, Ghana and Guinea (Mauritania has also asked for assistance). They comprise a diesel engine built on a steel structure capable of carrying various tools such as a corn mill, a hulling mill, a battery charger, a pump, and others. Coupled to the engine one after another and according to need, these equipment transform the motive power into the various energy services (milling, pounding, lighting, airconditioning, pressure-driven water) [Häusler, N'Guessan and Dessallien 2007]. These services have the huge potential to boost daily productivity in the villages and enable women and children to save much time and energy (Häusler, N'Guessan and Dessallien 2007). While no impact assessment and evaluation studies have been conducted on how women's degree of autonomy and control over these assets and services are being affected, these MFP are showing some promise. In a mid-program evaluation report by Häusler, N'Guessan and Dessallien (2007), MFPs have considerably saved time for women (2-3 hours per day). They find that a significant increase in girls attending school and increased productive and economic activities by women. However, they also highlight that the biggest challenges for these multifunctional platforms is their cost recovery and financial sustainability. Rigorous evaluation and impact assessment of these types of potentially-promising technologies can be useful to understand how to improve their design, development, and dissemination.

More promising technologies that are useful in easing the burden of women's work are carrying devices and transporting technologies, such as donkeys, wheelbarrows, and carts. Mwankusye (2002) cited by World Bank, FAO and IFAD (2008) find that the use of a wheelbarrow can reduce the time spent on water transport. In addition to helping with the collection of water and fuelwood, such technologies can also help women with a range of other transport tasks related to carrying tools to and from the fields, carrying crops from fields to grinding mills and markets, and transporting children and the elderly to health clinics.

Improved roads are also useful in bringing technologies and inputs to farmers and bringing farmers to markets. Evidence compiled by World Bank, FAO and IFAD (2008) suggests that rural roads increase the productivity and incomes of men and in particular women farmers who rely on them more heavily, by reducing time and opportunity costs and expanding their access to markets and inputs. In Peru, the rehabilitation of nonmotorized tracks in isolated communities reduced poverty from 83 percent to 74 percent, and 77 percent of the women travelled more frequently (World Bank, FAO and IFAD 2008). Planning and implementing for rural infrastructure project does not always take women and gender issues into account. It is important to use participatory approaches and pay explicit attention to gender inclusion throughout the policy formulation and project cycle to design, implement, supervise, and evaluate the gender-disaggregated effects of investments. It is also crucial to use gender-disaggregated monitoring and evaluation indicators to measure gender equity in all aspects of policy, program, and project implementation and outcomes.

Not all women, however, will benefit equally from labor-saving technologies and thus, how different groups of women will gain, or lose, from the introduction of new technologies needs to be evaluated. Failed technology uptake suggests that new technology design needs to take into account culturally permissible roles for women. Involving women in the maintenance of new technologies can be one strategy for challenging rigid gender roles. When the SEWA began a campaign to mobilize women for water management in Gujarat, India, women resisted participating because they regarded the development and management of water infrastructure as male territory. However, as women became trained as hand-pump technicians to repair broken pumps, involvement in the campaign increased and women began to take ownership of water management (Panda 2006).

5.1.5. Affordability of technology and complementary resources

More affordable fertilizer packages: Quisumbing and Pandolfelli (2010) emphasize that promoting divisible technologies or smaller input packages that are more affordable is proven to be effective in Malawi. This “small pack seed approach” success story has been implemented in at least 9 countries in Africa (Burundi, DRC, Ethiopia, Kenya, Malawi, Mozambique, Nigeria, Niger, and Tanzania) and has spread across crops (for example, beans, cowpeas, groundnuts, and soybeans) (personal communication with Louise Sperling, September 7 2011). Quisumbing and Pandolfelli (2010) also find that fertilizer-for-work programs can be targeted to women where women do not have enough cash to pay for fertilizer.

Targeting credit to female farmers for fertilizer purchases has been recommended for more than a decade (Quisumbing and Pandolfelli 2009). Gladwin (2002) and Quisumbing and Pandolfelli (2009) have suggested exploring gender dimensions of fertilizer use in Sub-Saharan Africa in relation to both inorganic and organic fertilizer and soil fertility management techniques and assessing which strategy would work best given certain local contexts. To date, gender-disaggregated impact assessment of providing subsidized fertilizer and seed packages to women have not been rigorously evaluated in the field (Quisumbing and Pandolfelli 2009). If countries are indeed to pursue a fertilizer/subsidy distribution system, the Malawi experience suggests the need to identify and use existing structures that are cost-effective distribution systems at the same time ensuring that women are reached by fertilizer vouchers.

More affordable irrigation system: It is also promising to develop and disseminate small scale water management or drip technologies. In Nepal, Upadhyay (2004) found that low cost irrigation technology can help rural women meet their water needs thereby saving time and energy and also increasing incomes and that drip irrigation is accessible to small farmers, especially women farmers, through local dealers. Unlike larger state funded irrigation projects which benefitted mostly large farmers who are mostly men and irrigated only 20 percent of the land, drip irrigation can be made accessible to small and women farmers through local dealers. Drip irrigation has reduced time spent by women doing irrigation in their fields; required less capital-intensive investment; increased incomes which were spent on household expenses and schooling of kids; increased production; and improved nutritional intake of children in the household.

Land and water rights will also need to be protected. Ashby et al. (2008) synthesize studies on Africa, India, Nepal, Ecuador, Bangladesh, Yemen, Nicaragua, Bolivia, Zimbabwe, Pakistan and the Gambia and concluded that multiple use water rights (that is, taking into consideration the interrelationship and complexity of needs for water for drinking, home production, and economic activities) designed to benefit women increased their efficiency and income generation (Quisumbing and Pandolfelli 2009). Moreover, improvement in equitable outcomes of water user associations and women’s participation and decisionmaking in these associations are also important entry points for easing constraints of access to water in production and processing.

More available and affordable seeds: Local seed banks, small-scale seed enterprises, and local seed exchange are the main and most reliable source of seed for resource-poor farmers, especially women (FAO 2008; Pionetti 2006; Smale et al. 2007). Often these seeds are cheaper, available in small quantities, better adapted to local conditions, and easier to obtain (World Bank, FAO and IFAD 2008). Interventions to strengthen local seed supply systems, such as establishing seed banks and breeding and multiplying seed is an important strategy to strengthen women farmers’ access to seeds.

Increasing land tenure security: Access to land and security of tenure are important in technology adoption and increasing productivity. Changes in the laws governing property rights are needed so that women may hold individual or joint title to land. This may also help ensure that women maintain control over land and any profits the land may incur. In Bolivia and Nicaragua, providing land titles to household heads rather than to both spouses, effectively deprived women of their customary access to land (Ashby et al. 2008).

In addition to joint titles, legal awareness is also important. Deininger et al. (2008) found that households' awareness of their land rights as defined by the 1998 Uganda Land Act, which strengthened tenure security and legal protection of customary owners and women, increased the propensity to undertake soil conservation measures. An increase of a household's legal knowledge by one element would potentially increase the propensity to undertake soil conservation that is equivalent to increasing the length of possession by more than 15 years or the head's level of education by more than 7 years. Moreover, because only a minority of land users are aware of these provisions, legal literacy campaigns can have a potentially large impact on agricultural productivity, but to date there have not been rigorous impact assessments of legal literacy programs.

