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Farmer Managed Irrigation Systems in the Chitwan Valley of Nepal

Abstract

Despite many valuable lessons that have been learnt regarding resource and resource user attributes there are some relationships that have yet to be understood. One such confounding issue has been the impact of heterogeneity among the users of a community-based natural resource. Traditional commons research has mostly assumed the prevalence of homogeneity among resource users, however, it is known that differences (e.g. in socio-economic attributes, natural resource endowments, physical circumstances etc) can be present. It is mostly under assumptions of homogeneity that researchers have been able to collect evidence that shows that groups have been able to successfully self-organize (Ostrom 1990; Ostrom Gardner Walker, 1994; McKean 1992; Bromley 1992). What impact does heterogeneity have on collective action is an issue that is not yet fully understood and is the focus of much contemporary research in the common pool resource area. Similarly, the relationship between the nature of the resource and the ease with which users are able to organize around it is also not straightforward. This paper is an attempt to explore these issues with respect to Farmer Managed Irrigation Systems in the Chitwan Valley of Nepal.

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Introduction

Withdrawal of a volume of water from an irrigation canal means that there is less water for another to use and once the system is in place it is difficult to exclude users from its benefits. Two characteristics of the resource – non-trivial exclusion costs and subtractability - raises a cooperation dilemma. If exclusion cannot be achieved by some institutional design then the problem of free riding arises. No rational actor would want to contribute to the provision or maintenance of a resource if non-contributors can gain the same benefits as the contributors without making any contributions. Similarly, the subtractability attribute generates strong incentives for rational actors to maximize appropriation from a common pool hence speeding up the process of resource depletion (Ostrom, Gardner, 1993). Irrigation like all other common pool resources (CPR) faces this fundamental problem.

How should such a problem be resolved? What type of a governance and management regime ought then to be in place to manage common pool resources? These questions have generated numerous responses. Despite the many disagreements there is agreement on one point: that it is an institutional problem and if one were to get the rules and governance structures right then resources can, indeed, be used wisely (Acheson, 2000). The unresolved point, however, is what these institutions ought to be. Based on evidence form both the field and experimental settings, one thing is known for certain, that without effective institutions, CPRs will be underprovided and overused (Cordell, 1978; Larsen and Bromley 1990; Ostrom, Gardner, and Walker, 1994). What is less certain, and what generates the controversies is how such problems ought to be remedied.

There are those who believe that rational actors cannot extricate themselves from a "commons" dilemma and, therefore, an external "Leviathan" is required to prevent a "tragedy of the commons". Such a theoretical perception that governments are necessary to supply and organize collective action has resulted in actions such as the nationalization of forests and the concentration of power in government to supply irrigation water. Similarly, proponents of Privatization are also influenced by the same models and believe that the best way to avoid a "commons dilemma" is to impose a system of private property rights (Demestz 1967; Johnson 1972; Smith 1981). Again, this position is based on the premise that an absence of secure property rights results in high transaction costs, mal-distribution and over-exploitation of resources, and the presence of private property rights provide incentives to owners of resources to protect them (Acheson, 1989). A common theme that unites these two policy prescriptions is that institutional change must come from outside and must be imposed on the actors. An alternate competing idea that is emerging strongly is that of self-governance. Rejecting the assumption that external actors can easily design optimal institutional solutions and enforce rules at low costs, it is argued that users of a "commons" are better equipped to resolve the cooperation problem as the solutions tend to be conditional and situation specific (Ostrom, 1990). The question "*what could these conditions be*" has driven a voluminous amount of research work and the results emerging from this work indicate that self-governance in many instances can indeed be a viable policy alternative.

