Informing Change in the Indus Basin

Identifying Decision-making Niches for Social Network Analysis tools in Pakistan
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Introduction

Social network analysis (SNA) is rapidly-emerging as a social science tool that can help quantify the number and strength of social relations between individuals and institutions. Based on the idea that social life is determined by these relations and the network patterns they form (Marin and Wellman, 2009), these ‘Social Networks’ are comprised of nodes (individuals or collectives) that are interconnected by one or multiple types of relationships (Wasserman and Faust, 1994; Marin and Wellman, 2009). The analytical unit is not individual nodes but rather the relations between the nodes – as these are what determines how patterns change over time, and the implications of patterns for, say, decision making hierarchies and structures.

SNA research is therefore distinct from individualist or attribute-based social science (Marin and Wellman, 2009) and is increasingly being used via a range of methods, theories and mathematical tools that can assess and evaluate patterns of social relations (Borgatti et al., 2009; Stein et al. 2011) and help draw conclusions as to their significance for societal outcomes. These may include, but not be limited to, power and access to resources, social (in)equalities and the way resources are allocated and used by different groups.

Application of SNA Tools for Identifying Decision-making Niches

In recent years there has been increasing interest in the application of SNA to studies of natural resources management (NRM), in part spurred on by the failure of past natural resource governance efforts (Bodin and Crona, 2009). NRM systems usually involve a large number of different types of stakeholders, allied to different institutions and interacting in diverse ways and at multiple levels. Applications of SNA in studying how power and influence are distributed, how social ties explain social-system dynamics, how social structures and individual agency are connected and how shared attributes contribute to the formation of social clusters (around which resource access may be determined) are all considered to have immense relevance to NRM research, especially when related to socio-ecological systems relationships. (Salpeteur et al. 2017). A significant proportion of research on the topic has focused on characteristics of social networks that strengthen collective action or NRM (Prell et al. 2009), improving governance of the commons, or common pool resources. Six features that are considered important for adaptive management systems and how they translate into social network structures are detailed in Appendix 1.

SNA is a mode of analysis that is able to capture this complexity in terms of data collection, analysis and interpretation (Stein et al, 2011). An SNA approach to NRM can help to unravel how complex interactions between those connected to natural resources influence the management of these resources and how such interactions can be taken into account when creating and implementing NRM plans (Vance-Borland and Holley 2011). This applies as much to a shared irrigation system in the Punjab, say, as it does to grazing systems shared between pastoralists in East Africa.
Applications of SNA in decision-making niches for NRM and water resources management (WRM) are discussed below. As the literature on such applications in the context of Pakistan is limited, applications in other contexts have also been considered in these sections.

1. Understanding Multi-actor and Multi-level Natural Resource Governance Arrangements

Polycentric institutional arrangements – a term used by Ostrom (1998) – are increasingly seen as alternatives to state-centric management systems and better, overall, at the management of complex socio-ecological systems. However, the focus of many of the analytical methods that assess natural resource governance has largely been formal administrative structures, as defined by public policy documents and laws. Such approaches can tend to overlook how natural resources are governed, which in reality involves several informal institutions and relationships between levels. SNA can help in drawing out these institutions and informal networks of collaboration (Stein et al. 2011; Lienert et al. 2013). Through this SNA can help in assessing and ultimately strengthening knowledge sharing, resource mobilization and consensus building arrangements to improve the management of resources (for sustainability) and distribution of resources (for equity). SNA can also play a role in the identification of key stakeholders to engage in management and allocation of resources who may otherwise lie outside formal systems of governance (Lienert et al. 2013). In this sense, SNA can help in identifying non-conventional actor-stakeholders as part of wider network analysis, improving overall representation in decision-making.