Other gender-responsive activities implemented as part of the low-cost community land registration project in Ethiopia include (1) land administration committees at kebele level (the smallest administrative unit in Ethiopia) were required to have at least one female member and land certificates were issued after public registration for transparency; and (2) land certificates included maps and, in some regions, pictures of husband and wife (Deininger et al. 2007). Complementary reforms of family law can also play an important role in ensuring that women can inherit land or continue to use family land in case of divorce. Implementation and enforcement of gender-equitable laws and policies are also urgent issues in many developing countries.

Protect women's rights and control over economic gains: Special policies and provisions are often required to ensure that women retain control over important income generating assets - control which can be jeopardized when commercialization makes them more profitable and men may seek to take over control of the assets. An example is by giving contracts in the name of women and having systems that enable direct payment to women (Development and Training Services, Inc. 2009). Regulations that defend women's control over loans against the demands of other family members can make rural finance a more effective instrument for poverty reduction. Prospective threats to women's access to and control over productive assets, including their own labor and the income it generates, need to be carefully assessed and accounted for in the design and planning of interventions.

5.1.6. Greater access to rural finance

The most consistently mentioned factor affecting technology adoption is access to rural credit. In many cases, successful projects and programs that promote the development and dissemination of technological innovations are coupled with a component on credit provision. For example, SEWA adopts a holistic approach comprising of training and education of technologies; group-based lending; capacity strengthening and support services; market-orientation and developing mechanisms to improve the farmer's bargaining power and market access; strong linkages to researchers, input suppliers and markets; and developing farmers' organizations' networking, policy dialogue, and knowledge management skills. Various evaluation studies on specific activities adopting SEWA approach find that this approach increased both women and men farmers' productivity, improved their access to inputs and services, lowered their production and marketing costs, and increased their incomes (based submitted documents from this study's call for case studies).

Liquidity constraints of farmers should be a main consideration for technology dissemination projects. However, there is a need to strengthen the broader rural finance system rather than ad-hoc pumping of credit to rural areas. There is a need for more systematic framework and investments to strengthen the rural finance sector to see productive technologies and profitable enterprises in the hands of the rural population in a sustainable way. Rural finance is a complex topic and looking at its gender dimension adds another layer of complexity. World Bank, FAO, IFAD (2008) provide an excellent discussion on various ways to strengthen the credit system, especially in making it more responsive to women clients. What are outlined below are the important points.

Complexity: There are various providers and various products and instruments and it is important to consider these alternative products and providers in designing project/programs. Among the various

providers are the private sector providers (formal, informal); specialized microfinance institutions (provide financial services to poor and low-income populations; membership-based financial organizations (including rural financial cooperatives, credit unions, and other village-based entities); and integrated rural development programs and multisector nongovernmental organizations (NGOs) that offer financial and nonfinancial services as part of integrated development strategies. Among the products are loans, leasing arrangements for assets; insurance to protect from risks and vulnerability; mobilizing savings; and remittance transfers. Understanding these alternatives or mix of instruments and providers can take advantage of current capacity and opportunities to address liquidity and financing constraints to investing in productive ventures. In other societies, there are also numerous voluntary and informal credit associations that have been sustained for centuries and still continue to expand to other different communities such as the “Dhikur” in Nepal or “Palwagan” systems in the Philippines. These are institutional arrangements that evolved over time, which can be employed and promoted in projects and programs and ensure that these structures are not undermined.

Microcredit can help in some cases but limited in many other cases: Particularly in societies in which women do not already have extensive networks, well-designed, group-based models for financial services can be empowering and solve liquidity constraints. In Bangladesh, most evaluation studies of microfinance programmes have documented positive impacts on women’s decision-making and bargaining power in the short-term (for example, Pitt and Khandker 1998; Khandker 2005). Using the same dataset as these earlier studies, more recent studies (e.g., Roodman and Morduch 2009; Duvendack and Palmer-Jones 2011) find much weaker impacts than earlier studies and they attribute the difference to the unsatisfactory account for the endogeneity of participation in collective action (that is, women who are more “empowered” and well-off to begin with are more likely to join the groups).

Microcredit can help in some cases but limited in terms of its effect on productive ventures for women. Women’s credit needs are more diverse than the initial focus on small group loans and microcredit: women need longer-term and larger amount of credit to build assets and invest in viable and productive activities. It is a cyclical and self-perpetuating issue where banks are less likely to lend to women because they often are in low-return enterprises and they are in low-return enterprises partly due to lack of access to larger financing. This means that mainstreaming gender equality and women’s empowerment throughout the financial sector, including large-scale rural finance and leasing arrangements for agricultural development and value chain upgrading, is important.

Moreover, special policies and provisions are often required to ensure that women retain control over credit and income generated. National policies which promote smallholder credits, disbursing loans through local and rural banks and simplifying the process required to obtain a loan will go a long way in easing credit constraints faced by both women and men borrowers. Since women are more likely and more seriously affected by procedural and regulatory burden, women will benefit more than men with these process simplification and reforms.

Gender awareness and training will be important and the message that women have often proved to be better savers than men, better at repaying loans, and more willing to form effective groups to collect savings and decrease the cost of delivering many small loans has to reach rural financial institutions. It has to be brought to the attention of these institutions that targeting women can improve the financial sustainability of rural finance institutions.

Gender staffing policy: A clear and agreed-on gender staffing policy that promotes gender balance within the organization and fosters a culture in which women and men interact on a basis of equality has important benefits and consistent with internal sustainability. World Bank, FAO, IFAD (2008) provides an excellent discussion. NGOs and many commercial banks increasingly have gender or equal opportunity policies to encourage and retain skilled women staff. Components of this staff gender policy include: (1) child care facilities; (2) have implemented proactive promotion policies for women staff to attain greater diversity in the organization and better develop new market niches. In

many social settings, increasing the number of women staff is essential to increasing the numbers of women clients. The evidence clearly links levels of women staff in a financial services organization with women's access to services and the organization's contribution to women's empowerment. Gender-aware male staff members are central to contacting men within the community and changing their attitudes. When male staff members have good relations with women clients, they can increase women's confidence in dealing with men's hierarchies and break down cultural barriers.

Exploring innovative ways of meeting clients' credit needs: There will be a need to devise innovative ways of addressing gender-specific constraints and social biases against women that may be hindering serving the most productive and profitable potential clients. In designing loan packages for a heterogeneous clientele, lenders need to explore innovative ways of meeting clients' needs, even if it means departing from a traditionally successful business model. For example, interest rate cuts produced more borrowing by poor females (Quisumbing and Pandolfelli 2009). Changing the duration of the loan significantly affected sizes of loans demanded, particularly for poorer clients (Quisumbing and Pandolfelli 2009). Allen (2005); Murray and Rosenberg (2006); and Ritchie (2007) cited by World Bank, FAO and IFAD (2008) highlight that commitment saving products and savings-led groups perform better than credit-led groups.

