climate

MDPI

Article

The Role of Social Networks in Agricultural Adaptation to Climate Change: Implications for Sustainable Agriculture in Pakistan

Muhammad Abid [1,2,*], Grace Ngaruiya [3], Jürgen Scheffran [2] and Farhad Zulfiqar [4]

1 Centre for Climate Research and Development (CCRD), COMSATS Institute of Information Technology, Islamabad 45550, Pakistan
2 Research Group Climate Change and Security, Institute of Geography, University of Hamburg, Grindelberg 7, 20144 Hamburg, Germany; juergen.scheffran@uni-hamburg.de
3 Department of Plant Sciences, Conservation Biology Section, Kenyatta University, P.O. Box 43844-00100 Nairobi, Kenya; Ngaruiyag@gmail.com
4 Department of Economics, COMSATS Institute of Information Technology, Islamabad 45550, Pakistan; farhad.zulfiqar@comsats.edu.pk
* Correspondence: muhammad.abid@comsats.edu.pk or abiduaf@gmail.com; Tel.: +92-333-7473-972

Received: 13 August 2017; Accepted: 21 November 2017; Published: 23 November 2017

Abstract: Incorporating adaptation into subsistence farming systems is an important strategy to reduce damages related to climate change and to protect livelihoods in developing countries. Using a dataset of 450 farm households collected from three agro-ecological zones, this study examines rural networks, assesses farm-level institutional support and documents any existing structural gaps on climate change adaptation in the agricultural sector of Pakistan. For this purpose, a social network analysis method is used. The study findings reveal that farmers reported a decrease in crop production and increase in pests and diseases due to climate change. Further, changing crop varieties, sowing dates, input mixes and planting trees are the key measures adopted by farmers. Lack of information, finances and resources are the key adaptation constraints. The study findings show that only 28% and 13% of the respondents do not have access to financial services and climate adaptation knowledge, respectively. Support to farmers mainly consists of marketing information and farm equipment from community-based organizations, while private institutions offer weather forecasting services. Public institutions are poorly represented in the network analysis. We also found that extension services are key institutions in the climate adaptation network, while agricultural credits, post-harvest services and marketing of produce were dominant but weakly connected in the financial support network. We also found that with an increase in the provision of services at the farm level, farmers not only adapt more but also move from low-cost and short-term measures to advanced measures. This study proposes an integrated framework to improve the stakeholders' networking through different kind of partnerships and better adaptation to climate change.

Keywords: social network analysis; local institutions; climate change adaptation; agriculture; Pakistan

1. Introduction

Projected changes in climate and the increasing frequency of extreme events over the 21st century pose serious threats to agricultural development in developing countries [1]. Over the last two decades, Pakistan has become highly vulnerable to climate change events like floods, droughts, extreme temperature and uncertain rainfalls [2–4]. The agricultural sector, which is a source of livelihood for more than half of the population in Pakistan, has particularly been the most affected sector by climate change due to a lack of infrastructure and adaptive capacity [5]. For instance, the floods in

2010 damaged two million hectares of standing crops and caused a 4.1 billion USD loss only to the agricultural sector [6].

Adaptation of current farming systems is one of the ways to avoid the risks of climate change and to protect livelihoods and local food security [2]. However, the type and extent of adaptation strategies vary across regions and changing socio-economic and agro-ecological settings. A lot of studies, e.g., [2,7–10] are evidence of the effectiveness of local and farm level adaptation efforts towards improved adaptive capacity and protection against climatic risks. Since climate change adaptation is largely local, its effectiveness highly depends on the functioning of local actors and institutions (public, private and civic) that interact to provide institutional support and incentives to farmers and locals [11]. The role of local government interactions is crucial to ensure sustainable adaptation among poor and smallholding farmers, who are also more vulnerable in most cases [12,13]. These institutional arrangements and collaborations at the local level may be more effective than individual efforts to enhance the adaptive capacity and resilience in the agriculture sector to climate change [11,14].

A vast literature is available on various aspects of climate change and agriculture linkages ranging from mitigation studies, e.g., [15,16] to impact, e.g., [17,18] and adaptation and resilience studies, e.g., [10,19–21]. There is an increasing recognition of the role of social capital in the adaptation literature, e.g., [22–26] where it is considered to be an important part of support systems at the rural level [27]. Various studies, e.g., [27–30] reported the significant role of access to different institutions in shaping adaptation decision-making and improving farmer wellbeing. Such kinds of literature mainly come from either developed countries or developing African countries [1]. However, studies from South Asia hardly explore institutional aspects of adaptation. A growing literature from South Asian countries including Pakistan mainly focuses on incremental impacts of climate change on different crops [31–35] and rather little on adaptation perspectives [2,36–38].

The role of social networks has particular importance in developing countries like Pakistan where access to institutions in limited [1]. Particularly the small landholders are often deprived of access to institutional services that are biased towards landlords or influential farmers [2,39]. Given the limited knowledge and information on climate change adaptation in Pakistan, the institutional aspect of adaptation is yet to be explored. There is a dire need for studies focusing on the current linkages and interactions among different stakeholders and their role in the local adaptation process. Such knowledge will be helpful to assess the potential of social capital and its use as an effective tool to improve farm households' resilience and adaptation to climate change.

Keeping in mind the current knowledge gap, this is the first study of its kind that particularly focuses on social capital and the role of social networks in farm level adaptation to climate change in Pakistan. Specifically, this study responds to four research questions: (1) What is the current status of social networks at farm level in term of source and type of services? (2) What are the structural gaps in current institutional support to climate adaptation? (3) Is the current local institutional setup enough to support climate change adaptation? (4) What kinds of policy interventions and institutional arrangements are required to enhance farmers' adaptive capacity to climate change?

The paper is divided into four sections. After the introduction, Section 2 describes the conceptual framework and methodology, Section 3 presents the results and discussion, and finally, Section 4 concludes the study findings and provides recommendations for policy and further research.

2. Materials and Methods

2.1. Case Study

This study was conducted in the Punjab province of Pakistan, which is the most populous, and the second largest province in terms of area [2]. The province accounts for 74% of the total cereal production and half of the agricultural GDP [40]. Punjab consists of four agro-ecological zones: irrigated plains, the Barani (rain-fed) region, the Thal region and marginal land. For this study, we considered only three regions and excluded the Thal region due to its similar characteristics such as climatic condition, cropping patterns and socioeconomic settings with the marginal land zone. The district Toba Tek Singh, from the irrigated plains, the district Rahim Yar Khan, from the marginal land zone, and the district Gujrat from the *Barani* (rain-fed) region were selected. All three selected districts are different in term of local climate, environment and geography and hence are subject to various kinds of environmental and socioeconomic constraints [1,2]. The district Rahim Yar Khan has a very hot and arid climate in summer with a maximum and minimum temperature recorded at 49.7 °C and 6.8 °C, respectively. The district receives an overall annual rainfall of 165 mm [2]. The historical climate records of the district show an increasing trend towards seasonal temperature and rainfall over the period 1980–2013 [2]. The district Toba Tek Singh is characterized by hot temperatures in summer and cold temperatures in winter. The average temperature in the district ranges between 17 °C–31 °C, and the average rainfall is 383 mm per annum. The historical climate records show an increasing trend for seasonal temperatures and a decreasing trend in winter rainfall over the period of 1980–2013. The district Gujrat has a moderate climate with annual average temperature ranging between 17 °C–30 °C and an average rainfall of 864 mm annually. The historical climate records show an increasing trend towards seasonal temperatures and a decreasing trend for rainfall over the period 1980–2013 [2]. Figure 1 shows the map of case study areas located in the Punjab province.

Figure 1. Case study area map, Punjab, Pakistan.

2.2. Social Network Analysis

There is growing recognition in the literature to use social network analysis in resource governance and adaptation studies at various scales ranging from regional to local [41,42]. A social network mainly consists of interdependent actors that interact with each other to establish the flow of resources or information. These interactions may be either one-directional or two-directional. Grounded in systematic empirical data, social network analysis is primarily motivated by identifying the structural ties linking interdependent social actors and uses graphic imagery and computational models to uncover patterns that might otherwise go undetected [43,44]. Unlike the standard social science research that heavily focuses on the attributes of individual actors, social network analysis focuses on the characteristics and linkages of social actors to uncover the hidden theoretical motivations behind the social relationships that shape environmental outcomes and individual decision-making [45]. Studying the role of social networks in adaptation and governance can reveal deficiencies in the existing farmer support management that can be useful to enhance the local adaptive capacities and resilience to climate change. Based on network theory, this study selected two measures (structural holes and density) of the social network to analyze patterns of interrelationship and to understand the level of synergy among local stakeholders in agriculture and adaptation implementation.

2.2.1. Structural Holes

This study is mainly interested in understanding how social networks facilitate the identification of stakeholder positions in a network and how these actors link various parts of the system together [42,44,46]. Further, through social network analysis, the study also explores the structural holes among different actors. Structural holes represent the empty spaces in social structures that exist between two actors when they are not connected, even by having some common or mutual goals. There are many ways to measure structural holes, including bridge counts, hierarchy, constraint values, and ego betweenness [46].