Water resources governance often involves multi-level actors who are both cross-sectoral and trans-boundary and are part of complex informal governance arrangements (Stein et al. 2011). Applying SNA in studying stakeholders and their networks that directly or indirectly impact water flows in the Mkindo catchment in Tanzania, Stein et al (ibid) looked at how collaborative social networks affect governance and how such knowledge can be used to improve water resources management. They found that while no single organization coordinated management at the catchment level, village leaders played important functions in bringing together disparate parts of wider water governance processes. This role has however not been captured by formal systems. Further, the Water User Associations (WUAs) that were in the process of being established did not account for informal water user arrangements that were already in existence. An important application of SNA in similar contexts is uncovering existing governance network structures and points of intervention that can make the case for strengthening existing systems instead of establishing new institutions, leading to the development of more locally-anchored institutions (ibid).

*Application to Decision Making Niches in Pakistan:*

In a study on the Management of Natural Resources Governed under Multiple Systems: In the Northern Areas of Pakistan (Bilal et al, 2003), polycentric, pluralistic legal systems are found to be the norm for natural resources governance. Apart from statutory law laid down by the State, traditional forms of law play an important role with regard to resource use rights and management of natural resources, including in resolving any associated disputes. This includes *Rawaj* or customary law that is passed down through oral tradition and *Shariah* or Islamic law from the Holy Quran. Such customary laws govern natural resources through regulations related to grazing rights in pastures, forest use and water distribution systems. It is felt that the close association between natural capital resources and livelihoods has fostered development cooperation over the years, including the collective maintenance of water channels by neighborhoods or villages. Recent efforts by the State to impose statutory law (*Qanoon*) in response to natural resource depletion has largely been viewed as impersonal and restrictive, prompting the response ‘All the natural resources restricted by the Qanoon we steal and use’ from some of the respondents in the study. (ibid)
Establishment of new institutions: The Water User Ordinance launched in 1982 led to the creation of nearly 17,000 WUAs as part of the On-Farm Water Management project. The newly-created WUAs received large subsidies for watercourse renovation and, afterwards, maintenance. However, the program ignored the existence of traditional watercourse committees in the creation of these new institutions and is one reason why the program’s success is felt to have had mixed results. (Siegmann and Shezad, 2006).

2. Assessing Coordination and Fragmentation of WRM Measures

Another potential application of SNA in decision making niches is in understanding processes of coordination and fragmentation in Water Resources Management (WRM) (Lienert et al., 2013; Ngaruiya et al., 2015). In assessing the above, SNA can be useful in uncovering how the perceptions and behaviors of stakeholders affect the implementation of official policies and plans (Bell et al. 2013).

An SNA approach can assist in understanding and improving linkages between local and centralized levels of planning. For example Cohen et al. (2012) analyzed governance networks of coastal ecosystems in the Solomon Islands and found that it consisted of stakeholders at different levels including representatives from the government, NGOs and local communities and in which geographic, logistical, and institutional factors acted as barriers to cross-scale coordination and learning for effective adaptive management of the coastal ecosystems.

Lienert et al. (2013) use SNA in combination with stakeholder analysis to understand water infrastructure planning processes in the Swiss water sector, examining the nature of fragmentation, how the diversity of actors is represented and what their priorities are. The use of SNA through the analysis of behavior of stakeholders in planning processes revealed that there was limited collaboration between the water supply and wastewater sectors and between local and national stakeholders. The study also found that local stakeholders – mainly from the engineering realm – had a stronger influence on planning processes than national actors who were considered to be less important (Lienert et al. 2013).

Similarly, Ngaruiya et al. (2015) use SNA to analyze how coordination among actors involved in water governance influences climate adaptation processes in Southern Kenya. They find that while the IWRM strategy that has been put in place in Kenya requires decentralization in institutional arrangements, this does not necessarily translate into strong adaptation action at the rural level. The study finds that the main contribution to rural water security has been through independent attempts at water conservation, with little coordination and integration of these measures. The authors note the potential use of SNA in identifying where the missing linkages are and in understanding how addressing this can lead to better synergies and upscaling of climate adaptation actions (Ngaruiya et al. 2015).