5.1.7. Market-orientation and value addition

Technology adoption is much faster if the technology and enterprise has a direct link to markets and livelihoods and if it adopts an integrated approach. The promising results of the integrated approach used by the Greater Noakhali Aquaculture Prawn Market in Bangladesh are good example. Key elements include gender-responsive targeting in extension services and technology dissemination; linking poor women and men farmers to international prawn markets through strengthening farmer-based organizations and training on good aquaculture practices and traceability systems; partnership with private providers for reliable credit and input supply; and quota systems for women in executive committees and raising social development issues with rural producer organizations, which substantially reduced the incidence of social abuse among women.

Women require access to infrastructure services, information, credit, and other business development services in order to capitalize on the new market opportunities along changing or emerging value chains. Additionally, access to larger loans will be useful. In many African countries, commercial banks that developed new products and services targeting women entrepreneurs significantly increased the number of women-owned businesses (World Bank, FAO and IFAD 2008). Business incubators have proved effective in bringing very poor women entrepreneurs into markets when they customize training, legal advice, loans, insurance, and market intelligence to the particular economic needs of women (World Bank, FAO and IFAD 2008).

Information on returns on technology options: Farmers' knowledge about new technologies must also include information about the returns from adoption, including profitability and risk. A growing body of empirical evidence in developed countries suggests that, by and large, women are more risk averse and less prone to competition (Croson and Gneezy 2009). Fletschner, Anderson and Cullen (2010) find that women are more likely to choose activities with lower expected returns and with lower risks. Extension services and capacity strengthening initiatives can help farmers calculate or understand the profitability and risks associated with new technologies. For example, marketing extension approach implemented with numerous community-based organizations in Bangladesh has been proven in increasing incomes, especially for poor women (World Bank, FAO and IFAD 2008).

Agro-processing technologies: There are very limited avenues to make any earnings during off peak agricultural seasons as off farm rural employment for women is often limited. Depending on the local context, high-value agriculture and agro-processing have been cited as promising business ventures for poor women.

Agro-processing activities vary across countries and are dependent on the type of crop produced in a place, but in most cases these industries employ a majority of women. Technologies used in agro-processing facilities could range from being primitive, where women usually do small agro-processing ventures at home to the recent trends to more advance facilities where large food corporations subcontract the agro processing venture to local firms while maintaining similar product quality (White 1999). Women often form the majority of the labor force due to the low cost of hiring women and minimal skill requirements in agro-processing ventures.

White (1999) finds that in most rural areas across India, Bangladesh, Pakistan, Uganda, Tanzania and Kenya, women were significantly involved in agro-processing industries at the village level. In East Africa, food processing involves a considerable amount of a woman's time and contributes to the economy. However, most of it is informal and often does not get accounted for in the formal calculation of GDP. However, with increasing focus of governments on agriculture and agro-industry exports to Europe, this industry is gaining more prominence in government programs. South Asia has a more developed food processing industry and also women's involvement with food processing has increased which has enhanced women's empowerment. Reports from the Middle East also show that women's involvement in agro-processing industries is high, though they are limited to low-technology sectors like tobacco processing (UN 2001). In Sub-Saharan Africa, the greatest potential growth in small-scale agro-industries is in fruit and vegetable processing as many producers experience problems in marketing of fresh produce such as lack of readily available marketing information and lack of market integration, lack of data on supply and demand trends and prices, reliance on spot or road-side markets, transport constraints and spoilage (Mhazo et al. 2003; Boyd et al. 1997).

Program interventions in various countries focusing on women's training in various agro-processing activities have gone a long way to enhance women's skills in this sector and introduce them to modern technologies. Providing them with credit, literacy training and business skills and identifying marketing and export opportunities for the processed goods would also enhance women's self-sufficiency. Adoption of improved and appropriate food processing technologies, enforcement of quality and hygiene standards and regulatory instruments can assist local small- and medium-scale agro-processors to compete favorably in the market place.

5.1.8. More inclusive, equitable, and effective rural institutions

Group-based dissemination works: The formation of groups is a well-established means of improving rights and access to technologies, information, and services. Village women can organize sizeable networks and federations of networks capable of effectively demanding improved technologies and services and asserting land and water use rights. Quisumbing and Kumar (2011) find strong evidence of long-term impact of collective and group-based dissemination of agricultural technologies using 10-year panel data on Bangladesh. A strong national-level women's producer organization in Papua New Guinea that is hosted at the national agricultural research institute has enabled more women and men researchers to be engaged in research planning, innovation process, and technology dissemination and evaluation. In addition to formal organizations, Pandolfelli, Meinzen-Dick and Dohrn (2008) show that informal networks have been instrumental in disseminating innovation. It is useful to understand existing social networks among women and men farmers and support them in the process.

Promoting women's participation in mixed groups: Women in mixed groups found it easier to tap some of male resources, gain contacts and information, and obtain help and assistance in case of need than women-only groups (Gotschi, Njuki and Delve 2008). Various studies suggest that gender-balanced groups exploit the complementary advantages of men and women and have better access to information and services. However, many mixed groups have failed to transform power relations between men and women, continue the underrepresentation of women in leadership, and perpetuate female subordination. Gender norms and traditional gender roles can be challenged and addressed to

provide greater gender equality in mixed groups. Capacity strengthening and empowerment of women members and sensitization of both male and female members can help in easing persistent female subordination in mixed groups. A good starting point is training and sensitization among development and extension agents to be aware and responsive to these gender differences in mixed groups (Gotschi, Njuki and Delve 2008). Quota systems and reservation policies for women in leadership have also worked in some instances. Agarwal (2009) also supports the need for a critical mass (at least one-quarter proportion of women) for effective women's participation in mixed groups.

Holistic approach in supporting self-help groups: Women organizing themselves into women-only groups, formal or informal, show potential to empower women, gain better access and use of technologies and improve livelihoods. Bantilan (2006) finds for groundnut crop in India, collective action and social capital among women are the major factors of the high levels of adoption of the innovative groundnut production technology (GPT) in the site Umra. In comparison, in the other site, the adoption was very low as there was minimal collective action and high level of gender discrimination which prevented women from participation in meetings and having a strong voice.

Creating women-only groups are necessary but not sufficient condition as it often avoids addressing and tackling gender relations and traditional gender roles. In cases where mixed groups are not culturally possible or difficult to set-up, organizing women into self-help groups can offer a great potential for women to interact amongst themselves, get useful information, gain social capital, gain confidence and skills, and improve their livelihoods. For women, the presence of self-help groups in the village allows them to not travel far away from their villages, yet get the benefits these groups bring. As a mechanism of self-empowerment of women, these groups have played an important part in enhancing confidence and self-esteem for the women who are members, which often translate into real economic benefits for women. Self-help groups in Bihar, India are effective in improving the livelihoods of women and bringing positive outcomes in agricultural development (World Bank and IFPRI 2009). In Karnataka, India, Bharati and Badiger (2006) find that women members who joined the self-help groups during the project saw an increase of 45.47 percent increase in their confidence building index, 33.5 percent increase in their decision making ability and 41.9 percent increases in their social empowerment index. In Gambia, the Vegetable Growers Association provides services like purchasing, marketing, processing and utilization and its insurance and financial divisions take care of health and livestock insurance and also provide deposit services and loans.