Although the theory of Common Pool Resources has advanced significantly, there is still uncertainty as to when appropriators are able to extricate themselves from the cooperation dilemma and supply themselves with successful institutions. However, a consensus has emerged over the set of variables that enhance self-organization. They are: i) scope for feasible improvement, ii) availability of reliable indicators of the resource condition, iii) relative predictability of the flow of resource units and iv) spatial extent i.e. the ability of resource users to develop a knowledge about external boundaries and internal microenvironments (Ostrom, 1994). Similarly, attributes of resource users conducive to self-organization identified are salience, common understanding, discount rate, distribution of interests, trust, autonomy and prior organizational experience (Ostrom, 1994). These attributes, among others, reflect the users demand for, dependence on, and knowledge of the resource and are thought to be important characteristics of the group which increases incentives for self-organization (Uphoff et al 1990, Wade 1988). Similarities in resource access, perceptions of risk, and consistency of norms are also believed to enhance the possibility of cooperation (Bardhan, 1993; Ostrom 1990).

Despite the many valuable lessons that have been learnt regarding resource and resource user attributes there are some relationships that have yet to be understood. One such confounding issue has been the impact of heterogeneity among the users of a community-based natural resource. Traditional commons research has mostly assumed the prevalence of homogeneity among resource users, however, it is well known that differences (e.g. in socio-economic attributes, natural resource endowments, physical circumstances etc) can be and are very often present. It is mostly under assumptions of homogeneity that researchers have been able to collect evidence that shows that groups have been able to successfully self-organize (Ostrom 1990; Ostrom Gardner Walker, 1994; McKean 1992; Bromley 1992). What impact would asymmetries such as differences in economic and political assets and physical relationships have on their abilities to enhance output or distribute output equitably are issues that have not been fully understood and is the focus of much contemporary research (Johnson and Libecap, 1982; Keohane, Mcginnis and E. Ostrom,1993). This paper attempts to explore some of these relationships through the analyses of Farmer Managed Irrigation Systems in the Chitwan Valley of Nepal.

The Theory of Common Pool Resources

Most studies till the mid-eighties on Common Pool Resources (CPRs) relied on a similar set of assumptions (Feeny, Hanna, McEvoy 1996). Not only did they assume appropriators to be homogenous in terms of their assets, skills and discount rates but they also assumed them to be short-term, profit maximizing actors who possessed complete information. Other assumptions that were made were that the resource system is open-access, appropriators act independently and that they do not coordinate their activities (Ostrom 1998). Analysis based under such a set of conditions consistently predicted that over-harvesting and resource degradation would occur. Garret Hardin's widely recognized "Tragedy of the Commons" (Hardin, 1968) best reflects this position. This used to be the conventional theory of a simple common pool resource until mounting empirical evidence from the field, contrary to theoretical predictions, suggested that there were many instances when resource users were able to coordinate and prevent the tragedy (Berkes 1989, McCay and Acheson 1987; Bromley et al 1992).

That a "commons" is characterized by open access conditions – a key assumption in Hardin's model was challenged early on. Researchers (Thompson, 1975) pointed out that where common property existed there were rules that determined entry as well as use rights and appropriators did have incentives to avoid resource overuse. Runge, in a series of papers, made an observation that families of appropriators living together in villages for generations and expecting to live for more generations would not have defection as their dominant strategies (Runge 1981, 1984). He pointed out that users of CPRs in such situations faced a repeated coordination game rather than a one-shot PD game. The solution to such games indicated that that there was no dominant strategy - universal cooperation and universal defection were both possible equilibriums. Under such a structure the degree of *communication* between players was believed to be a crucial variable in achieving cooperation (Ramussen; Meinzen-Dick, 1995). However, what action would eventually be taken depended on mutual expectations and was a function of the degree of trust among members of the group (Baland & Platteau, 1994; Runge 1984). Similarly, modeling the Prisoner's Dilemma as an iterated game Axelrod (Axelrod, 1984) was able to demonstrate that a tit for tat strategy could also sustain cooperation in an iterated PD game. Axelrod's work implied that it was possible for perfectly rational players to extricate themselves from a dilemma without external intervention. Further, challenges to the basic CPR theory concern the role of communication and innovation.