Applications in Decision Making Niches in Pakistan:

Addressing Fragmentation in the NRM and WRM sectors: The challenges of fragmentation affect Pakistan’s water sector at different stages. In the WASH sector, fragmentation arising from poor sector coordination is stated as a possible reason for ineffective policy implementation. While actors and forums that could fill this void exist, the absence of vertical and horizontal linkages at different points means that any coordination is informal and patchy (Water Aid, Pakistan, 2016).

According to Suhardiman et al. (2018) climate adaptation action in Pakistan has largely remained separate from WRM. It is possible the National Water Policy (2018) of Pakistan which stresses the implications of climate change for WRM could contribute towards resolving this issue, and provides an important potential entry-point for SNA application.
The significance of institutional linkages, fragmentation and coordination in assessing adaptive capacity in the agriculture sector of Pakistan was examined by Abid et al. (2017) in a study that applies SNA to the role of social networks in climate adaptation in agriculture in three agroecological zones in Punjab. The study found that while both public and private institutions are involved in providing services related to crop productivity and climate adaptation, linkages between institutions were weak, with the possible exception of the department involved in providing extension services which maintained linkages to other institutions. The study also found that public institutions were in general poorly represented in the social networks involved in climate adaptation. Where they were represented, larger farmers had better connections to public extension officers and better access to these services. There were strong linkages between many of the farmers and private sources providing weather information. Services and information related to marketing and informal credit was mainly exchanged among circles of co-farmers. The study proposed a more integrated and strengthened stakeholder network for better adaptive capacity in the area (ibid).

Understanding Perceptions of Institutional Structures: Decentralization of decision making in the water and agriculture sectors in Pakistan has been ongoing in recent years. This includes Irrigation Management Transfer (IMT) processes initiated in the mid-1990s as well as the 18th Amendment to the Constitution of Pakistan, which transfers several centralized governance functions to provincial levels. Bell et al. (2013) attempt to understand how stakeholders in the water resources and agriculture sectors perceive and accept these processes of decentralization. They do so by applying a ‘net-map’ exercise, a mode of analysis that combines social network analysis (SNA), stakeholder mapping and power mapping. The authors found that even after several years of implementation of IMT the perceptions of several stakeholders of the role of Area Water Boards, Farmer Organizations and Water User Associations that are part of IMT, differed significantly from the organizational structure that was originally devised for them. They also have a weaker impression of the role that IMT could play in water governance than was initially expected, given that it was initiated nearly two and a half decades ago.

3. Assessing Extent of Knowledge Sharing for NRM

Social networks can be critical for knowledge flows on NRM, especially in relation to adaptive management for increased resilience (Cassidy and Barnes, 2012). SNA can help in assessing how the characteristics of a social network can contribute to different aspects of knowledge and information transfer, as well as identifying individuals and pathways that have the potential to be good conduits for knowledge flows. (Barnes-Mauthe et al. 2014)

Bodin et al. (2006) examine the role of ‘degree centrality’ in knowledge exchange. Degree centrality (the number of nodes in a network that are connected to a single node) can be a measure of higher levels of trust in the group as well as strong social learning. The usefulness of ‘bonding ties’ and ‘bridging ties’ in knowledge sharing is discussed by Cassidy and Barnes (2012). Bonding ties are between members of a group and can assist in internal exchange of knowledge and idea sharing. Strong bonding ties can support increased resilience. Bridging ties are connections to other groups and can assist in carrying new ideas to the group and hence are important for innovation.

Reed et al. (2009) discuss how ‘strong ties’ and ‘weak ties’ affect knowledge transfer. Strong ties in a network lead to higher influence on other network members and thereby a greater degree of mutual learning. On the flipside, there is a higher degree of redundancy in the knowledge that is shared among this network. Weak ties are often found in networks with dissimilar individuals. They enable more varied pools of information and knowledge to come together. Weak ties can better enable new ideas and
innovation, which are important in adaptive management. However, a network with weak ties can more easily come apart (Reed et al. 2009).

The role of connectivity in supporting stronger household resilience in a rural community in Botswana is looked at by Cassidy and Barnes (2012). The authors use two attributes of social networks that are indicative of a higher degree of resilience — degree centrality and betweenness — in assessing household resilience. They conclude that households that are part of healthy networks and able to have at their disposal a higher number of livelihood strategies and a higher level of social and overall capital also displayed greater resilience.