However, many of self-help groups in other developing countries remain small in terms of economic activities and continue to have low access to resources, information, and support. Women-only groups need to be supported at least when they are just starting. Once they are supported and helped to help themselves, for example, respondents felt that the technology and equipment gained provided by National Agricultural Technology Project reduced their drudgery and freed up their time for other productive activities (Bharathi and Badiger 2006). In their study area of western Gambia, Sanyang et al. (2009) find that the women's vegetable garden performed better in terms of higher production and net profits than all the gardens in that area as they were backed up by local or regional NGOs who gave them access to the technology and financial resources. In Kenya, one group of women solved their transporting issues by registering as a cooperative to obtain a loan and then buying their own bus, which operates successfully as a profit-making enterprise and gives preference to women cooperative members (Kneerim 1980 cited in World Bank, FAO and IFAD 2008).

Market-orientation is key: In India, the role of dairy cooperatives as an important medium for providing and accessing livestock services accounts for the higher coverage for both women and men in the livestock sector. In Andhra Pradesh, India, the organization of over eight million women into self-help groups around community procurement centers enabled dispersed commodities to be aggregated and sold, with a cumulative turnover in four years of over \$120 million that created jobs for over 10,000 villagers in supply chain management (World Bank 2011). The income gain on some commodities exceeded 200 percent (World Bank 2011). Women became active managers and traders

in rural markets and hugely increased their economic and socio-political leverage in households and communities.

Quota systems must be coupled with capacity strengthening: In many mixed gender organizations, quotas are useful in increase the representation of women and to ensure their participation in management decisions (for example, Gemidiriya Community Development and Livelihood Improvement project in Sri Lanka). Institutional mechanisms that enable women to join mixed groups and remain active members include: (1) allowing non-household heads and non-landowners to be group members; (2) timing meetings to accommodate women's workloads an schedule; (3) ensuring that poorer women have opportunities to voice their concerns in group meetings; and (4) soliciting women's feedback in project monitoring and evaluation (Pandolfelli, Meinzen-Dick and Dohrn 2008). Women are also more likely to participate when projects directly incorporate their concerns.

Multisector approach is important: In Bolivia, an initiative of the ministry of agriculture and PROINPA, the CIP-Papa Andina Program, focuses on promoting women's participation in producer organizations. The project has worked with 700 families, particularly with women. There are no available quantitative studies of the success of the project, but qualitative case studies indicate that the project has been beneficial to the communities and women's welfare by: (1) contributing to biodiversity through the conservation of traditional roots and tubers; (2) reincorporation in families' diet and understanding of the nutritional value of these roots; (3) generating more income for the family; and (4) improving women's social capital and self-esteem (Cadima et al. 2009). This experience highlights that women's traditional knowledge play a critical role on biodiversity conservation in the Andes. This experience also finds that engaging other sectors, e.g., health and education sectors, contribute to further promote the use and conservation of Andean biodiversity (Cadima et al. 2009). The SEWA approach widely implemented in India illustrates also the need to have a holistic and integrated package of financial services, organizing and collective responsibility, and access to capacity building services in order to improve women's incomes and improve households' welfare. The contribution for future studies and policy formulation is that that a holistic approach serves better to capture complementarities in the different sectors.

5.1.9. Address social and cultural constraints

In sectors and areas where women are disadvantaged by gender norms, explicit targeting would be necessary to catalyze a change process for circumventing gender discrimination and securing women's access to key resources.

Explicit targeting of women in projects has been proven to be necessary, although not sufficient condition for tackling deeply-rooted social and cultural biases against women. Gender targeting in projects should not just end with measuring the number of women beneficiaries but should monitors the actual benefits and impact of women and household's welfare. Token participation or selecting women beneficiaries just to fill the quota/number specified in the project targets even though they are not qualified or the intended beneficiaries can be counter-productive. Monitoring and evaluation systems should include gender-disaggregated impacts rather than just counting the number of those who received assistance. At the same time, evidence suggests that getting men's support is critical and often necessary for the success of gender-responsive projects. Continuous gender-awareness and raising social development issues with rural producer organizations and other civil society organizations is key.

Reservation or quota systems for women as project beneficiaries, in membership in producer organization, committees or associations, or in key executive or decisionmaking positions can also play contribute to reducing social and cultural constraints in accessing and using technologies, information, and economic opportunities. For example, in Bangladesh, reservation policy and quota systems for women on number of job opening and in management positions in producer associations have been reported successful and it being attributed to a 50-percent increase in women's employment

and equal wages (Ashby et al. 2008). Chattopadhyay and Duflo (2004) analyze a constitutional amendment that mandates seats to be reserved for women in local councils on investment decisions made in West Bengal and Rajasthan, India, and find that female representative regimes make more requests for goods that satisfy women's needs, such as drinking water, while male regimes favor male goods, e.g. roads. Female reserved villages have a higher public goods provision compared to non-reserved villages, and women leaders are less prone to corruption (Duflo and Topalova 2004). In addition, female reservation was found to increase the likelihood that women actively participate in village meetings by approximately 25 percent in West Bengal (Pande and Ford 2011). A recent study on the longer-term impact of the reform finds female reservation reduces difficulties in the delivery of public goods and the likelihood to voice public problems. In addition, reservation reduces female time spend on domestic duties and increases household labor market participation and incomes. Beyond economic outcomes, reservation impacts on the female position within the household as it increases the likelihood of using birth control methods and to have a bank account (Deininger, Nagarajan and Paul 2011). These studies suggest that there is a promising role for quota systems and reservation policies, but capacity strengthening for women will be important for them to take full advantage of their potentials and the opportunities presented to them.

5.2. Supply-side opportunities

5.2.1. Strengthening capacity, incentive and responsiveness of extension organizations

There are several innovative approaches that are being piloted and implemented to increase women's and men's access to extension services that respond to demand and needs and they are discussed below are also described below.

Explicit gender targeting in institutional reforms: Institutional reforms toward more community-based, market-driven, or farmer-led extension system does not automatically guarantee greater inclusion and participation of women and marginalized groups and explicit targeting are often required. Private sector, including POs non-government organizations and church-based organizations are playing an increasing role in many communities to complement public sector extension systems in providing advisory services on agriculture, livelihoods, and development services to rural areas. Given the major sustainability issues and concerns of lack of responsiveness and impact of earlier training and visit (T&V) system for extension delivery, community-based extension systems are increasingly being promoted in developing countries with a promise of greater responsiveness and accountability of the systems to farmers and end-users. In their purest form, community-based approaches involves the providers of service that are contracted out directly by farmers' groups or communities to deliver information and related services that are specified or demanded by farmers. There are emerging examples in developing countries but funds are coming partly or fully from the government and the contracts are issues and monitored by the community of clients. Two commonly cited community-based extension systems are being implemented in Uganda through the National Agricultural Advisory Services program and in India the Agricultural Technology Management Agency (ATMA).

In Uganda, gender-disaggregated assessment is limited. A study by Obaa, Mutimba and Semana (2005) in the Mukono district show that farmers perceive that "poor farmers were left out" and suggests that the "required relatively high levels of literacy and the lengthy debates (on prioritization) precluded women and the poor". Many women do not make use of extension services and agricultural technologies due to limited education, lack of control over land, and in some communities, cultural factors that limit women from using some technologies (for example, like sitting on tractors). The enterprise approach embraced by NAADS had tended to favor farming enterprises requiring substantial amounts of land or capital, thus putting women and youth at a disadvantage compared to men (Bukonya 2010). Moreover, although many elderly women belong to the groups, they are not empowered to influence group decisions in the groups, and very few have leadership positions. Despite the overwhelming participation of women in farmer groups, men still

retain control over NAADS processes and actual decisionmaking, even in supposedly women-only groups.

