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Current Opinion in Environmental Sustainability

Towards characterizing the adaptive capacity of farmer-managed irrigation systems: learnings from Nepal

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Small-scale irrigation systems managed by farmers are facing multiple challenges including competing water demand, climatic variability and change, and socioeconomic transformation. Though the relevant institutions for irrigation management have developed coping and adaptation mechanisms, the intensity and frequency of the changes have weakened their institutional adaptive capacity. Using case examples mostly from Nepal, this paper studies the interconnections between seven key dimensions of adaptive capacity: the five capitals (human, financial, natural, social, and physical), governance, and learning. Long-term adaptation requires harnessing the synergies and tradeoffs between generic adaptive capacity that fosters broader development goals and specific adaptive capacity that strengthens climate-risk management. Measuring and addressing the interrelations among the seven adaptive-capacity dimensions aids in strengthening the long term sustainability of farmer-managed irrigation systems.

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Current Opinion in Environmental Sustainability 2016, **21**:37–44

This review comes from a themed issue on **Environmental change assessments**

Edited by **Gregg Garfin** and **Robert Merideth**

Received: 03 March 2016; Accepted: 20 October 2016

http://dx.doi.org/10.1016/j.cosust.2016.10.005

Introduction

Local institutions across the globe to varying degrees are coping with and adapting to changing climate and rapidly evolving socioeconomic conditions like migration, urbanization, and income diversification [1••,2]. Farmer-managed irrigation systems (FMIS) in Nepal and other Asian countries (e.g., Philippines, Thailand, and Cambodia), are among the prevalent local resource-governance institutions that have survived decades and even centuries of social, ecological, and cultural changes [1••,3,4]. FMIS are autonomous institutions whose community members are responsible for overall irrigation management including water appropriation, distribution, canal maintenance, and conflict management through collective action [3,5]. In Nepal, they are characterized by use of low-cost technology appropriate for heterogeneous local conditions such as diverse geographic terrain, autonomous decision making suited to local sociopolitical contexts, and collective action for maintenance and operation of infrastructure [6–8]. FMIS are adaptive to changing hydroclimatic and socioeconomic conditions partly attributed to the high autonomy in farmers' decisionmaking; flexible rules that suit users' needs; and high social capital in the form of trust, mutual cooperation, and collective action [9].

While many FMIS remain functional, dramatically changing hydroclimatic conditions, accelerated biophysical risk, and rapidly evolving socioeconomic change — together understood as global change [10] — have weakened their capacity to cope with and adapt to these changes. Climatic change and variability have contributed to delays in the onset of monsoon and winter rainfall, which means more intense and unpredictable precipitation causing flash floods and drought [11]. Higher evapotranspiration and temperature causes shifts in irrigation-water demand and crop choice [12]. The situation is further compounded by socioeconomic changes including a palpable rise in responsibility of women in FMIS governance due to male out-migration; and erosion of interest in collective action due to decreased productivity and profitability of irrigated agriculture [1••,13,14]. Understanding and strengthening the key elements of adaptive capacity is crucial for the long-term sustainability of FMIS. This paper reviews the main components of adaptive capacity of FMIS, with case examples mostly from Nepal, and identifies potential indicators to measure them.

Since very few articles are published on adaptive capacity and FMIS, we first reviewed the literature on adaptive

capacity in general. The seven dimensions and indicators of adaptive capacity were short-listed (see Table 1) based on their relevance to FMIS (see the additional notes for a description of the methodology).

Characteristics of adaptive capacity

Institutional adaptive capacity has been defined focusing on various aspects like climate risk management [15], multi-level learning process [16], and diversity of

Table 1

Generic and specific adaptive capacities

Generic adaptive capacity	Dimensions of generic adaptive capacity	Indicators of generic adaptive capacity	Dimensions of specific adaptive capacity	Indicators of specific adaptive capacity	References
Human capital	Labor force	- Economically active labor population			[50,51]
	Education attainment	- Literacy rate			
	Knowledge and skills	- Years of agriculture and irrigation experience	Knowledge related to climate risk management	- Local knowledge on drought - Crop diversification knowledge - Water conservation knowledge	
Social capital	Formal and informal rules[a]	- Water distribution, resource sharing & other rules - Resource & labor contribution by head/tail end users	Contingency plans for risk management	- Water allocation rules during water shortages	[20,40,52,53•]
	Trust	- Perception of trust	Information sharing	- Information sharing about vulnerability and adaptation strategy	
	Membership	- Membership in FMIS			
	Access to institutions & resources	- Rules on access to irrigation water & WUA			
Physical capital	Basic services infrastructure — health, transportation, Market access	- Distance to road, hospital, and market	Irrigation infrastructure	- Concrete lining - Reservoir	[21,51]
	Irrigation & agriculture technology	- Adoption rate of technology	Climate risk management technology	- Adoption rate of water saving/augmenting technology	
Natural capital	Water source	- Cropping intensity	Water quality and quantity	- Alternate water source	[36,54]
	Forest condition	- Forest cover rate			
Financial capital	Income	- Annual income per household			[33]
	Income distribution/ inequality	- Farm size - Gini Coefficient			
	Access to finance	- Account at financial institution	Internal and external financial support	- Support from external agencies	
Governance	Transparency & accountability	- Financial audits - Meetings and disclosure - Graduated sanctions - Monitoring & evaluation			[28,45,46,52]
	Equity, inclusive and participatory process	- Cropping intensity at head and tail-end - Labor contribution at head and tail-end - Participation in decision making			
	Leadership	- Leadership performance rating			
	Multi-functional Institutions	- Organizational activities	Multiple functions	- Services provided by FMIS	
Learning	Flexibility	- Room for rule change	Intra- and inter institutional interactions	- Meeting with other agencies	[39]
	Collective learning	- Interactions with diverse stakeholders			

[a] Since most of the rules are informally made by farmers, formal and informal has been categorized in social capital.