Isaac et al. (2014) look at the role of migrant farmers in the transmission of agroecosystem management practices in the context of a forest-savanna transition zone in Ghana. The study was based on the premise that migrant farmers, based on their interactions with other kinds of environments, would possess agro-ecological knowledge that could contribute to adaptive management in destination areas that were undergoing transitions. It also tested the hypothesis that the reconfiguring of social networks due to the arrival of the migrant farmers carrying such prior knowledge could position them as brokers of knowledge in the new area. The study found that local farmers were part of smaller networks, whereas those of migrant farmers tended to be twice as large in size. The study also found that a diffuse knowledge network connected the three communities that were studied, and that the cohesion of this network was dependent on the brokering roles played by migrant farmers. The migrant farmers therefore played a central role in the transmission of agro-ecological knowledge between socially and geographically less connected groups (Isaac et al. 2014).

SNA can assist in identifying individuals who are best placed to propagate information within a community. Barnes-Mauthe et al. (2014) in a study of Hawaii’s longline fisheries find that individuals in the network with higher levels of education and who have been longtime residents of the community were both approached for information and had the network connections to receive and pass on this information. However, previous efforts to disseminate information among the community, for instance of conservation tools, relied on industry leaders and fisher representatives with fewer network connections, which the authors conclude is a possible reason that such endeavors were not successful.

Applications in Decision making Niches in Pakistan:

Assessing Knowledge Transfer to Local Levels: The setting up of WUAs and Water User Federations as part of IMT (as described earlier) was not accompanied in several instances with parallel efforts to inform farmers about the functions of these institutions. In many cases, the technical training provided to the presidents of the Federations and information on decisions made during Federation meetings was not passed onto farmers. These are considered to have been another shortcoming of the IMT processes. (Siegmann and Shezad, 2006).

4. Assessing Distribution of Power and Marginalization

A strategy that is often employed in NRM to achieve greater reach is engagement with key individuals in a social network. SNA can support this process, ensuring that important groups are not sidelined (Reed et al. 2009), and thereby maximizing efficiency in NRM initiatives (Bodin and Crona, 2009). Individuals who have advantageous positions in the network and therefore high social capital might also hold more power on decisions related to NRM, greater ability to influence others in the network and bring about collaboration (Barnes-Mauthe et al. 2014). On the other hand, due its usefulness in identifying where
power asymmetries exist in social networks (Salpeteur et al. 2017), SNA can and also be utilized in identifying marginalized groups for engagement. This could be of use in ensuring that individuals from such groups are included in participatory processes (Bodin and Crona, 2009).

Prell et al. (2009) use SNA in conjunction with stakeholder network analysis to identify individuals and groups who play central roles in the sustainable management of the Peak District National Park in the United Kingdom. Hauck et al. use a similar combined approach to identify key stakeholders for a participatory scenario development process to support the assessment of different implementation options of the European Green Infrastructure strategy.

Barnes-Mauthe et al. (2014) apply SNA in assessing what factors determine social capital in communities involved in longline fisheries in Hawaii, USA. They find that ethnicity was the most important factor in determining the social capital of an individual, influencing the strength of ties, network prominence, and brokerage in the social network. Vietnamese-American fishermen possessed a higher level of social capital and better ties to external industries and stakeholders in formal positions, and therefore more ability to influence management decision making. On the other hand, while Korean-American fishermen also had strong ties within their ethnic group, they lacked prominence in the network and brokerage positions and often felt marginalized. They were less able to form relations that could influence management and policy and decision making.

Applications in Decision Making Niches in Pakistan:

Understanding marginalization in community managed services: An initiative under the Social Action Programme (SAP) in the early nineties to involve user communities in the preparation of rural WASH services and, following this, in operation and maintenance was frequently hijacked by politically connected groups, thus resulting in these services not reaching the more marginalized groups. In Khyber Pakhtunkhwa Province, low tariff levels and poor collections meant that fewer resources were available which were then appropriated by politically connected groups, leaving other sections of the community deprived of access. (Siegmann and Shezad, 2006).