In India, several gender-specific provisions are included in ATMA model including mandating resources for women farmers ‘ activities and quota system for women in trainings-of-trainers and in all committees and groups at the district level (Meinzen-Dick et al. 2010). These provisions were not always followed and evidence suggests that the impact of ATMA on women farmers is limited (World Bank and IFPRI 2009; Meinzen-Dick et al. 2010). For example, “in a case study in Bihar, a group of landless female members of a self-help group was selected for an exposure visit to West Bengal to learn new agricultural technologies. It turned out that the new technologies required access to land, and instead of sending five women for the exposure visit, as specified, only three were sent and the remaining two positions were filled by men from a dominant caste group” (World Bank and IFPRI 2009).

Capacity strengthening of farmers’ organizations may be useful in enabling producers to become effective leaders, managers and evaluators of funds and innovations. Enabling environment and capacity strengthening of a wider range of research and extension service providers will be very important. Explicit targeting for women in membership and decisionmaking in groups, gender sensitization, and gender balance in research and extension organizations can be useful, especially in situations and areas where social biases and gender norms are restricting women’s equal participation and engagement in these innovation processes.

Gender staffing policies and focus on gender-equitable outcomes: Regardless of the institutional set-up of the national extension system, there are several key lessons that can be learned from past experiences in extension delivery in developing countries. First, it is important to increase the number of female extension workers and improve their work conditions in order to increase outreach to more women farmers, especially in areas where cultural norms restrict male-female interaction.

Creating incentives for reaching female farmers, such as rewarding such outreach in performance reviews, would be important. Extension services also need to be brought closer to female farmers at times when they can attend meetings, since women often cannot attend trainings organized outside their villages due to childcare responsibilities and income-generating activities. At the same time, there is a need to design and implement strategies that will help male agents to work better with women farmers, e.g., training male extension agents in extension methods and communication skills suitable for female farmers and in tasks typically performed by women.

Second, efforts to recruit and train female extension agents will be more successful if they take into account sociocultural norms that may limit women’s participation. In areas with cultural norms influencing male-female interaction or where it is difficult to attract or retain female extension agents, men extension agents can be sensitized and provided with incentive to work with and meet the needs of both male and female farmers. The same intervention in regions in Nigeria (subsidized motorcycles given to both female and male extension agents) has differentiated outcome. In the southwest region of the country, where motorcycling is not culturally appropriate for women, most of the female extension agents gave their motorcycles to their male relatives instead of using them to travel to the villages (Quisumbing and Pandolfelli 2009). Adetoun (2003) cited in Quisumbing and Pandolfelli (2009) find that the female extension agents reported their preference for cars, instead of motorcycles, in which former are more culturally appropriate means of transportation for women.

Farmer advisors or farmer-extension agents can offer a good opportunity for greater outreach to both women and men farmers. Experience suggests that both women and men farmer advisors and extension agents are being trained (e.g., 17 percent of farmer trainers in Kenya and 52 percent in Uganda trained in forestry conservation and management practices are women [Kip-Tot 2011]). Many NGOs are increasingly using this approach which can be cost-effective and help to hasten the dissemination and adoption of technological innovations in rural areas. The community-farmer group

support program called “Leadership for Green Agriculture and Community in Rwanda is a good example of a promising women-extension-farmer approach.

Women groups and mixed groups are also able to access farmer-managed innovation funds and participate in multi-stakeholder learning processes such as the case of the PROLINNOVA (PROmoting Local INNOVAtion in ecologically oriented agriculture and natural resource management) program being implemented in various countries in Asia, Africa and Latin America. Key elements of this program include: (1) focus on farmers’ joint experimentation; (2) mixed approaches of learning using multimedia, training, fairs, exchange visits, and videos; and (3) competitive grants to enable farmers to start their experimentation and facilitate their learning (Waters-Bayer 2011). It has been reported that the activities of this program have improved gender relations, where women started setting-up cooperative and strengthening their capacities (Waters-Bayer 2011). Putting farmers at the driver’s seat can foster innovations, but farmer’s groups that had received support from research or extension service providers performed better based on the PROLINNOVA experience. The key lesson is that while the focus of innovation projects should be on farmers and on cultivating their innovativeness, this should be coupled with strengthening research and extension organizations and other service providers and enabling and incentivizing them to be responsive to the needs and demands of poor women and men farmers.

Third, promising approaches from other countries and regions need to be pilot-tested to ensure that they fit the local context. It is important to explore what works and how information is flowing within a given local condition. For example, farmer field schools (FFS) are promising approaches and increasingly being used for education and extension, but existing studies show mixed impacts on women. In an impact assessment of FFS done in Kenya, Tanzania and Uganda, Davis et al. (2010) find that there was more participation by women in FFS and a significant higher productivity increases among women than men. Adoption of nearly all major technologies was significantly higher among the FFS farmers. Participation in FFS increased income by 61 percent in analysis that pooled the three countries; and female-headed households benefited significantly more than male-headed households in Uganda (Davis et al. 2010).

In Vietnam, Braun et al. (2006) show that women’s participation in FFS has positive effects on women’s leadership, incomes, and livelihoods. However, the authors acknowledged that other countries have lagged behind, which is remains a major concern. Van den Berg (2004) synthesizes 25 evaluation studies of integrated pest management (IPM) FFSs and finds immediate impact of the FFSs in terms of reduced pesticide use and changes in yields, reporting considerable reductions in pesticide use, with some studies also showing an increase in yields.

However, these impacts have not translated into changes beyond the local level; several studies suggest that FFS are having limited or no effect on the agricultural sector’s economic performance, environmental sustainability, and on dissemination of information by FFS participants to other farmers. There are also many questions about their sustainability (Davis 2006); cost effectiveness (Quizon, Feder and Murgai 2001); and scaling up their impacts beyond the relatively small numbers that can be reached directly (Braun et al. 2006). For example, in Uganda, Isubilaku (2007) relates that although women outweighed men in number, men dominated most discussions and activities in FFS. Capacity strengthening of women in leadership and negotiation skills will be important. In Indonesia, World Bank (2000) concludes that despite substantial increases in women’s participation in FFS (the average percentage of women trained in IPM field schools increased from 5.6 percent at the beginning to 21.5 percent in the last year of the project), findings of the gender studies were not always applied correctly and excessive pressure to meet gender targets resulted in participation of non-farmers (i.e. farmers’ daughters who were students) in field schools in some provinces where women do not play an active role in farming. Policies, regulations, or explicit provision in project documents on women’s empowerment or gender quota may be present, but impact boils down to implementation and effective targeting. Greater supervision and more regular monitoring and evaluation will be needed; and more

importantly there will be a need to change mindset and practices on how we monitor and evaluate progress shifting from output-orientation (and using indicators such as number of women trained or number of women beneficiaries) to impact-orientation (and using indicators such as number of women who have increases in incomes and number of families that have increases in nutrition and food security). Evaluating progress of projects and performance of staff and organizations (public sector, NGO, civil-society organizations and other service providers) along these lines will be crucial for greater accountability.