Several mathematical indices are used to define the significance of an individual unit or actor within the network domain [46]. Equation (1) describes the betweenness centrality index that counts the number of network pathways passing through an actor, and is used to measure how much potential control an actor has in sharing relevant information across the social network [42].

$$B_C(i) = \sum_{i \neq j \neq k} \frac{\partial_{ijk}}{\partial_{jk}} \tag{1}$$

where $B_C(i)$ represents the betweenness centrality of actor i, ∂_{ijk} shows the number of paths linking actors i and k that passes through actor j, and ∂_{ik} is the number of paths connecting actor i and k. This definition works under the assumption that interactions between two nonadjacent actors might depend on other actors, particularly the actors who lie on the path between two [45]. In other words, we can say that the actors, who rest among many others, may act as "broker" to disseminate adaptation information to other actors. Through information sharing with other actors, they are not only able to positively affect the individual decision-making of others, but they will also influence the level of collective knowledge in the community to resolve common resource problems. For instance, if a community has well-equipped brokers or well-connected actors, then the overall adaptive capacity of the community will increase and it may reduce the damage from climate change and related risks. On the other hand, unconnected or weakly-equipped brokers may negatively affect the adaptive capacity of the community and may increase its exposure to climate change and its adverse impacts [46].

2.2.2. Density

Network density represents the average strength of the connection between actors [42] and indicates how actors are linked together [44]. The density (d_i) in Equation (2) calculates the proportion of ties existing in a network and explores the community behavior, attitudes, and performance.

$$d_i = \frac{L}{n(n-1)/2} \tag{2}$$

where n depicts the number of actors connected to actor i and L is the number of lines between the actors. Density scores represent the cohesion levels among actors, where higher density indicates the higher number of ties between actors based on the assumption of close communication in the community. For instance, poor adaptation at farm level may be due to fragmentation or missing links in the community that may be identified through social network analysis and may be improved accordingly.

2.3. Data Collection and Analysis

Fieldwork was conducted in March–April 2014. A multi-stage sampling technique was used to select the study districts and 450 farm households. Details on the sampling method may be found in [1]. A structured questionnaire was used to collect the relational (social network) data on actor linkages, their socio-economic attributes, and adaptation to climate change (for the detailed survey questionnaire, please see [47]). Before the final data collection, the questionnaire was pre-tested in the field to avoid missing any important information. Data collection was done with the help of three enumerators hired from the local agricultural university located in Faisalabad, Pakistan. The enumerators were trained in the questionnaire terminology and data collection techniques.

After that, the social network data were converted into an actor matrix and analyzed for brokerage using the algorithm for measuring the extent to which a vertex (actor) lies on the path between other vertices (actors) (called betweenness centrality) that finds the geodesics (specific structure) in the network and then computes the potential connections of every actor in the community. The output data were then visualized as a sociograph using NetDraw™ that efficiently illustrates the actual situation at the grassroots [48].

To simplify our understanding of the networks at the local level, we divide the data sets into two main categories, climate adaptation access (CA_Access) and financial support. Climate adaptation access deals with activities directly related to climate change and adaptation and includes extension services, weather information and water delivery. Financial support deals with activities that increase the adaptive capacity of farmers through an increase in agricultural output or income for the farmers and includes agricultural credit, marketing information, post-harvest processing and the marketing of produce and farm machinery. Table A1 in Appendix A describes the acronyms representing the nodes in both networks.

3. Results and Discussion

3.1. Descriptive Statistics

Table 1 shows the socioeconomic characteristics of the sample households in the study regions. The average years of schooling of the respondents were around nine years and the average age was around 47 years. These findings were similar to other studies conducted in Punjab, e.g., [49,50]. The average household size was around 10, which was a bit higher than the provincial average of seven members [50]. The study findings show that the average farm size was around six hectares and the average income around 1326 thousand Pakistan rupees. For the majority of the farm households, agriculture was the main source of earnings, as it contributes about 71% of the total household income in the study regions, while the share of non-agricultural income was around 29%. Regarding the use of formal credit facilities, the study findings show that only a small fraction of respondents (8%) had actually used credit services from any formal source. However, the majority of farmers (81%) reported having access to marketing information and modern telecommunication tools. It is also observed that both of these services play a major role in accessing production and climate-related information among farmers. However, the access to farm advisory services (21%) was found to be limited in the study area. This might be due to the limited human resources available to the public organization to provide advisory services at the farm level. These results are in line with the findings of [51] that show limited access to an extension in other parts of Pakistan as well.

Table 1. Descriptive statistics.

Variables	Mean	Standard Deviation
Years of schooling	8.63	4.25
Age (years)	47.46	12.44
Land holdings (hectares)	6.47	11.33
Household size (numbers)	9.90	5.05
Average Income (000 PKR)	1326	98
Agricultural share in total income	0.71	0.49
Non-Agricultural income	0.29	0.36
Credit use	0.08	0.27
Marketing information	0.64	0.48
Access to modern telecommunications (mobile phones, internet)	0.81	0.47
Agricultural extension services	0.21	0.41

3.2. Climate Change Impacts and Adaptation Strategies

Farmers in the study area were mainly of the view that climate change is happening and affecting their crops and livelihoods mostly in a negative sense (Figure 2). The majority of the farmers reported a decrease or uncertainty in crop yields, an increase in the cost of production due to climate-induced pests and diseases and water shortages as key negative impacts of climate change at the farm level. However, the farmers in the rain-fed district (Gujrat) perceived more negative impacts in terms of a decrease in crop production than the other two districts. In response to the perceived changes, farmers adapt various measures to climate change. Overall, 58% of the farmers adapted to climate change. However, adaptation was highest in the Gujrat district (70%) and lowest in Rahim Yar Khan (49%). Changing crop varieties, sowing dates, crop types, sowing and harvesting dates and planting trees are the key adaptation strategies in the study area. Few farmers also adopted crop diversification, soil and water conservation, migration as adaptation measures to climate change. The adoption of adaptation strategies varies across the three regions depending on the nature of climatic risk. For instance, changing cropping varieties and sowing dates were adopted more in rain-fed regions, because farmers in Gujrat mainly rely on rainfall for their crop production and due to changes in climate they have had to adjust their farming practices accordingly. Changes in input mixes and crop types are adopted more by farmers in Rahim Yar Khan, where farmers have better access to irrigation water and can afford such changes in farming practices. Similar to the findings of the study, other studies conducted in different parts of Pakistan, e.g., [36,37] are also evidence that farmers are aware of changes in climate and adopting different coping strategies to reduce the negative impacts of climate change at the farm level.

However, some farmers do not adopt any measures, mainly due to some constraints reported by farmers, such as lack of information, lack of financial assistance and limited resources. Here, lack of information deals with access to information on how to cope with different climatic risks and possible adjustments to current farming practices in light of climate change. However, due to the limited outreach of extension services, mostly farmers remain unaware of advanced measures to tackle issues at the farm level. It is also observed that mainly small farmers complain about little access to extension services, while large farmers mostly have good connections with public extension officers to avail themselves of different kinds of information [1]. Further, a lack of financial assistance deals with the financial capacity of farmers to invest in agricultural adaptation. As we have already seen, only a few farmers have actually availed themselves of formal credit, since the farmers in the study area are small and are unable to fulfill the requirements to obtain formal credit. Sometimes, they are also hesitant to obtain formal credit due to high interest rates and credit-tenure [1,40]. The third constraint deals with access to resources, which are limited in the study area. Limited access to resources such as water and farm inputs is mainly due to small-scale farming and biased resource access to farmers. Many resources like water and quality fertilizer and pesticides are accessible by large farmers.

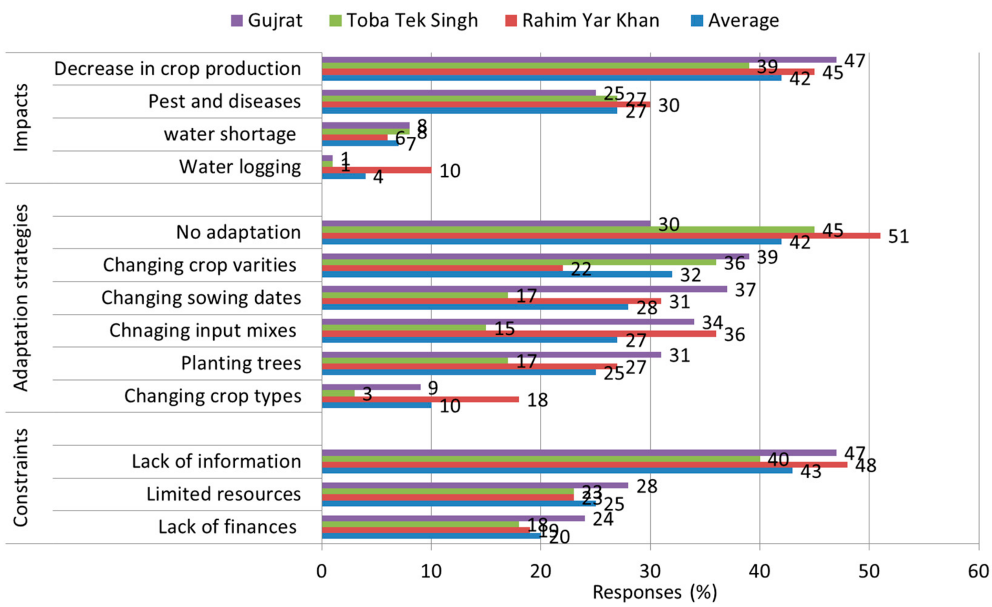

Figure 2. Climate change impacts, adaptation strategies and constraints in the study area.