Standard theory treats communication as cheap talk and its presence is thought unlikely to change results unless individuals involved can call upon external agents to enforce agreements (Farrel, 1987). Evidence from the field, however, has repeatedly shown that individuals can make and do keep promises even in the absence of external authorities to enforce agreements confounding the explanations of standard theory. Further, laboratory experiments (Sally, 1995; Cason and Kahn 1996; 1991; Issac and Walker 1991; Ostrom and Walker 1997) have also demonstrated that communication and face-to-face communication more so has an unmistakable influence in fostering cooperation and collective action. In repeated common pool resources game subjects with repeated opportunities to communicate have obtained higher yields on average than in baseline experiments without communication. Since communication is most likely to affect individual trust that others will keep to their commitments, researchers have increasingly begun to see a strong role for communications in second-generation models of rationality (Ostrom, 1998).

The ability to change the rules of a game (innovation) or using sanctions to punish those who do not cooperate is considered not to be a viable option in standard CPR theory (Ostrom, 1997). Standard theory predicts that no body should spend resources to punish others because others share the positive impact of the action equally whether they contribute or not. Extensive research, however, indicates that resource users in many CPR situations have been able to change the structure of the social dilemma (Bloomquist 1992, Bromley et al 1992, Tang 1992, Ostrom 1990) by devising a wide variety of rules that they themselves have been able to enforce. Experimental results (Ostrom, Walker, Gardner, 1994) also point out that when subjects are given the opportunity to use a costly sanctioning mechanism this option is frequently exercised and the use of sanctions also increases the level of cooperation. Conventional theory is unable to explain why appropriators are willing and able to bear the costs in overcoming a second-order level dilemma by monitoring and enforcing their own rules (Ostrom, 1998).

Though the generalizability of conventional CPR theory has been challenged by experimental and field research Ostrom (Ostrom, 1998) points out that "a fully articulated and reformulated theory encompassing the conventional theory as a special case of a more general theory does not yet exist". However, she points out that many scholars (Ostrom 1990, 1992; Schlager 1990; McKean 1992; Tang, 1992; Wade, 1994; Baland and Plateau, 1994) have agreed upon a set of resource and user attributes that enhance the likelihood of self-organization (see Ostrom, 1998). For instance, reliable and valid indicators of resource conditions, accurate knowledge of resource boundaries, predictability of resource units, reliance of appropriators on resource for livelihood, and a shared understanding of resource systems among others are believed to increase the likelihood of self-organization. CPR research also suggests that the performance of self-governed CPRs varies across systems and time and there can be many variations in the rules-in use that are adopted.

Although commons research has been able to identify a large number of potentially critical factors conducive to self-organization and sustainability of CPRs a complete theory that explains sustainable CPR management remains to be developed (Agrawal, 2002). There are also unresolved theoretical issues relating to the effect of size and heterogeneity (Ostrom, 1998).

The effect of the number of participants facing problems of creating and sustaining a self-governing organization is not yet clear. Although some scholars who have studied many-user governed forestry institutions have reported that success is more likely with smaller groups (Cernea, 1989), others have found that smaller user groups are less able to undertake the level of monitoring needed to protect resources as moderately sized groups (Agrawal, 2000). Lam (1998) in his study of irrigation systems in Nepal also does not find any relationship between the number of appropriators and his performance measures. Similarly, like size, the effects of heterogeneity on collective action are also problematic (see subsequent section). Groups can differ along various dimensions – cultural backgrounds, interests, and endowments (Baland and Platteau, 1996) – and each can operate differently. Since size and heterogeneity are not variables with a uniform effect on likelihood of self-organization Ostrom (Ostrom, 2001) suggests that instead of focusing on the variables themselves per se, studies should be directed towards determining how these variables affect other variables as they impact the cost-benefit calculus of those involved in negotiating and sustaining agreements.