5. Assessing Points of Conflict and Cooperation

A key tenet of SNA is that weak linkages are associated with decreased levels of trust. Therefore, by evaluating levels of trust, SNA can identify points of potential conflict and cooperation between individuals and groups. It can be applied in identifying individuals who are better able to work with each other, and therefore avoid creating conditions for conflict among individuals and groups. (Reed et al. 2009) suggest that social network analysis can provide an additional layer of information that can assist not only in identifying likely sites for intervention, but also in making important decisions about which individuals in those locations will be influential and effective in ensuring that such schemes work as intended.

Applications in Decision Making Niches in Pakistan:

Understanding points of conflict and cooperation for development interventions: Analysis of farmer networks in relation to irrigation management can assist in identifying sites of high or low potential cooperation, as was concluded in recent research on the Indus Basin in rural Punjab (Box 2).
Box 2: The study by Lyons (2019, forthcoming) in the Indus Basin in rural Punjab considers both individual persons and parcels of land as nodes in the network to look at:

- The social relationships of landowners and managers in the village: what factions and alliance clusters exist among landowners/managers
- The distribution of social relationships of land
- Key individuals that exercise maximum influence among local farmers: Connections to maximal number of poorly networked (connected) farmers (arguably more powerful for those more isolated farmers) and connections to maximal number of well networked (connected) farmers (arguably more influential but perhaps less powerful)
- The closeness of land related relationships in the village
- The likely cooperation indices for different villages

The approach adopted provided methods for analyzing factions of land owners and managers and, perhaps more importantly, had the potential to reveal sites of cooperation and competition between those factions and clusters of factions. This can be used by decision makers for policy formulation and interventions that more effectively target water management intervention schemes.

This approach can operate at multiple levels. At a macro level, it can be used to generate a map of riverine basins with areas marked by their potential for cooperation. At the meso level, it will allow relatively meaningful metrics to identify potentially useful networks within which development workers should target their interventions. Finally, at the micro level, it can assist in identifying not only important individuals within those networks, but also key bridging individuals within the network who might be in a position to facilitate better cooperation across factions, whether actual or potential (ibid).
Assessment of Opportunities for SNA in Water Management in the Indus Basin

1. Used in Conjunction with Stakeholder Analysis

SNA can be used together with stakeholder analysis to select actors for engagement in participatory NRM initiatives (Prell et al. 2009). Stakeholder analysis has been a popular tool employed in NRM management and governance programs, providing a means of capturing the diversity and complexity of stakeholders associated with natural resource systems as well as identifying who amongst these actors should be considered as significant for engagement (Lienert et al. 2013; Hauck et al. 2016). However, stakeholder analysis has also been associated with certain shortcomings such as lacking quality and consistency (Lienert et al. 2013).

Social network analysis provides further depth to stakeholder analysis (Lienert et al. 2013) and can therefore form a next step in this exercise, enabling the identification of the roles and influence exerted by different stakeholders and stakeholder categories (Prell et al. 2009). As SNA studies use data that is highly detailed, such an approach can assist in consolidating any preliminary patterns that emerge from the stakeholder analysis as well as testing out any initial hypotheses. The knowledge obtained from SNA can then be fed back into the stakeholder analysis to evaluate whether stakeholders considered important should also be considered central or peripheral to the analysis (Lienert et al. 2013). Such a combined approach can assist in understanding how the network is structured and through this assist in identifying stakeholder categories, ensure that key groups are given prominence as well as help in selecting actors who can represent different groups (Prell et al. 2009).