3.3. Linking Climate Change Adaptation Social Networks and Institutional Services

3.3.1. Institutions Providing on-Farm Services

Access to different institutional services could play an important role in determining farmers' resilience or adaptive capacity to cope with the consequences of climate change at the farm and household level. For instance, with better institutional access, farmers could be well prepared and also be able to adjust their farming practices according to changes in the climate, and hence may protect their crops and livelihoods from the negative impacts of climate change. On the other hand, limited institutional access may become the cause of the increasing vulnerability of farmers to climate change and could also reduce the level of adaptation to climate change. Here, we discuss a different kind of institution and their services in the context of climate change adaptation.

There are three types of institutional governance systems active in rural Pakistan that support farmers in the provision of different kind of services to improve crop productivity and adaptation to climate change (see Table 2 for details). The first system is the public agencies or entities that have the vast public infrastructure and top-down institutional hierarchy to serve farmers at the grassroots level. These entities are present at the federal, provincial, district and even at union council level. Most of these entities are established with the sole objective of enhancing agricultural productivity in the region by providing low-cost or free-of-cost services to farmers. Some of the key services provided by these entities include an extension or advisory services regarding the enhancement of crop and livestock productivity, pest scouting, subsidized water-saving technologies, soil and water testing, marketing information and credit facilities. Particularly, the extension department is of much importance as it directly links to farmers in providing crop-specific information to enhance productivity. In Punjab, the extension and adaptive research wing of the department of agriculture (headquarters in Lahore) are responsible for providing public extension services to farmers through its extended extension network ranging from the regional (province to district) to the local level (union council to village and farm level). The second type of institutional governance system consists of private organizations, including non-governmental organizations that are present from the regional to the local scale and are mainly involved in the selling and distribution of farm inputs and services to farmers. Some of the key services provided by private entities include agricultural credit, input distribution, farm advisory services, farm implements, weather, and marketing information. Although some of these free services, i.e., farm advisory services could be the part of the marketing strategy of a private organization that aims to increase their profits through selling different agricultural products (fertilizer, seeds, and pesticides) to farmers. The third type is the informal community-led groups or connections that farmers use to avail themselves of different services including informal credits, farm implements, weather, and marketing information. Mostly, these connections consist of small circles of friends and co-farmers that work on the principle of trust and sharing and help each other in times of need.

Table 2. Institutions that provide on-farm services to farmers.

Institutions	Location	Type	Services
Agricultural Extension	Regional/village level	Public	Advisory services regarding crop and livestock production
On-Farm Water Management	District	Public	Watercourse improvement and subsidized farm implements including water-saving technologies
Pest Warning & Quality Control of Pesticides	Sub-district level	Public	Pest scouting, farmer training
Punjab Seed Corporation	Sub-district level	Public	Seed sales, farm advisory services, seed quality testing
Soil and Water Testing Laboratories	District	Public	Soil and water testing services to farmers
Directorate General Agriculture (Field)	District	Public	Land leveling, soil and water conservation and water resource development
Directorate of Agriculture (Economics & Marketing)	Provincial/Sub-district level	Public	Online agriculture marketing information service, capacity building at farm level
Pakistan Agricultural Storage and Services Corporation	Sub-district level	Public	Marketing of cereal grains
Pakistan Meteorology Department	National/provincial	Public	Weather forecasting information
Irrigation Department	Sub-district	Public	Irrigation water services
ZTBL	Provincial/sub-district	Public	Credit
Micro Credit institutions	Sub-district	Private	Credit
Input producing and distribution companies	Sub-district/Village level	Private	Input sales and distribution, agricultural information services
Friends and colleagues	Village level	Community	Informal credits, farm implements, weather and marketing information,
Telecommunication sources (TV/Radio/Internet)	Online/Local	Private	Extension, weather and marketing information

Figure 3 shows the connections and linkages between public and private institutions, where the color shows the active (dark blue lines) or inactive connection (light blue lines) between two institutions, whereas the density of lines shows the strength of the connection between connected institutions. Active connection means that two or more institutions work jointly for the provision of some on-farm services to farmers, while the inactive linkage means that an institution does not have any interaction on linkage with other institution and works separately. Figure 3 shows the presence of many inactive connections between actors, implying that most of the institutions are not well-connected and normally work in isolation from other neighboring institutions. However, only the extension department is somehow connected to other institutions such as on-farm water management (OFWM), irrigation department, pest warning, agricultural field and some private companies that provide advisory and information services to farmers. On some occasions, these institutions work jointly with the extension department to provide on-farm services to farmers, such as information on water-saving technologies, farming practices, new fertilizers and pesticides. In line with our findings, various studies, e.g., [51–53] also stated the weak linkages and coordination between allied state and non-state institutions related to agriculture in Pakistan. This lack of coordination could lead to the inefficient use of the public resources allocated to agriculture and may also be one of the reasons behind the poor performance of most of the public institutions in providing services to farmers. It is quite possible that through joint collective actions, these institutions could provide services to many farmers using fewer resources. However, this kind of horizontal integration and collective actions require proper policies.

Figure 3. Connections and linkages between different institutions that provide on-farm services to farmers; bold blue lines represent active links while dim blue lines show missing or inactive links between different actors.

3.3.2. Farmers' Access to Institutional Services

The study results reveal that 89% of the farms surveyed have access to any of the 24 categories of institutions and eight main types of services that are offered to farmers, while the remaining respondents do not participate in the services offered by various institutions. However, not all the farmers have complete access to all services, as this depends on the farmer's socio-economic status and resources.

Private, public and community institutions offer the community information related to weather conditions and also ways to adapt their agricultural livelihoods. The services provided to farmers can be classified into two categories, namely access to financial services and access to adaptation knowledge services. The results from the study show that only 28% and 13% of the respondents do not have access to any financial services and climate adaptation knowledge respectively.

Access to financial services is provided through agricultural credit services, affordable farm equipment (lease/buy options), marketing farm produce, post-harvest services and general marketing information. These services enhance the farmers' ability to increase their capacity to buy more seeds, equipment to plough larger parcels of land, avenues to market their products or learn new agricultural skills or plants with higher profits and increase the value of their harvested produce before selling for more profits. This is the business-as-usual scenario for most agricultural sectors.

However, in addition to increasing agricultural productivity, there are institutions that offer services related to climate-related matters and new knowledge in smart agriculture to increase livelihood output despite changing climatic conditions. The access to climate adaptation knowledge services includes agricultural extension services, provision of weather information and delivery of water to villages. The study revealed that respondents have 32%, 96% and 82% access to extension services, weather information and water delivery services, respectively, in the climate adaptation knowledge area.

3.3.3. The Institutional-Services–Farmers Network

The social network data were analyzed to assess the network density, structural holes, and suitable brokers. Figures 4 and 5 show the adaptation access and financial support networks, where farmers in three districts (Rahim Yar Khan, Toba Tek Singh and Gujrat) are connected to different institutional actors in both networks.

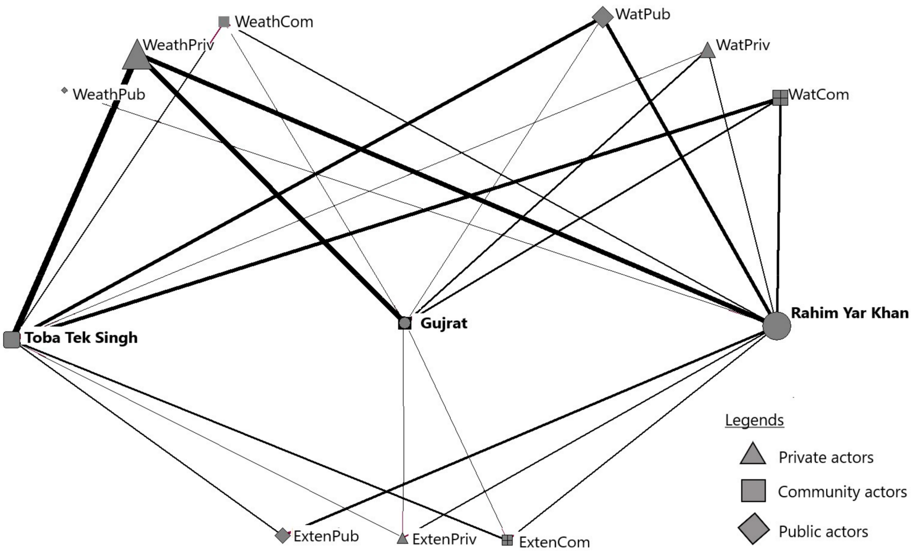

Figure 4. Social network showing linkages from farmers to climate adaptation knowledge sources. Thick and bold links represent higher link densities between actors, while actor size is an indication of the number of linkages an actor has in the network. The type of line indicates how strong or weak the linkage is in the network. Similarly, an actor with more connections with other actors appears bigger compared to actors with fewer connections in the network.