Collective Action and Heterogeneity

Research looking into the impact of heterogeneity on collective action can be grouped into two broad categories. In the *first category* are research results that posit that inequalities may actually favor the provision of collective goods. Olson's ideas that asymmetric resource endowments in a small group can drive even a single member to absorb all costs of providing for a collective good if he/she sees a good proportion of that benefit accruing to him/her self is the underlying theoretical foundation for this type of research results. Examples of this type of research work is Leach's (1961) account of collective duties in pre-independence Ceylon where large landowners did provide canal-cleaning efforts even if no other irrigators followed suit; and Vaidyanathan's (1986) historical account of the role of elites in promoting the emergence of irrigation management regimes in India, China and Japan.

Researchers have attempted to explain this idea of wealthier farmers taking the initiative to derive benefits from collective action by pointing out to the existence of nonconvexities in the production function. Benefits derived from collective action are considered to be a nonconvex function if a minimum aggregate effort is required to cross a threshold before any benefits are realized. Irrigation is one example where large set up costs are required for dam or canal construction before any benefit can be derived. Such a setting, it is argued, can induce wealthier farmers to absorb the initial expenses (Bardhan and Dayton-Johnson, 2002).

The *second category* includes results from case studies and experimental literature that show that cooperation tends to be more difficult when actors have heterogeneous characteristics (e.g. Bloomquist, 1992; Hackett, 1992; Kanbur 1991; Ostrom, 1990; Libecap 1989; Issac and Walker, 1988). This category also comprises studies which show that heterogeneous communities find it more difficult to design, monitor and enforce rules and that they are more likely to be weak at conflict resolution (Baker 1997, 1994; Blair 1996; Chambers et al, 1989). Research work that further strengthens the aforementioned results are Jayaraman's (1981) study of surface-water irrigation in Gujrat, Easter and Palanisami's (1986) study of tank irrigation systems in Tamil Nadu. Whereas Jayaraman points out to the importance of a relatively egalitarian structure for the formation of water users association Easter and Palanisini's emphasis is on the small variation in farm size among farmers.

Research results on the impact of heterogeneity are beginning to indicate that heterogeneity can either facilitate or hinder cooperation, depending on the type of heterogeneity and the context. Work on the impact of socio-cultural differences – one major source of heterogeneity - indicates mixed results. Whereas Cernea (1988, 1981) reports that class differences can cripple efforts at organizing for collective action in the villages due to mistrust and lack of mutual understanding, Wade's (Wade, 1994) study of South Indian farming communities show that members of groups can overcome socio-cultural barriers and cooperate. Similarly, differential endowments - another source of heterogeneity – can also have two different opposing impacts on efforts to govern common pool resources. Johnson and Libecap (1982) reason that it is often the difference in the skills and knowledge of different kinds of fishermen that frequently prevents them from arriving at agreements on how to allocate quantitative harvesting quotas. Heterogeneity of wealth or power, however, has also been shown not necessarily to be associated with a difference in interests (Vaidyanathan, 1986) and that elite members of a group have absorbed initial costs of organization. There are also studies that show that moderate differences in wealth distribution, in fact, promotes collective action (Baker, 1997) and studies which also show that equal distribution of land ownership may also be a cause of collective action problem (Molinas, 1988). There are other studies that have also examined the role of exit options (Dayton-Johnson, Bardhan) on resource conservation. Dayton-Johnson et al theorize that exit options weaken the prospects for cooperation because a community would have fewer mechanisms to enforce cooperation on a footloose population. Empirical work by Baland and Platteau (1994) illustrate this point with reference to fisheries around the world.

Apart from the aforementioned case studies there have also been large-N studies based on multivariate analyses that have looked into the effects of heterogeneity. Tang (1991) reports, “A low variance of the average annual family income among irrigators tends to be associated with a high degree of rule conformance and good maintenance.” Lam’s regression analysis (1998) indicates that *income inequality* is significantly and negatively related to productivity but not significantly to the physical condition of the system. Similarly, Bardhan (2000) and Dayton-Johnson (2000) find that *wealth inequality* is significantly and negatively associated with canal maintenance in their Tamil Nadu irrigation systems. They also report that conflicts tend to be highest not at low or high levels of wealth inequality but somewhere in the middle range. Bardhan’s (2000) study further finds that *exit options* are negatively and significantly related to system maintenance. He also reports that homogeneity in caste is associated with absence of inter-village conflict but not with rule conformance. Similarly, Dayton-Johnson in their Mexican study (2000) share similar findings i.e. social heterogeneity is negatively associated with infrastructure maintenance.