5.2.2. Initiatives to increase responsiveness of service providers to farmers

There are several initiatives at the research and extension organizations level that can make them more responsive to the needs and demands of women and men farmers and other supply chain actors. Greater attention to effective performance monitoring and evaluation system and reward systems tailored to solving farmers' problems and focusing on impact on farmers can provide motivation to researchers and extension agents toward this goal. Performance targets such as number of partnerships or linkages formed, number of women and men farmers' problems solved, number of women and men farmers' with increase incomes and increased nutrition and health conditions. Explicit gender targets can also be included in the menu of performance indicators. However, commitment of leadership and management is needed for these targets to be implemented effectively.

Research institutes can continue to design effective networks and platforms for women and men farmers as well as other supply chain actors to be engaged more into innovation processes. Moreover, funding the participation of the poor will be crucial so that they can voice their needs and problems. Still in many cases, research institutes project an image that they are beyond the reach of ordinary farmers. For example, field visits in Ghana, Kenya and DRC, suggest that farmers interviewed, particularly women, have a perception that research institutes as being closed and or unavailable for visits or questions from farmers. In other instances, the perceptions are more negative: that research institutes are just not effective and cannot help farmers. Research institutes can strive to reach out to farmers, such as hosting women's organizations or mixed groups in their institutes and establishing community information and resource centers with strong presence and engagement of researchers and subject matter specialists.

Question and answer (Q&A) programs using radio stations and availability of subject matter specialists and scientists to respond to questions and concerns by women and men farmers are also showing some promise in reaching rural areas in various countries, especially in Africa (Sani et al. 2011; Kasangaki and Oguya 2011). An approach of using mixed tools such as radio-based Q&A, internet-based posting of questions and answers, as well as providing vouchers as rights for farmers to ask important questions for the community is being pilot-tested in 7 districts in Uganda and is showing some success (Kasangaki and Oguya 2011). Key lessons include the need for capacity strengthening (e.g., for farmers to articulate their needs and demands; for field agents to deliver vouchers and discuss the process to farmers; for rural information broker to manage the ICT tools; for subject matter experts to provide the needed technical information being requested by women and men farmers (Kasangaki and Oguya 2011)).

A similar approach of using financial incentives is being pilot-tested through the Peru Agricultural Research and Extension Program (INCAGRO) to strengthen both the agricultural technologies and services delivery (supply side) as well as the articulation of the demand for them (demand side). The use of competitive funds to co-finance research and extension projects and strong focus on indigenous peoples and women's organizations are showing some promise in fostering responsive and equitable rural innovations in Peru.

5.2.3. Capacity strengthening and affirmative action for women in research and education

A number of initiatives are already in place to strengthen support and mentorship for girls and women into science and agriculture. The AWARD program is showing some positive impacts to enhancing capacity and opportunities for women professionals. SASAKAWA program also pays close attention to training women extension agents. Current approaches need to be scaled up while launching similar new initiatives at the same time.

Campaigns and affirmative action to encourage more girls taking up agriculture and sciences will be needed. Change in outdated and gender-biased curriculum in many developing counties is a priority. The production-focus, as well as branding agriculture, field crops, and technical and scientific inquiries as male fields will need to change. There has to be a greater focus on a holistic and comprehensive view of “food” and emphasize on food nutrition and security, with greater recognition of women’s contribution and roles in the different stages of producing and providing food and nutrition for their families.

From a research-perspective, Kingiri (2010) finds that available studies in innovation systems have been relatively silent on gender issues. She suggests the need to conduct gender analyses using a systems-perspective, as well as developing diagnostic tools to better understand gender dimensions of agricultural innovation systems. While improved gender analyses are important, communicating and sharing the lessons and insights learned from these analyses are even more crucial part of the institutional learning. There is also need for greater gender mainstreaming and institutionalized efforts, with complementary capacity strengthening and funding, to provide incentives to do more gender research (Kingiri 2010).

5.3. Strategies for enabling environment and good governance

Gender-responsive activities and changes within the research, education and extension organizations to respond more to demands and needs of both women and men producers will not work without complementary changes in the wider policy environment. First, the most significant positive impact on agricultural labor and employment, for both men and women, will come through creating a dynamic rural economy in both agriculture and nonfarm sectors, focusing primarily on creating a good investment climate. There is also a need for explicit attention to gender bias in the labor market, including wage inequalities; occupational segregation; women’s time burden; and violence, health and safety in the workplace. Reducing labor market segmentation and wage inequalities improves the mobility of labor, increases employment, and contributes to economic growth. Empirical evidence also shows that women invest more than men in the development of children; thus higher levels of employment and earnings for women not only contribute to but also have intergenerational implications.

Second, affirmative action to increase the number of girls going to school is crucial in bringing forth changes in mind-set, awareness, and empowering the next generation of women. A number of initiatives have already been implemented, including the World Bank-led and multi-partner funded initiative of girls’ education. A number of countries, such as DRC, are in passing laws that will increase accessibility of schools to young children, especially girls, by building more schools in remote areas. These plans should be funded and implemented and scaled out in other countries. More education for women will payoff in terms of increasing the much-needed critical mass of more educated farmers, extension agents, researchers, service providers and policymakers, ready and able to respond to the needs of the poor and hungry.

Third, the representation of women in decisionmaking positions in research and extension organizations, governments and parliaments can be an important avenue to make agricultural policies,

technologies and service provision more gender-responsive. However, reservation should be coupled with capacity strengthening in decision making and negotiations for women. Training for women needs to provide them with the required skills, particularly in countries where education levels for women are low, and to ensure that they are fully conversant with their roles and accountabilities. Emphasis on women's education, including incentives and scholarships for women in science and policy is important to ensure a pipeline of well-qualified women candidates for senior positions in public and private organizations.

Third, funding for research and extension is low and several experts have already emphasized the need for government to invest more on them (Beintema and Stads 2011). This can also be coupled with greater farmer-based advocacy for more funds to farmer-led research and extension, together with initiatives toward gender-responsive budgeting to ensure that funds are allotted and benefits accrue to both women and men. Other structures and gender-specific activities, such as setting-up gender machineries or appointing gender focal points in relevant ministries, are often not effective due to limited capacity (human, financial, operating) and limited power and authority given to these structures. These women's machinery needs to be strengthened, along with their capacity for negotiation, to have an effective voice in the budget processes. These gender machineries and women's organization should be linked more closely with the research institutes and Ministry of Agriculture.