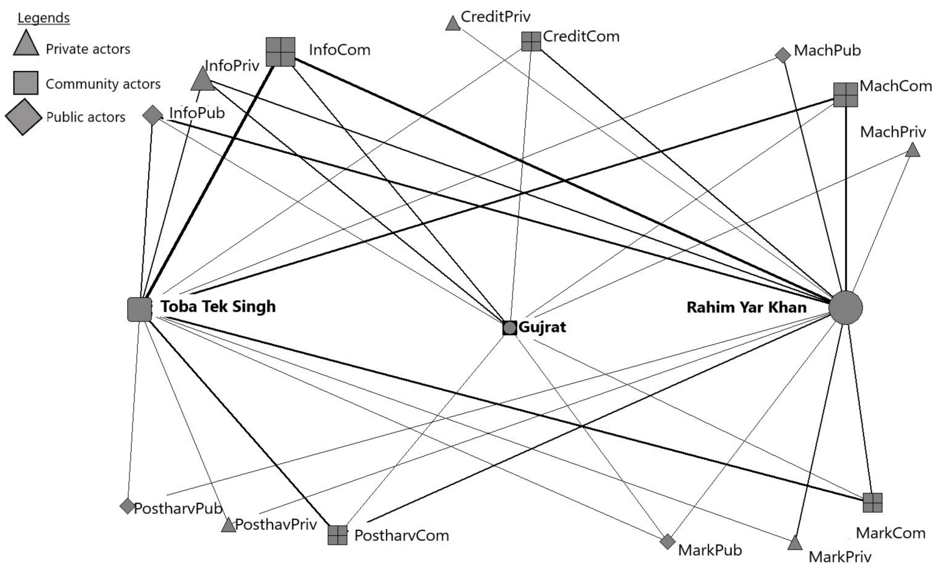

Figure 5. Social network showing linkages from farmers to financial services sources. Thick and bold links represent higher link densities between actors, while actor size is an indication of the number of linkages an actor has in the network.

According to the study results, network with density of 0.013 emanating from the 2938 ties between the actors confirms the few links between stakeholders involved in the agriculture sector. In the adaptation network represented in Figure 4, farmers in all three districts are well connected to weather information from private sources (WeathPrv), followed by water delivery information from public (WatPub) and community sources (WatCom). Private sources through which farmers acquire weather forecasting information include modern telecommunication means such as the internet, radio and television that are easily available even in rural areas. The higher dependence on private sources of weather forecasting information shows their lack of access to public information sources as shown in the network where farmers in all three regions are loosely connected with public actors. This lack of access is mainly due to lack of awareness, as there are various public entities at the federal (meteorology department) and provincial (agriculture department) levels using their web portals to disseminate information on daily and seasonal weather forecasting and issue alerts especially for farmers.

Further, water delivery information comes to farmers mainly from public sources, such as the irrigation department, or community sources including friends, relatives and co-farmers. In rural areas, it is common to have contacts with lower rank irrigation staff to acquire water-related information particularly during the crop sowing and early growth stages. These findings are in line with other studies, e.g., [1,54,55] conducted in parts of Punjab province of Pakistan showing the role of local connections in acquiring water and agriculture-related information. Agricultural extension, an important factor in the network, which is supposed to be an essential component of agricultural development, is found to be loosely connected to the network compared to the other two actors. Particularly, in the rain-fed district (Gujrat) access to public extension is highly restricted compared to the other two districts. Farmers rely mainly on community source actors to acquire extension and agricultural information followed by public and private extension sources. In line with our findings, Yaseen [56] also reported that about half of the farmers in Punjab rely on the community, while a very low percentage of farmers actually have access to public or private extension sources. Similarly, the findings of other studies, e.g., [54,55,57] also confirm the notion of the limited role of public institutions in the provision of various on-farm services to farmers in Pakistan. In light of the current changes in climate and the frequency of extreme events and their adverse impacts on the agriculture sector, the role of public and private extension services is very crucial [1]. However, the shortage of human resources and lack of infrastructure are some of the main challenges faced by public extension in Punjab, where each extension actor is responsible for serving hundreds of farmers. Another reason for low access to farmers may be the biased provision of extension services mainly to large farmers at the local level, as reported by many studies in Pakistan, e.g., [1,51,52].

In the financial support network shown in Figure 5, marketing information (InfoCom) and farm equipment (MachCom) from community sources and marketing information from private sources (InfoPrv) are highly-connected factors among farmers in all regions, while agricultural credit (Credit), marketing of farm products (Mark) and post-harvest services (Postharv) were loosely-connected factors. However, the connections within the financial network vary across regions. For instance, the study results suggest that farmers in Rahim Yar Khan are more connected to institutions and farmers in Gujrat are loosely connected. Further, the role of public institutions in providing financial support to farmers is not impressive, as farmers mainly rely on the community sources such as friends and co-farmers and private sources like input dealers and sellers. The loosely-connected public marketing information (InfoPub) is mainly due to the lack of recognition of it as a product among public institutions [56]. For farm equipment, farmers again rely mostly on the community and less on private and public sources. Here it is important to mention that the agriculture department in Punjab has launched a project to provide farm equipment such as laser-guided land levelers and water saving technologies at a subsidized cost through its on-farm water management departments, which are operative at the sub-district level [58]. Unfortunately, not all the farmers have access to those services due to a lack of awareness and capacity to pay the starting cost (initial investment) of the equipment.

Agricultural credit, an important factor in providing support to farmers in case of climate shocks and other disasters, is the weakest factor in the network. Access to public sources of credit is very limited in Gujrat and Toba Tek Singh and hence farmers in those areas rely totally on the community for financial support. These findings are in line with the results of the study [58,59], which reported that only 15% of farmers in Pakistan have access to a public source of credit. However, this ratio further decreased to 6.5% for poor farmers [58,59]. Further, a high interest rate, lack of collateral or guarantee and lengthy processing may be some other reasons behind this poor credit access at the farm level. Further, the loosely-connected marketing of produce and post-harvest services implies that farmers in Punjab are most likely to get unfair prices for their produce due to the non-availability of marketing services. Here the role of a middleman is very important to discuss. Due to the lack of marketing infrastructure and access to local and regional markets, small farmers mainly sell their produce to the middleman at lower prices, which is one of the many reasons for low income at the farm level. Further, the non-availability of postharvest services at the local level shows farmers' inability to add value to their crops by the use of advanced technologies such as cold storage and grading and selling products at higher prices. All these findings imply that limited access to financial support services may have an adverse impact on the adaptive capacity, and anticipated climatic changes may lead to more vulnerability at the farm level in the absence of proper support infrastructure.

3.3.4. Structural Gaps in Current Institutional Support

Given an ego-network representing the set of nodes (factors) with direct ties to the focal nodes (farmers in different regions), a structural hole represents the absence of a tie among a pair of nodes in the ego network [48,60]. The lack of structural holes around a node means that the node is well bound to other nodes to communicate and provide financial or adaptation knowledge services to farmers (focal nodes) [48]. Here in this study, we tried to explore the structural holes and gaps in the current institutional support to farmers using betweenness, brokerage and degree measures. The factors with more values in all three aspects may be better connected or bounded with farmers in providing different financial and adaptation services to farmers and vice versa.

Figure 6a,b presents the structural holes (betweenness, brokage) and degree of actors in both financial support and adaptation networks. Figure 6a shows that most of the adaptation factors are loosely connected to farmers and provide little support to farmers, especially in extension services for better crop production and information on new cropping technologies. The highest response (betweenness) is received by weather forecasting information from private sources (WeathPrv), with 60,256 ties and 330 degrees, while the lowest response was found in the case of weather information from the public (WeathPub) and private extension (ExtenPrv) with 87 and 85 ties and seven and 18 degrees, respectively. Similarly, Figure 6b shows that except for marketing information and farm machinery, all other services are loosely connected to farmers in the financial network. The highest response was found in case of marketing information from public sources (InfoPub), with 30,718 ties and 167 degrees; while the lowest connection was found in case of credit from public sources (CreditPub) with zero ties and degrees. All these results show that farmers in both networks have limited access to institutional services. Thus, institutions need to extend their support regarding all services so that farmers may benefit and enhance their adaptation and adaptive capacities.