There have also been quite a number of field studies that have shown that homogeneity is not necessarily a critical condition for collective action. Studies show that self-organized groups have in certain instances even been able to overcome strong asymmetries by devising rules that distribute benefits and costs fairly (see Varughese and Ostrom, 2001). However, discerning empirical regularities that link heterogeneity to better or worse common outcomes is still problematic because heterogeneity may not have a uniform effect on the likelihood of organizing collective action. The mechanisms by which differences or similarities among users may affect collective outcomes are not well explained. Similarly, the condition under which certain types of heterogeneity may undermine or enhance collective action also remains largely unknown. There is also an incomplete picture regarding why some groups of resource users are able to cooperate whereas others not given similar resource and community attributes. It is, therefore, important to understand how heterogeneities affect collective action in diverse field settings and also begin to understand how resource users cope with particular heterogeneities to ensure successful collective action.

Study Objective

The general objective of the study is to try and examine how heterogeneity influences collective action outcomes. I attempt to do this by looking at the Farmers Managed

Irrigation Systems in the Chitwan Valley of Nepal. First, I attempt a general analyses of 65 FMIS contained in the NIIS database, then I examine in detail a few irrigation systems drawing water from different river systems in Chitwan.

History of Irrigation Development Activities in Nepal

Although recorded information on development of irrigation systems prior to 1950 is scanty we know that there are many small irrigation systems scattered all over Nepal which have been operating for more than a 100 years. The Nepal Irrigation Institutions and Systems Database (NIIS) indicates that there are 33 systems in the database that have their origins before 1900 and 13 of them including the "Raj Kulo" of Argali, Palpa have been in operation before 1800. Similarly, at least 6 systems in East Chitwan alone date back to over a hundred years. Reviewing these statistics against the base year 1950, one begins to observe evidence of the capabilities of farmers to engage in fruitful collective action. 1950 is an important year in Nepalese history because it was only subsequent to this year that the state assumed an active role in the development activities concerning its citizens.

Demographic forces are believed to be the primary reason that led to agricultural intensification techniques, irrigation being one of them. The manner in which the earlier systems were developed has a colorful and mixed history. Yoder (1983) cites the development of some of the earlier systems as having taken place through the individual initiatives of courtiers or soldiers after receiving land grants from the King. Invested with the powers of the state to draft tenants into constructing the systems in lieu of paying higher revenues the incentives were strong for constructing irrigation systems to boost productivity. Other driving forces have been "guthis" (land endowments), initiatives of local elite and royal directives. Although farmer-managed irrigation systems may have had its origins in "birta" (land grants awarded by the state) or "jagir" (temporary assignment of land by the state to compensate for services tendered) and the coercion of the state, there is evidence that some of them were built by farmers themselves (e.g. Cherlung Kulo of Palpa). There is also contemporary evidence to suggest that the vast majority of the irrigation systems have been self-governing.

Paul Benjamin (1994) notes that the foundations for the development of autonomous and non-political governance was established as early as the 18th century ironically due to the benign neglect of the state. The King unwilling to preside over irrigation disputes declared that henceforth "trivial disputes" were not to be brought to his court. Since the court would not intervene on anybody's behalf conflicts had to be resolved locally giving governance a non-political character. Pradhan (1989) notes that probably due to such a setting communities of irrigators have always been able to institute their own rules, bidhan (charters), schedules of operation, and sanctions without undue interference from an irrigation agency or other administrative units. The legal and local administrative structures over a period of time have permitted farmers to operate their systems independently. Despite the historical presence of a national judicial framework for irrigation, farmer managed irrigation systems have always retained an independent and self-reliant character not through design but central neglect by the state.