6. Discussion and policy implications

Analysis of the constraints and opportunities for increasing technology adoption and impacts on women and men farmers described above points to a number of key approaches:

- Holistic and integrative approach that recognized complementarities of actors and services
- Explicit targeting, provision and support on poor women producers
- Putting women and men farmers at the center of innovation processes
- Incentives for organizations and service providers to respond to women and men farmers' needs
- Needs-based capacity strengthening for women and men farmers
- Promoting equal playing field for women and men producers
- Greater focus on outcomes and impact

Holistic and integrative approach: Most of the promising examples and projects have adopted an integrated or holistic approach, starting with clear and joint understanding of the problem and solving the problem through collaboration of various actors. Experience suggests the need to look at binding constraints on both the supply and demand sides of technology and service provision and use a systems-perspective to ensure that technologies generated and disseminated respond to farmers' and target clients' demands and needs. The SEWA approach illustrates the need to have a holistic and integrated package of financial services, organizing and collective responsibility, and access to capacity building services in order to improve women's incomes and improve households' welfare. The aquaculture project in Bangladesh described above used technical training on good aquaculture practices and compliance with traceability and food safety standards; linkage to credit and input suppliers; linkage to international markets; targeting the poor women producers; supporting collective action among women; reservation policies for women in executive committees; and empowering women to be champions for raising awareness and tackling social development issues in their communities.

Part of the holistic approach is the need to look at complementary inputs, services or infrastructure that would be required for adopting technological innovations. For example, the use of more advanced forms of ICT, such as mobile phone and internet, are also promising, but complementary investments are needed to make it more inclusive, effective and equitable. These complementary interventions include increasing mobility, liquidity and literacy for those resource-poor, with explicit targeting for

women. These have been highlighted by a majority of the case studies received. Investing in complementary physical infrastructure and power supply in many rural areas in developing countries is also important to ensure that these advanced ICT applications are useful.

An important element of an integrative approach to technology and innovation is to shift the orientation of many public organizations from crops and field production to the whole supply chain and food sector. This will open opportunities for a more systematic approach to food security and nutrition and for greater promotion of women activities and responsiveness to their constraints and needs.

Explicit targeting of poor women at the same time getting men's support: In sectors and areas where women are disadvantaged by gender norms, explicit targeting is necessary to catalyze a change process for ending gender discrimination and securing women's access to key resources. Explicit gender targeting often used by organizations includes quota for women as project beneficiaries and reservation policy for women in producer organizations' or committees' membership or leadership positions. One strategy that is proven to be responsive to poor women farmers is offering small packages and more affordable technologies and inputs. Fertilizer and seeds being offered in smaller packages were proven to be more affordable to poor women farmers and subsequently increased their adoption of these technologies and later on their productivity and incomes. Radio is proven to be an effective ICT tool to reach poor women and men, especially in remote areas. Moreover, the use of simple extension and education messages, illustrations, and educational videos, especially to those with lower literacy level.

Affirmative action is needed to ensure that more girls are going to school and more women professionals are getting equal opportunities as men in the area of research, extension, and education systems. This emphasis on women's education is important to ensure a pool of well-qualified women candidates for leadership and management positions in organizations. However, quota systems, focal points, and gender-balanced staffing in research, extension and education organizations do not often work without genuine empowerment among women professionals. Quota systems or reservation policies should also be complemented with genuine decisionmaking authority and empowerment by women, as well as confidence-building, greater mobility, decreasing time burden, training and capacity strengthening.

This is not to say that projects and programs should exclude men. On the contrary, evidence suggests that getting men's support is critical, and often necessary for the success of gender-responsive projects. Moreover, paying attention to heterogeneity of women and men producers and careful targeting are required to reach those who really need assistance. Understanding the local context and tailoring interventions that fit this context is important.

Women and men farmers at the center of innovation processes: Many of past technologies have failed because they were not able to engage farmers and other end-users into the whole innovation process starting from the upstream planning and priority-setting. Activities can be initiated to promote greater linkages among researchers, extension agents, farmers and other innovation actors. Poor women and men farmers and their organizations need to be funded for their participation and active and engagement in key priority-setting and innovation platforms. Other innovative ways to link research, service providers and farmers should be promoted, such as hosting women's organizations at the research institute or community information and resource centers with regular interactions with researchers and women and men farmers.

While a number of opportunities and initiatives are available that promote greater farmer and end-user involvement in innovation processes, gender inclusion is not automatic. There is increasing use of civil-society organizations as providers of research and advisory services. Group-based dissemination systems are also being used in extension, education and technology transfer. Farmer's organizations

are also discussed in the context of their greater role in research and extension fund management and M&E in countries and communities that have adopted more community-based innovation systems. However, attention to women's specific and differentiated constraints and their limited participation in these organizations and processes are often not the priority. Institutional and organizational arrangements such as research-extension-farmer linkage systems, innovation platforms, participatory approaches, multistakeholder networks, and competitive grants and other financial instruments often do not automatically ensure equal opportunity for participation and decisionmaking by women and men. Explicit targeting of women and gender-specific activities will be needed. Women organizations and community information and resource centers being hosted at research institutes and explicit gender targets in competitive grants, linkage committees, platforms and mixed-gender organizations are some examples of activities and initiatives that will be useful.

Needs-based capacity strengthening for women and men farmers: For women and men farmers to play a more leading role on innovation processes, capacity strengthening is required. Training activities should be more responsive and creative to the needs of women and men actors. Marketing extension and training are proven to be useful for improving women's livelihoods, but attention needs to be paid to increase its outreach to the ultra-poor, increase and sustain profit margins to enable numerous producers to break the cycle of poverty, and capacity strengthening of training resource farmers and field facilitators. Literacy training and promoting vocational training among the extreme poor can help in their participation in marketing processes. Value addition, agro-processing, seed multiplication, and high-value agriculture are some of the promising activities that can help women substantially increase their incomes and should be promoted wherever they are culturally appropriate. There is a need to pay close attention to the supply-side issues, particularly on the limited field facilitators that are crucial links of farmers to innovations and market information. There is need for increased investment to recruit more women and men field facilitators and training resource farmers and to provide them incentive to respond to and solve poor women and men farmers.

In addition to training directly related to livelihoods, women and men farmers and their organizations need to be equipped with key management skills given their increasing role in the innovation systems. Skills including the ability for demand articulation, participatory action research, fund management, and monitoring and evaluation of innovation and service provision are important for producer organizations to be more active players and leaders in innovation systems. Various capacity strengthening approaches beyond training (e.g., mentorship, exchange visits, and collaborative research) should be combined together and implemented to ensure more positive outcomes. Training and broader capacity strengthening efforts must be tailored to local context to better respond to the needs of both women and men farmers and other end-users.

Incentives for organizations and service providers to respond to women and men farmers' needs: More recent initiatives to foster responsiveness and inclusiveness, such as participatory and consultative approaches, are only effective if coupled with supply-side interventions to tackle the supply-side bottlenecks. A number of cases in this paper have shown that countries that just focused heavily on participatory approaches (e.g., DRC), without strengthening the capacity and incentive of the supply-side actors, remain plagued with inefficiency of the systems and inability to respond to the needs of the population. Lack of follow-up actions and response from research to problems, preferences and demands articulated by farmers and end users often discourages continued participation of farmers in participatory and consultative processes. Understanding and implementing other sources of incentives and accountability will help address deeply-rooted bottlenecks in innovation systems. This applies to the pluralistic research and extension systems, including government, private sector non-government organizations, church-based groups, farmers' organizations and other civil-society organizations.