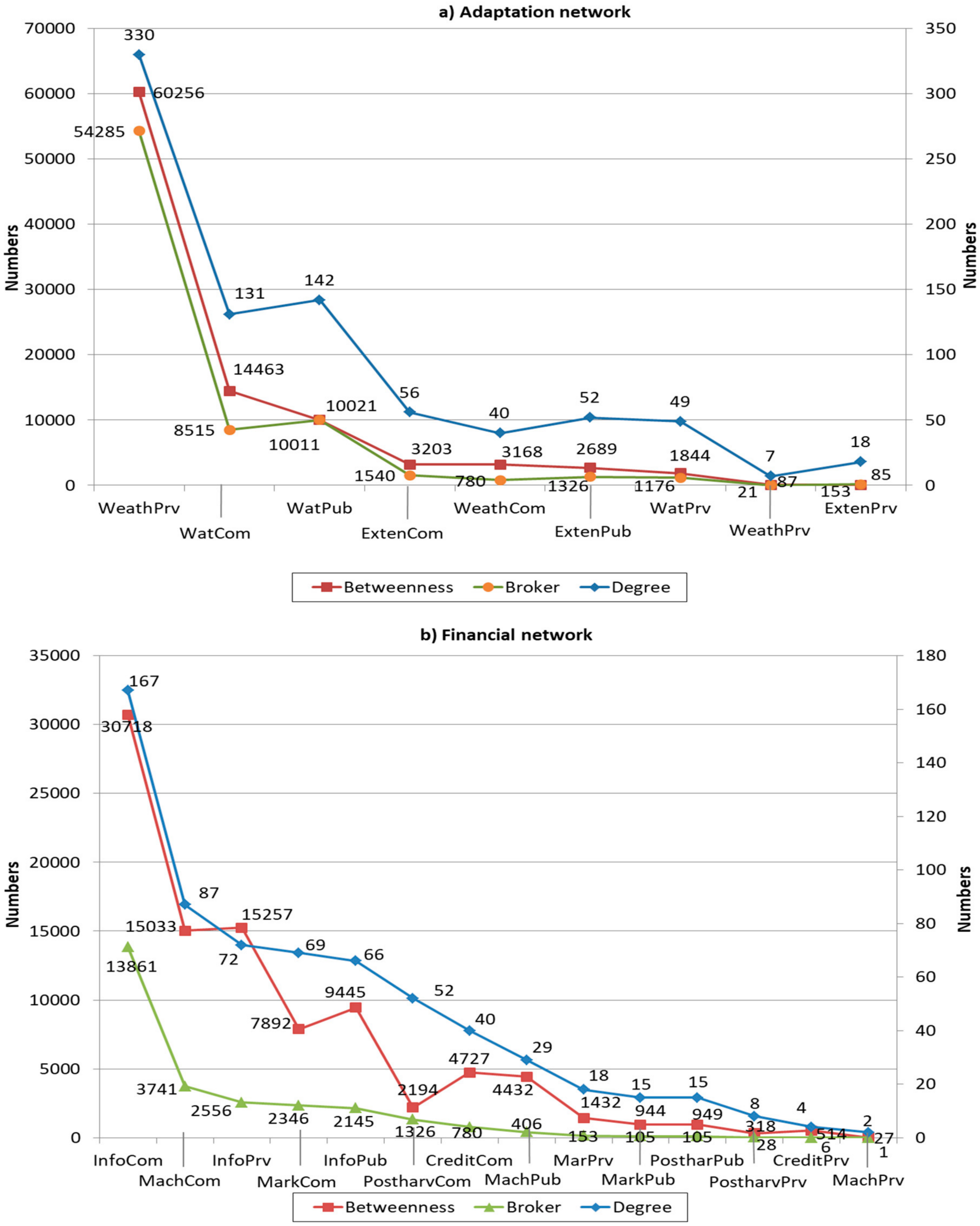

Figure 6. (**a**,**b**) Structural gaps in the current institutional support to climate adaptation. The red lines show the betweenness between farmers and different institutional factors that count the number of network pathways passing through an actor, the green lines show the broker linkages which indicate how much potential control an actor has in spreading information or providing services in a social network and the blue lines (on secondary vertical axis) indicates the degree of different factors showing the absolute number of connections of each factor with farmers from all regions.

3.3.5. Adoption of Different Adaptation Measures and Access to Institutional Services

The study findings show that farmers are aware of climate change and make changes to their farming and livelihoods according to perceived climate change impacts. However, their decision to adapt is mainly dependent on the availability of the resources and information required to implement certain adaptation options at the farm level. For instance, farmers in our study preferred to adopt those measures which are cost-effective and easy to adopt, such as changes in crop varieties, crop types, plantation dates and input mixes. However, the adoption of advanced adaptation measures such as soil and water conservation methods, tree plantation, farm diversification and renting out land or migration was not very common among farmers for several reasons.

Further, to assess the adoption of different adaptation measures concerning interaction with different social networks, we formed three cases based on access to different services provided by different actors (Table 3). Case 1 includes services that update farmers with knowledge related to crops, weather and the market. Case 2 deals with access to knowledge plus financial services that could enhance farmers' financial viability. Case 3 deals with access to adaptation knowledge, financial services and physical resources (farm machinery) that could enhance a farmer's overall adaptive capacity. The study results presented in Table 1 show that the adaptation response increases while moving from Case 1 (38%) to Case 2 (47%) and Case 3 (51%). This implies that adaptation increases when farmers have more access to different kind of services that are required for an effective adaptation to climate change. Further, we explore the adoption of adaptation measures under different access cases. It is clear from the study findings that farmers prefer the adoption of short-term and low-cost measures (changing crop varieties, crop types and planting dates), when they only have access to knowledge services (extension, market and weather forecasting information) under Case 1. However, when credit services are added to the knowledge services (Case 2), then farmers adopted some other measures (changes in input mixes like fertilizer, water and pesticide) that require more investment in addition to previous measures adopted under Case 1. Further, under Case 3, measures related to soil and water conservation, tree plantation and crop diversification are added to the list of adaptation measures. It implies that when farmers have sufficient physical and financial resources in addition to knowledge resources then they will also adopt advanced measures along with adoption of short-term solutions. These findings are in line with other studies, e.g., [1,11,39] showing positive role of social capital in enhancing local adaptive capacities to climate change.

Table 3. Adoption of different adaptive measures and access to farm services.

Access to Services	Adaptation Response	Adaptation Measures
Case 1: Simultaneous access to extension services, market and weather forecasting information	38%	Changing crop varieties, crop types and planting dates
Case 2: Services under scenario 1 and access to credit services	47%	Changing crop varieties, crop types, planting dates, irrigation and input mixes like fertilizer, water and pesticide
Case 3: Services under scenario 1 and 2 and access to farm machinery	51%	Changing crop varieties, crop types, planting dates, irrigation, input mixes, soil and water conservation, tree plantation and farm diversification

3.4. Enhancing the Role of Local Stakeholders in Adaptation to Climate Change

Following our previous results and based on a framework from [61], the study explored the interaction of three main stakeholders for effective adaptation by looking into four key areas, namely information sharing, innovation and investment, capacity building and insurance. Leftmost part of the Figure 7 describes the current situation of interaction between the major actors in the study area. The arrow signs show the direction of service from one actor to the other, which may be either one-directional or two-directional. The dotted line(s) shows the weak or missing links, while the straight lines show the significance of the interaction between actors. Our study findings reveal that public institutions are more active in providing information services and investing at the rural or community level to provide different on-farm services, while the private sector is more involved in information delivery, the capacity building of farmers and innovation and investment. However, one thing is common in the work of public and private sector organizations, namely that most of their services are supply-driven (one-directional) and do not incorporate backward linkages with farming communities [54].

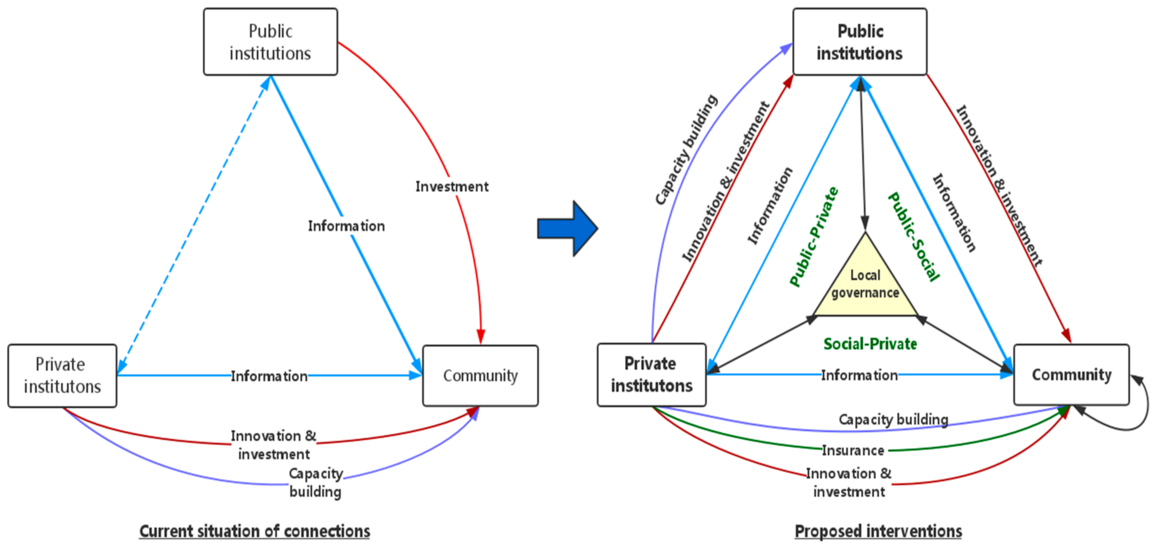

Figure 7. Current and enhanced interactions for local level adaptation to climate change.