SNA can also be combined with power mapping analyses in a technique known as the ‘Net-map’ tool developed by the International Food Policy Research Institute (IFPRI). The tool has been developed to assist in understanding multi-stakeholder governance processes, going a step ahead of an SNA approach to also account for the perceived power of the different actors in the network in shaping policy processes. (Schiffer and Waale, 2008). Further information on the study is provided in Box 1.
Entry-points for Application in the Indus Basin:

- Understanding formal and informal stakeholder networks with regard to decentralization of the water sector under the 18th Amendment to the Constitution of Pakistan
- Understanding coordination and fragmentation between stakeholders involved in WRM and climate adaptation at national and local levels

2. Combining qualitative and quantitative approaches

While SNA has its historical origins as an interdisciplinary field that combines both qualitative and quantitative methods, during the latter years of its development, it has largely been associated with mathematical techniques, supported by software packages that map and visualize social relations. The predominant methods used to collect relational data in SNA studies have been quantitative methods, such as name-generator surveys. However, combining quantitative and qualitative methods of data collection and analysis has also started gaining ground in recent years, where quantitative techniques are combined with methods such as interviews, ethnographies, historical archival research, and conversation analysis. Such an approach can provide the means to both map out and evaluate network characteristics but also understand the construction, reproduction, variability and dynamics of network ties, and the meaning that these ties have for the actors in the network. (Edwards, 2010)

Edwards (2010) describes three approaches that can be utilized in an interdisciplinary SNA study.
1. **Qualitative methods that can be used to guide quantitative studies and vice versa:** A multi-step methodology can be applied where one approach informs another, e.g. an ethnographic study can be used to understand the cultural context prior to a name-generating survey.

2. **Both data collection and analysis can employ quantitative and qualitative methods:** This can assist in ‘triangulating’—collecting and analyzing different types of data to understand the same phenomenon, e.g. using qualitative interviews to better understand network maps.

3. **Data collection through qualitative methods and data analysis using a mixed-methods approach:** Certain studies that collect relational data using a qualitative approach can then use quantitative and qualitative methods in the analysis of the data, e.g. analyzing ethnography and historical archival records using mixed methods.

**Entry-points for Application in the Indus Basin:**

- In areas where polycentric, pluralistic legal systems prevail (e.g. Northern areas of Pakistan), understanding formal (including traditional) and informal networks of governance and how community perceptions of customary and statutory law influence how these institutions function.
- Understanding systems of power and marginalization in community-managed WASH systems and Irrigation Management Transfer schemes.

**3. Integrating with Spatial Analysis Tools**

Integrating SNA with spatial analysis tools such as Geographic Information Systems (GIS) can help provide insights on how the actors within a network interact with each other in a particular geographic landscape (Andris, 2016). For development initiatives, such an integrated approach could be utilized in selecting sites for planned interventions (Saint Ville, 2013).

Andris (2016) discusses how social network analysis from data sources such as online social media, telecommunications and surveys within a geographic space can be combined with GIS analysis. The author highlights this through studies which utilize this approach to look at how shared boundaries between gangs impact their levels of violence and how the communicability of certain diseases is affected by geographic space. Mills et al. (2013) use a similar combined approach on an archaeological database to reconstruct network dynamics from A.D. 1200–1450 in the US Southwest, examining how widespread demographic changes at the time affected social networks and how spatial distance correlates or does not with social relationships.

Lyons (forthcoming, 2019) discusses how descriptive and analytical models of farmer networks in relation to irrigation management (further details of the study in Box 2) can be potentially applied in evaluating levels of cooperation at different sites for targeted interventions. Such analytical models looking at how factions of land owners and managers and sites of cooperation and competition between those factions and clusters of factions, when coupled with GIS data can be used to create a social map of ‘relations’ between significant parcels of land. The social networks of farmers can be mapped on to parcels of land which allows the development of robust geospatial maps of villages that reveal locations where competition is a potential obstacle to large scale water management interventions.
Entry-points for Application in the Indus Basin:

- Understanding locations of cooperation amongst farmer networks for development interventions (as described above)
- An SNA approach can be integrated with the geodatabase and Decision Support Tool being developed for the Kabul River Basin (a tributary of the Indus Basin shared by Afghanistan and Pakistan) to understand how social networks can contribute to increased resilience in climate change (e.g. flood risk) hotspots. Links to the tools can be found at [http://waterdata.iwmi.org/applications/kabul](http://waterdata.iwmi.org/applications/kabul) and [http://waterdata.iwmi.org/applications/icib_dss](http://waterdata.iwmi.org/applications/icib_dss)