One way to strengthen incentives for greater responsiveness and inclusiveness is to explicitly have them as part of research and extension organizations' performance monitoring and valuation systems. Projects have often used "number or proportion of women beneficiaries" as the indicator for gender-

responsiveness in projects. There should be a shift from this narrow focus to a broader orientation on outcomes and impacts such as looking at reduced time burden, women's empowerment, increase in incomes, improved livelihoods and improved nutrition and health conditions. This can increase the motivation and accountability of researchers, extension agents, and managers to improving the effectiveness and responsiveness of research and innovation systems. Other approaches can also be adopted, such as competitive grants and other financing instruments with explicit criteria and emphasis on women's organizations and marginalized groups. An example in Peru that is described above is showing promising results in terms of inclusion of women and indigenous groups in the rural innovation and more responsive delivery of technology and services.

Promoting equal playing field: Gender-responsive activities and changes within the research, education and extension organizations will not work without complementary changes in the wider policy environment. Moreover, participatory approaches and consultative processes require specific organizational commitment and policy initiatives. Farmers' associations and community-based organizations cannot operate in their members' interests in an environment hostile to grassroots and women's participation. Policies to foster equitable participation and social mobilization can provide operational funds to build resource-poor and marginalized groups' capacity to participate and cover the costs of their participation. It will also be important to strengthen women's land, property and water rights and investing in girls' schooling. In some countries, a priority is to start a change process to eliminate remaining discriminatory policies against women (for example, women are not allowed to own land and property or borrow money without permission from husband). In most countries, it is the implementation and enforcement of policies and regulations that are critical.

Greater focus on outcomes and impact: Greater attention needs to be paid to effective performance monitoring and evaluation and reward systems tailored to solving farmers' problems. Performance targets such as number of partnerships or linkages formed, number of women and men farmers' problems solved, number of women and men farmers with increased incomes and increased nutrition and health conditions can be pilot-tested. Explicit gender targets can also be included in the menu of performance indicators. However, commitment of leadership and management is needed for these targets to be implemented effectively.

There should also be careful planning and design of technology development projects to minimize adverse effects. Several initiatives that attempted to promote labor-saving technologies to poor women had unintended effects including the risk that men take over their productive ventures and technologies/resources accessed; men's capture and increased withdrawal from household budget for their own expenditure and luxuries; and negative effects on livelihoods for hired labor. Moreover, small increases in access to income may come at the cost of heavier workloads, increased stress, and diminished good health. Without providing substitute care for small children, the elderly, and the disabled and providing services to reduce domestic work, many organizations report that women's outside work adversely affects children and the elderly. Daughters in particular may be withdrawn from school to assist their mothers. Although in many cases women's increased contribution to household well-being has considerably improved domestic relations, in other cases it intensifies tensions. This problem affects not only poor women but women from all economic backgrounds, which indicates that the empowerment process must have effective strategies to change men's attitudes and behaviors. Economic cost-benefit analysis and poverty and social analysis are important in order to know which type of farmers or segment of the population are adversely affected; to support the transition and adjustments needed by those affected; and to devise ways to protect the vulnerable and resource-poor who would be affected.

From the research perspective, more attention to gender-disaggregated data and gender analysis in mainstream research is needed. While numerous gender analyses have been conducted and gender-disaggregated data are increasingly being collected, there are a number of remaining knowledge gaps and adjustments in research and methodology including clearly-defined gender indicators and disentangling the relationship of gender, household size, and income indicators in affecting

technology adoption and productivity. There is a need for more evaluation and impact assessment of technologies. In particular, it is important to evaluate gendered impacts of technologies and impact of technology adoption on the traditional gendered division of labor and shifts in activities and domains and control. Participatory approaches and decentralization are promising avenues for a more inclusive decisionmaking for food policy processes and rural service provision, but rigorous assessments will be useful in order to understand how these approaches affect the quality of participation and impact of representation by rural women and men. Findings and lessons from these evaluation studies and impact assessments need to be communicated to decisionmakers and form an integral part of organizational learning. Gender analyses need to be institutionalized, with effective capacity strengthening and incentives for greater attention to gender issues in research and impact assessments.

7. Conclusions

This paper reviews and integrates findings from existing empirical studies to identify demand- and supply-side constraints and opportunities in access to, adoption and impact of a wide range of technological innovations by rural women and men. Most studies consistently find that women have much slower observed rates of adoption of a wide range of technologies than men. Most of these studies conclude that it is the gender difference in access to these technological innovations, information about these innovations, or complementary inputs and services that explain gender differences in adoption. The relatively weaker participation and engagement of women farmers and stakeholders than men in priority-setting and decisionmaking also came out several times in the studies reviewed.

At the supply-side, there is evidence of weak capacity and incentive of innovation organizations and their staff to be more effective and responsive to the needs of both women and men farmers. Numerous attempts of participatory and consultative approaches seem to lack evidence of significant broad-based impact on technology adoption and gender-equitable outcomes. Several initiatives to increase more women graduates, scientists and extension agents are increasingly being implemented, but more need to be done. The overwhelming underrepresentation of women as scientists, educators, graduates, managers and extension agents remains to date. Moreover, the broader policy environment and political commitment to tackle a number of supply-side constraints and enforce accountability among supply-side actors are consistently emphasized by a number of studies as crucial in bringing about innovations that are responsive and able to solve the needs and constraints of women and men in agriculture and rural sectors.

Effective gender-responsive interventions examine gender relations and gender inequality and they do not target only one group, while ignoring the other. Interventions that look at technology from a holistic perspective and systems-approach and that pay attention to the complementarity of inputs have been the successful ones. Key elements of projects and programs that work well in providing positive outcomes in reaching women and achieving greater gender equality include: (1) providing small packages and affordable ways for bringing technologies to poor women and men; (2) a quota system or reservation policy for women, coupled with effective capacity strengthening, increasing mobility and reducing women's time burden; (3) promoting collective action and organizing among women, coupled with market-oriented capacity strengthening and mechanisms for women to secure their income and resources; and (4) utilizing a mix of delivery approaches such as radio, social networks, farmer field schools, and participatory approaches, coupled with affirmative action of staff gender policy and gender-responsive actions to ensure that useful innovations reach poor women and men farmers; and (5) paying attention to heterogeneity of women and men producers and proper targeting to reach those in need the most.

Despite some patterns of key elements of a promising gender-responsive projects and programs, the limited evaluation studies, impact assessment, and rigorous evidence hinder understanding under what conditions or contexts certain approaches or strategies work or do not work. More evaluation studies and impact assessments are needed and more gender-disaggregated data and analyses will be

important for institutional learning, maximizing desirable development impacts of scarce resources, and minimizing adverse and unintended effects on the poor and marginalized groups.

Over the years, the development community and local organizations have been actively working to find ways to bring technological innovations closer to poor women and men farmers and ensure that they are involved from the research priority-setting and technology development. There are a few success stories, but many initiatives have failed to reach the poor and marginalized groups. Scaling up pilot projects and replicating success stories have been the major challenges. This review paper suggest three interrelated considerations that can help in scaling up promising approaches: (1) intensifying research and analyses to understand local contexts to identify the conditions under which certain approaches and activities work or do not work; (2) paying more attention to criteria on cost-effectiveness, efficiency, and financial sustainability in project and program design and implementation; and (3) strengthening leadership and political commitment leading to results- and mission-oriented organizations and championing the cause of gender equality and women's empowerment.

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