For instance, various public and private sector institutions are investing and providing small- or medium-scale agricultural loans to farmers, but they do not care for which purpose farmers use that credit. Similarly, the provision of advisory services to farmers is one-directional, where public or private extension workers are supposed to provide advice to a certain number of farmers and to meet their targets [1]. They do not even care about the actual needs of farmers. Here, public institutions have the advantage of their presence at the local level through its top-down hierarchy, but they are unable to deliver services adequately due to a lack of physical and human resources. On the other hand, private institutions have sufficient financial viability, but their outreach is limited in terms of area and scope. Further, capacity building is completely missed in the framework, with some exceptions in the case of private sector organizations that have designed limited ability building programs and training for farmers. Further, linkages between private and public institutions are very weak and no single instance was found in the study area where both kinds of institutions interact together to provide joint services to farmers.

To enhance the effectiveness of the existing institutional setup and to prepare it for effective adaptation to climate change, we propose an improved framework as shown in the rightmost part of the Figure 7. This framework involves filling missing links and suggests focusing on partnerships and collaborative work at the various levels to provide better services to farmers so that they may effectively adapt to climate change. The basic stimuli for such collaborative actions arise from the limitations in terms of the function, capacity and scope of institutions within the public, private and community domains. Each institution has some limits and may not have all the required expertise. Hence, through active cooperation and collaboration, different stakeholders may benefit from each other's expertise to fulfill their common goal of agricultural sustainability and improving farmers' wellbeing.

Increasing adaptive capacity is dependent on the acquisition of information and technologies at farm level; hence an increase in the coverage by on-farm services in the study area will enhance adaptive capacity [12]. Therefore, through this study, we proposed an integrated framework to improve the support to farmers so that they may be able to better adapt to climate change. This frame, provided in Figure 7, suggests four types of partnerships, i.e., public–private, private–social, public–social and community–community. For collective action and collaboration, the role of the central government is critical and may act in this framework as a connecting body to facilitate and connect all stakeholders. Now we will discuss these partnerships one by one.

Public–private partnerships: Public–private partnerships (PPPs), which involve the private sector as a partner in recognizing and adapting to climate change in developing economies, are essential for multiple reasons. PPPs may play a key role in mobilizing financial resources, enhancing technical capacity, engaging communities and developing climate services and adaptation technologies [62]. Public and private sector organizations may use each other's expertise and may thus serve better than individually. The public sector may dominate in providing the startup infrastructure and physical resources required to initiate joint adaptation efforts. Private entities may provide their expertise to infrastructure investments and agricultural research to develop more drought-resistant varieties, water management infrastructure and technologies, capacity building of government officials and service providers. It is observed that most public institutions are related to agricultural work in isolation from their sister institutions. Therefore, public–private partnerships will not only help to connect public and private entities, but will also join all public institutions to work together for climate change adaptation in the agriculture sector. Further, these partnerships may also be helpful in designing effective dissemination and training models to provide adaptation services and training to farmers such as joint farmer field days, discussion groups, exchange visits [63]. The local adaptive capacity may also be improved through public–private collaborations, where the private sector may be engaged to develop financial assistance services to farmers exposed to climatic risks and disasters such as floods, extreme temperature events and droughts [64].

Social–private partnerships: Social–private partnerships are mainly suggested to improve communication between communities and private sector organizations working in rural areas. As various private sector bodies provide advisory and technical services to farmers to improve their crop productivity. Private sector institutions may involve communities to get their feedback about provided services and may enhance their services according to farmers' needs [65]. Private sector organizations in cooperation with public entities and communities may design schemes to provide farm level access to advance on-farm services such as water and soil testing laboratories, need-based farm advisory services and climate-smart loans. However, active monitoring and checks may be required to ensure the effective use of climate-smart loans.

Another component of climate change adaptation is the insurance to climatic risks, which has been completely ignored in the agricultural sector in Pakistan. The private sector may take advantage of this gap and may develop some insurance schemes to protect farmers from climatic shocks. Risk is always recognized as a constraint to the adoption of new practices and technologies [66]. Providing farmers with risk insurance will enable them to take more risk to generate more profit. Initially, risk insurance schemes may be tested on a small scale for single crops before it is extended to a larger area and multiple crops.

Public–community partnerships: Public–community collaboration is essential to transform supply-driven services towards need-based services. Most of the on-farm services, including extension and on-farm management, do not consider the currently changing needs of farmers [67]. Through public–community partnerships, public entities may be able to collect information from farmers on their needs and issues to improve service delivery, introducing need-based services and solutions to farmers. Here, the collaboration of public–private partnerships may also play a useful role in this transformation.

Another important aspect of these collaborations may be to use already-established networks and farmer groups. For instance, in Punjab, under the new irrigation reforms, farmer organizations have been established at canal circle level to manage irrigation water and to collect water charges [68]. These organizations have elected members and public offices and have connections at the grassroots level. Thus, public entities may use these established organizations to improve their service delivery and extend their scope, including climate change adaptation services.

Community–community collaborations: Another perspective of social networking may be to enhance community-to-community and farmer-to-farmer interactions to enhance local adaptive capacity and service provision. Various studies, e.g., [1,39,40] have identified the potential role of such cooperation in enhancing local adaptation decision-making. Further farmer organizations may also play a significant role in increasing such forms of networking among farmers through community meetings. Public and private institutions may collaborate with each other to arrange capacity-building training for farmers to highlight the importance of collective work and to teach methodologies to increase resilience to climate change.

4. Conclusions

Social networks can play a key role in enhancing the adaptive capacity of farming communities to climate change. Using a cross-sectional dataset of 450 farm households, this study examines social networks at the local level and their role in the adaptation process and investigates the structural gaps in the current institutional support at the farm level.

The study reveals that most of the farmers have access to various kinds of institutional services. However, still, there were some respondents who do not participate in any services provided by various institutions. Private, public and community sources provide diverse types of climate change adaptation and financial support services to farmers. However, the findings of the social network analysis indicate that the network has very low density, showing various loosely connected factors in the system. The results from both networks show that District 3 (Gujrat) has the lowest response to activities across the study area and within the three categories. In the climate change adaptation network, farmers are strongly connected to private sources to acquire weather forecasting information and are loosely attached to a public source of weather forecasting information. Weather forecasting information from public sources was completely missing in the case of Gujrat and Toba Tek Singh and only a few farmers in Rahim Yar Khan have access to a public source of weather forecasting, which could be due to the presence of the weather station in Khanpur. Weather stations in the other two locations are far away from the respective cities. Particularly agricultural extension, an important source of information for farmers to improve farm productivity, is found to be very weak in the Gujrat district. This could be due to several factors: it has the highest null response rate of 31%, because the area is characterized by high subsistence agriculture, low education and the low availability of surface water. Similarly, in the financial support network, farmers were mainly connected to marketing information from community sources and marketing information from private sources. This indicates how loosely farmers are linked to public sources of services and how positively community sources are serving farmers to improve their resilience and adaptation to climate change. The social network analysis also reveals that the farmers in Gujrat district are least connected, compared to farmers in the other two districts. Further, the adaptation response was high in cases where farmers are well connected with social actors and are provided with sufficient services. Greater adoption of advanced measures by farmers with sufficient knowledge, physical and financial resources implies that the provision of physical and financial resources to farmers is very important to enhance their local adaptive capacity and the adoption of all kinds of adaptation measures.

The study further analyzed the current institutions (public, private and community) at the local level in terms of four key areas (information, innovation and investment, capacity building and insurance) and found that public and private institutions are not linked at the local level. Further, most of the services provided by public and private institutions are one-directional and miss the backward linkages with communities and farmers. Public and private organizations also fail in the insurance part of the framework. Based on the study findings and review of the literature, this study suggests an improved integrated framework to enhance the networking between different stakeholders. This framework mainly focuses on the four kinds of partnerships between the various ties of the local network such as public–private, private–social, public–social and community–community linkages. Such collaborations at the local level could improve the financial viability and adaptive capacity of farmers and may help them to improve their crop productivity and livelihoods.