Conclusions

SNA has recently gained prominence as a tool that can assist in understanding natural resource management and governance processes, particularly with regard to the number and diversity of stakeholders and institutions and their complex interactions at multiple levels. This mode of analysis can be applied in various decision-making niches in Pakistan and the Indus River Basin, including:

- **Understanding Multi-actor and Multi-level Natural Resource Governance Arrangements** where SNA can help in identifying institutions and informal networks of collaboration, as well as key stakeholders who may lie outside formal systems of governance;
- **Assessing Coordination and Fragmentation of WRM Measures** where SNA can assist in understanding how the perceptions and behaviours of stakeholders affect the implementation of official policies and plans and serve to improve linkages between local and centralized levels of planning;
- **Assessing the Extent of Knowledge Sharing for NRM** where SNA can help in assessing how the characteristics of a social network can contribute to different aspects of knowledge and information transfer, as well as identifying individuals for engagement in this regard;
- **Assessing Distribution of Power and Marginalization** where SNA can facilitate engagement with key individuals as well as ensuring important groups are not sidelined;
- **Assessing Points of Conflict and Cooperation** where SNA can assist through evaluating levels of trust amidst actors in the network.

SNA can be applied in conjunction with stakeholder analysis, in an integrated approach, combining quantitative and qualitative methods as well as in association with GIS systems. Some key potential opportunities for application in WRM in the Indus Basin include understanding decentralized systems, coordination and fragmentation processes, formal and informal networks of governance, participation in community-managed systems as well as resilient social networks.
Figure: Farmer irrigating his fields in Pakistani Punjab
Photo credit: Faseeh Shams / IWMI
### Annex 1: Characteristics of successful adaptive management systems and how they translate to social network structures (Prell et al. 2009)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
<th>Links to Social Network Structure</th>
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| Social memory    | Collective memory/experiences to be used in times of change and uncertainty | - Reachability: access to many individuals  
- Density: many links to others in the network                                                   |
| Heterogeneity    | A diversity of many types of actors or actors with differing knowledge will broaden the collective knowledge base and increase the capacity for innovation and maintenance of different knowledge systems and frameworks for interpretation | - Betweenness/modularity: A certain degree of separation of groups in the network is needed to maintain heterogeneity.  
- Density: High density may have a negative effect on heterogeneity because it promotes homogeneity of experience and attitudes among actors and reduces the potential for innovation |
| Redundancy       | Provides buffering capacity in case of loss, i.e., if one or more actors are weakened or lost, others can fill the position and continue to perform the management function | - Density: Many links makes the loss of single actors less disruptive, with a lesser effect on the average distance in the network.  
- Betweenness/modularity: A high degree of betweenness of single actors makes the network vulnerable to fragmentation should these actors disappear |
| Learning         | Knowledge about ecosystems can be continuously increased and improved, and thereby governance and management can be updated and adapted to changing conditions | - Betweenness/modularity: Maintenance of strong links within a group to some extent requires high modularity and strong links are needed to transfer tacit knowledge and complex knowledge, i.e., knowledge that involves interpretation of a number of non-linear and non-causal variables.  
- Reachability: access to many actors from whom knowledge and information can be amassed or to whom it can be distributed  
- Centrality: A high degree of centrality may give rise to centralized management and thereby fewer experiments and experiential learning |
| Adaptive capacity| New knowledge and/or changing conditions require adaptive capacity and innovation to meet new needs | - Reachability: Collective action requires multiple actors to collaborate, but too much decentralization may have negative effects on the potential for collective action |
| | • Centrality: Coordination ability, which is important in times of change and rapid response, increases with centrality  
| Density: Too many links to others may lock an actor into a political position (e.g. because of peer-pressure), thereby limiting his/her ability to innovate and act |
References