Acknowledgments: This study is part of Ph.D. research at the University of Hamburg, Germany at the School of Integrated Climate System Sciences (SICSS). We gratefully acknowledge all the funding sources for this research such as Higher Education Commission (HEC), Pakistan; Deutscher Akademischer Austauschdienst (DAAD); Kompetenzzentrum Nachhaltige Universität (KNU) and the Research Group Climate Change and Security (CLISEC) in the Exzellence Cluster "Integrated Climate System Analysis and Prediction" (CliSAP) supported by Deutsche Forschungsgemeinschaft (DFG). We are also thankful to the local agricultural departments, farm households and enumerators for their time and coordination of the successful data collection during March and April 2014.

Author Contributions: M.A. developed the study framework and conducted the field research to collect data for the study. M.A., N.G. and J.S. designed the methodology. M.A. and N.G. analyzed the data. M.A., N.G. and F.Z. described and discussed the results. J.S. and F.Z. critically reviewed the paper for improvements.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Acronyms representing nodes in adaptation and financial support networks.

Factors in Networks	Acronyms
1. Adaptation Network	CA_Access
Public extension services	ExtenPub
Private extension services	ExtenPrv
Community extension services	ExtenCom
Weather information public sources	WeathPub
Weather information private sources	WeathPrv
Weather information community sources	WeathCom
Water delivery information public sources	WatPub
Water delivery information private sources	WatPrv
Water delivery information community sources	WatCom
2. Financial support network	Fin_Support
Agricultural credit public sources	CreditPub
Agricultural credit private sources	CreditPrv
Agricultural credit community sources	CreditCom
Marketing information public sources	InfoPub
Marketing information private sources	InfoPrv
Marketing information community sources	InfoCom
Post-harvest processing public sources	PostharPub
Post-harvest processing private sources	PostharPrv
Post-harvest processing community sources	PostharCom
Marketing of agricultural products public sources	MarkPub
Marketing of agricultural products private sources	MarkPrv
Marketing of agricultural products community sources	MarkCom
Farm machinery and implements public sources	MachPub
Farm machinery and implements private sources	MachPrv
Farm machinery and implements community sources	MachCom

References

1. Abid, M.; Schilling, J.; Scheffran, J.; Zulfiqar, F. Climate change vulnerability, adaptation and risk perceptions at farm level in Punjab, Pakistan. *Sci. Total Environ.* **2016**, *547*, 447–460. [CrossRef] [PubMed]
2. Abid, M.; Scheffran, J.; Schneider, U.; Ashfaq, M. Farmers' perceptions of and adaptation strategies to climate change and their determinants: The case of Punjab province, Pakistan. *Earth Syst. Dyn.* **2015**, *6*, 225–243. [CrossRef]

3. IUCN. Climate Change; Vulnerabilities in Agriculture in Pakistan. 2009. Available online: http://cmsdata.iucn.org/downloads/pk_cc_agr_vul.pdf (accessed on 10 August 2016).
4. Kreft, S.; Eckstein, D. *Global Climate Risk Index 2014: Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2012 and 1993 to 2012*; Germanwatch eV: Bonn, Germany, 2013.
5. Intergovernmental Panel on Climate Change (IPCC). *Mitigation of Climate Change, IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation 2011*; IPCC: Geneva, Switzerland, 2011.
6. Government of Pakistan (GOP). *Pakistan: Flood Impact Assessment*; Special Section: Economic Survey of Pakistan; Ministry of Finance; Government of Pakistan: Islamabad, Pakistan, 2011.
7. Adger, W.N.; Huq, S.; Brown, K.; Conway, D.; Hulme, M. Adaptation to climate change in the developing world. *Prog. Dev. Stud.* **2003**, *3*, 179–195. [CrossRef]
8. Bryan, E.; Ringler, C.; Okoba, B.; Roncoli, C.; Silvestri, S.; Herrero, M. *Adapting Agriculture to Climate Change in Kenya: Household and Community Strategies and Determinants*; ILRI Report to the World Bank for the Project "Adaptation of Smallholder Agriculture to Climate Change in Kenya; George Washington University: Washington, DC, USA, 2011.
9. Bryan, E.; Ringler, C.; Okoba, B.; Roncoli, C.; Silvestri, S.; Herrero, M. Adapting agriculture to climate change in Kenya: Household strategies and determinants. *J. Environ. Manag.* **2013**, *114*, 26–35. [CrossRef] [PubMed]
10. Bryant, C.R.; Smit, B.; Brklacich, M.; Johnston, T.R.; Smithers, J.; Chjotti, Q.; Singh, B. Adaptation in Canadian agriculture to climatic variability and change. *Clim. Chang.* **2000**, *45*, 181–201.
11. Agrawal, A. Local institutions and adaptation to climate change. In *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*; The World Bank: Washington, DC, USA, 2010; pp. 173–198.
12. Smit, B.; Wandel, J. Adaptation, adaptive capacity and vulnerability. *Glob. Environ. Chang.* **2006**, *16*, 282–292. [CrossRef]
13. Stringer, L.C.; Dyer, J.C.; Reed, M.S.; Dougill, A.J.; Twyman, C.; Mkwambisi, D. Adaptations to climate change, drought and desertification: Local insights to enhance policy in Southern Africa. *Environ. Sci. Policy* **2009**, *12*, 748–765. [CrossRef]
14. Kiragu, S. *The Role of Local Institutions in Shaping Climate Risks Adaptation Processes and Practices among the Semi-Arid Rural Households of Mwingi, Kenya*; Universität Bayreuth: Bayreuth, Germany, 2010.
15. McCarl, B.A.; Schneider, U.A. The cost of greenhouse gas mitigation in US agriculture and forestry. *Science* **2001**, *294*, 2481–2482. [CrossRef] [PubMed]
16. Metz, B.; Davidson, O.; Bosch, P.; Dave, R.; Meyer, L. *Mitigation of Climate Change*; Cambridge University Press: Cambridge, UK, 2007.
17. Mendelsohn, R. The Impact of Climate Change on Agriculture in Asia. *J. Integr. Agric.* **2014**, *13*, 660–665. [CrossRef]
18. Reed, B.; Mendelsohn, R.; Abidoye, B.O. The economics of crop adaptation to climate change in South-East Asia. *Clim. Chang. Econ.* **2017**, *8*, 1740002. [CrossRef]
19. Alam, M.M.; Siwar, C.; Bin Toriman, M.E.; Molla, R.I.; Talib, B. Climate change induced adaptation by paddy farmers in Malaysia. *Mitig. Adapt. Strateg. Glob. Chang.* **2012**, *17*, 173–186. [CrossRef]
20. Deressa, T.T.; Hassan, R.M.; Ringler, C. Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *J. Agric. Sci.* **2011**, *149*, 23–31. [CrossRef]
21. Mugi-Ngenga, E.; Mucheru-Muna, M.; Mugwe, J.; Ngetich, F.; Mairura, F.; Mugendi, D. Household's socio-economic factors influencing the level of adaptation to climate variability in the dry zones of Eastern Kenya. *J. Rural Stud.* **2016**, *43*, 49–60. [CrossRef]
22. Carlson, K.; McCormick, S. American adaptation: Social factors affecting new developments to address climate change. *Glob. Environ. Chang.* **2015**, *35*, 360–367. [CrossRef]
23. Jordan, J.C. Swimming alone? The role of social capital in enhancing local resilience to climate stress: A case study from Bangladesh. *Clim. Dev.* **2015**, *7*, 110–123. [CrossRef]
24. Kithiia, J. Resourceless victims or resourceful collectives: Addressing the impacts of climate change through social capital in fringing coastal communities. *Ocean Coast. Manag.* **2015**, *106*, 110–117. [CrossRef]
25. Lei, Y.; Zhang, H.; Chen, F.; Zhang, L. How rural land use management facilitates drought risk adaptation in a changing climate—A case study in arid Northern China. *Sci. Total Environ.* **2016**, *550*, 192–199. [CrossRef] [PubMed]
26. Paul, C.J.; Weinthal, E.S.; Bellemare, M.F.; Jeuland, M.A. Social capital, trust, and adaptation to climate change: Evidence from rural Ethiopia. *Glob. Environ. Chang.* **2016**, *36*, 124–138. [CrossRef]

27. Alam, G.M.M.; Alam, K.; Mushtaq, S. Influence of institutional access and social capital on adaptation decision: Empirical evidence from hazard-prone rural households in Bangladesh. *Ecol. Econ.* **2016**, *130*, 243–251. [CrossRef]
28. Chen, H.; Wang, J.; Huang, J. Policy support, social capital, and farmers' adaptation to drought in China. *Glob. Environ. Chang.* **2014**, *24*, 193–202. [CrossRef]
29. Deressa, T.T.; Hassan, R.M.; Ringler, C.; Alemu, T.; Yesuf, M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Glob. Environ. Chang.* **2009**, *19*, 248–255. [CrossRef]
30. Wolf, J.; Adger, W.N.; Lorenzoni, I.; Abrahamson, V.; Raine, R. Social capital, individual responses to heat waves and climate change adaptation: An empirical study of two UK cities. *Glob. Environ. Chang.* **2010**, *20*, 44–52. [CrossRef]
31. Abbas, F. Analysis of a historical (1981–2010) temperature record of the punjab Province of Pakistan. *Earth Interact.* **2013**, *17*, 1–23. [CrossRef]
32. Hanif, U.; Syed, S.H.; Ahmad, R.; Malik, K.A.; Nasir, M. Economic impact of climate change on the agricultural sector of Punjab. *Pak. Dev. Rev.* **2010**, *49*, 771–798.
33. Jeswani, H.K.; Wehrmeyer, W.; Mulugetta, Y. How warm is the corporate response to climate change? Evidence from Pakistan and the UK. *Bus. Strategy Environ.* **2011**, *17*, 46–60. [CrossRef]
34. Siddiqui, R.; Samad, G.; Nasir, M.; Jalil, H.H. The impact of climate change on major agricultural crops: Evidence from Punjab, Pakistan. *Pak. Dev. Rev.* **2012**, *51*, 261–276.
35. Ali, S.; Liu, Y.; Ishaq, M.; Shah, T.; Ilyas, A.; Din, I.U. Climate Change and Its Impact on the Yield of Major Food Crops: Evidence from Pakistan. *Foods* **2017**, *6*, 39. [CrossRef] [PubMed]
36. Ahmad, M.; Iqbal, M.; Khan, M.A. *Climate Change, Agriculture and Food Security in Pakistan: Adaptation Options and Strategies*; Climate Change Brief; Pakistan Institute of Development Economics: Islamabad, Pakistan, 2013.
37. Rahut, D.B.; Ali, A. Coping with Climate Change and its Impact on Productivity, Income, and Poverty: Evidence from the Himalayan Region of Pakistan. *Int. J. Disaster Risk Reduct.* **2017**. [CrossRef]
38. Gorst, A.; Groom, B.; Dehlavi, A. *Crop Productivity and Adaptation to Climate Change in Pakistan*; Working Paper No. 189; Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science: London, UK, 2015; Available online: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2015/04/Working-Paper-189-Gorst-et-al.pdf (accessed on 9 June 2015).
39. Saboor, A.; Hussain, M.; Munir, M. Impact of micro credit in alleviating poverty: An Insight from rural Rawalpindi, Pakistan. *Pak. J. Life Soc. Sci.* **2009**, *7*, 90–97.
40. Abid, M.; Schneider, U.A.; Scheffran, J. Adaptation to climate change and its impacts on food productivity and crop income: Perspectives of farmers in rural Pakistan. *J. Rural Stud.* **2016**, *47A*, 254–266. [CrossRef]
41. Bodin, Ö.; Prell, C. *Social Networks and Natural Resource Management: Uncovering the Social Fabric of Environmental Governance*; Cambridge University Press: Cambridge, UK, 2011.
42. Ngaruiya, G.W.; Scheffran, J.; Lang, L. Social networks in water governance and climate adaptation in Kenya. In *Sustainable Water Use and Management*; Springer: Berlin/Heidelberg, Germany, 2015; pp. 151–167.
43. Freeman, L. *The Development of Social Network Analysis*; A Study in the Sociology of Science; ΣP Empirical Press: Vancouver, BC, Canada, 2004.
44. Prell, C.; Reed, M.; Racin, L.; Hubacek, K. Competing structure, competing views: The role of formal and informal social structures in shaping stakeholder perceptions. *Ecol. Soc.* **2010**, *15*, 34. [CrossRef]
45. Wasserman, S.; Faust, K. *Social Network Analysis: Methods and Applications*; Cambridge University Press: Cambridge, UK, 1994; Volume 8.
46. Ngaruiya, G.W.; Scheffran, J. Actors and networks in resource conflict resolution under climate change in rural Kenya. *Earth Syst. Dyn.* **2016**, *7*, 441. [CrossRef]
47. Abid, M. Climate Change Impacts and Adaptation in the Agricultural Sector of Pakistan-Socioeconomic and Geographical Dimensions. Doctor's Disseration, Department of Earth Sciences, Universität Hamburg, Hamburg, Germany, 2017.
48. Borgatti, S.P.; Mehra, A.; Brass, D.J.; Labianca, G. Network analysis in the social sciences. *Science* **2009**, *323*, 892. [CrossRef] [PubMed]
49. Abid, M.; Ashfaq, M.; Hassan, S.; Fatima, N. A resource use efficiency analysis of small Bt cotton farmers in Punjab, Pakistan. *Pak. J. Agric. Sci.* **2011**, *48*, 65–71.

50. Government of Pakistan. *Household Integrated Economic Survey 2015–2016*; Pakistan Bureau of Statistics: Islamabad, Pakistan, 2016. Available online: http://www.pbs.gov.pk/sites/default/files/pslm/publications/hies15-16/write%20up%2015-16-HIES-final.pdf (accessed on 25 October 2017).
51. Jan, I.; Khan, H.; Jalaluddin, M. Analysis of agricultural extension system: A discrepancy between providers and recipients of the extension services empirical evidence from North-West Pakistan. *Sarhad J. Agric.* **2008**, *24*, 349–354.
52. Saqib, R.; Tachibana, S. Contribution of agricultural and forestry extension services to inclusive extension system in North-West Pakistan: A case study of Mansehra and Swat districts of Khyber Pakhtunkhwa Province. *J. Agric. Ext. Rural Dev.* **2014**, *6*, 175–187.
53. Shahbaz, B.; Mbeyale, G.; Haller, T. Trees, trust and the state: A comparison of participatory forest management in Pakistan and Tanzania. *J. Int. Dev.* **2008**, *20*, 641–653. [CrossRef]
54. Davidson, A.P.; Ahmad, M.; Ali, T. *Dilemmas of Agricultural Extension in Pakistan: Food for Thought*; Overseas Development Institute (ODI), Agricultural Research & Extension Network (AgREN): London, UK, 2001.
55. Luqman, M.; Shahbaz, B.; Ali, S.; Butt, T.M.; Ashraf, S. Rural Women's Involvement and Their Constraints in Accessing Livestock Extension Services in District Faisalabad-Pakistan. *Glob. Vet.* **2014**, *12*, 550–556.
56. Yaseen, M.; Xu, S.; Yu, W.; Hassan, S. Farmers' access to agricultural information sources: Evidences from rural Pakistan. *J. Agric. Chem. Environ.* **2016**, *5*, 12. [CrossRef]
57. Rahman, S.U.; Hussain, A.; Taqi, M. Impact of agricultural credit on agricultural productivity in Pakistan: An empirical analysis. *Int. J. Adv. Res. Manag. Soc. Sci.* **2014**, *3*, 125–139.
58. Hussain, A.; Thapa, G.B. Smallholders' access to agricultural credit in Pakistan. *Food Secur.* **2012**, *4*, 73–85. [CrossRef]
59. Amjad, S.; Hasnu, S.A.F. Smallholders' access to rural credit: Evidence from Pakistan. *Lahore J. Econ.* **2007**, *12*, 1–25.
60. Meinzen-Dick, R.; Bernier, Q.; Haglund, E. *The Six 'ins' of Climate-Smart Agriculture: Inclusive Institutions for Information, Innovation, Investment and Insurance*; International Food Policy Research Institute (IFPRI): Washington, DC, USA, 2013.
61. Glendenning, C.J.; Babu, S.; Asenso-Okyere, K. *Review of Agricultural Extension in India: Are Farmers Information Needs Being Met*; IFPRI Discussion Paper; The International Food Policy Research Institute: Washington, DC, USA, 2010.
62. Hoang, L.A.; Castella, J.C.; Novosad, P. Social networks and information access: Implications for agricultural extension in a rice farming community in northern Vietnam. *Agric. Hum. Values* **2006**, *23*, 513–527. [CrossRef]
63. Biagini, B.; Miller, A. Engaging the private sector in adaptation to climate change in developing countries: Importance, status, and challenges. *Clim. Dev.* **2013**, *5*, 242–252. [CrossRef]
64. Nelson, G.C. *Agriculture and Climate Change: An Agenda for Negotiation in Copenhagen*; Policy Paper Number; The International Food Policy Research Institute: Washington, DC, USA, 2009; Volume 16.
65. Binswanger, H.P. Attitudes toward risk: Theoretical implications of an experiment in rural India. *Econ. J.* **1981**, *91*, 867–890. [CrossRef]
66. Meinzen-Dick, R.; Quisumbing, A.; Behrman, J.; Biermayr-Jenzano, P.; Wilde, V.; Noordeloos, M.; Beintema, N. *Engendering Agricultural Research, Development and Extension*; The International Food Policy Research Institute: Washington, DC, USA, 2011; Volume 176.
67. Senanayake, N.; Mukherji, A.; Giordano, M. Re-visiting what we know about Irrigation Management Transfer: A review of the evidence. *Agric. Water Manag.* **2015**, *149*, 175–186. [CrossRef]
68. GOP. Subsidies for Farmers, Government of Punjab, Pakistan. 2016. Available online: http://www.ofwm.agripunjab.gov.pk/info_subsidies (accessed on 6 October 2016).