Agency Managed Irrigation Systems (AMIS)

It was only after the political changes in 1951 that the Government started taking responsibility for developing different sectors of the economy. As part of its plan to develop the agriculture sector the Department of Irrigation (DOI) was established in 1952. This department today is the principal government agency for planning, designing, executing and managing government owned irrigation projects in Nepal. Although there are evident changes now in the approach adopted by the department towards development work; in the earlier days it assumed entire responsibility for construction, operation, and management of the entire system. An irrigation system managed entirely by the agency is referred to as Agency Managed Irrigation Systems (AMIS).

Planned modes of irrigation development were initiated through the five-year national plans adopted since 1956. The first three development plans had modest targets and efforts were focused on developing minor irrigation schemes within the Kathmandu Valley and medium scale projects in the Terai. During the first, second and third plan periods targets were set to develop irrigation infrastructure to irrigate 20,785, 32,544 and 50,645 hectares of land respectively. In the fourth plan the targets over the previous plan increased five-fold to 253,711 ha and major large-scale schemes were initiated. Since the fourth plan targets in the consequent periods appear to have stabilized at 230,000 hectares.

Farmer Managed Irrigation Systems (FMIS)

Effective governance of Irrigation systems is crucial to Nepal because it is predominantly an agrarian economy dependent upon irrigated rice agriculture to feed a growing population. Agriculture contributes 40% to the GDP and provides employment to 80% of the labor force (Ministry of Finance, 1998). The Irrigation statistics of the nation further indicates that of the 2.621 million hectares of land cultivated nationally, only 853,030 hectares are serviced by some kind of irrigation system (Department of Irrigation, 1997). Farmer Managed Irrigation Systems (FMIS) contribute 75% towards the total irrigated area. There are 15,000 FMIS in the hills and 1700 systems in the Terai (Pradhan, 1988). Until the 1950s irrigation development nation-wide was a result of farmers' initiatives and investments in the construction and management of irrigation systems. These farmer initiated irrigation systems are referred to as FMIS.

In the past a lot of investment was made on developing irrigation infrastructure by the government, however, the performance of these systems were reported to be unsatisfactory relative to the resources put into the sector (HMG/N National Planning Commission of Nepal, 1994). Failure to provide an assured supply of water, failure to reach water to farmers in the tail-end, and failure to achieve economies of scale in all spheres of construction, operation, and maintenance in the systems supplied by the Government were among the problems reported. Systematic study comparing the performance of Agency managed systems (AMIS) to FMIS in Nepal (see Lam, 1998) further showed that FMIS outperformed AMIS on most key parameters – agricultural yield, cropping intensities, ability to reach water to tail end. The farmers on the whole were able to overcome collective action problems but it cannot be assumed that the process is automatic. Although there are many key attributes of both resources as well as resource users that could interact in a multitude of ways to influence collective action, salience of the potential joint benefit and the existence of a supportive political system are considered to be important variables conducive to promoting collective action.

While the potential of FMIS is substantial, not every FMIS operates at an optimum level of performance and not every FMIS is successful in self-organizing and self-governing activities. It is important to understand why this occurs. Commons research indicates that the role of heterogeneity – unequal resource endowments, cultural differences etc. – in a commons outcome is not too well understood. Advancing our understanding in this direction can perhaps provide valuable inputs to designing intervention policies to support the irrigation sector in Nepal.

Irrigation Typology

The classification of Irrigation Systems in Nepal has been based on the topography of the terrain traversed by the rivers. Systems that tap into rivers whose gradients change rapidly as they flow downhill are called Hill Irrigation Systems, those that draw water from rivers that cut across valleys with gentle gradients are termed River-Valley Irrigation Systems, and those that draw water from relatively large rivers flowing across the flat Terai lands are called Terai Irrigation Systems (Pradhan, 1989). Although there are physical and institutional differences between these systems in terms of rate of change of gradient, idle canal length, efforts required at canal maintenance, farm types irrigated, the size of the command area, and rules governing resource mobilization & water allocation there are similarities too (Pradhan 1989, Ostrom, 1992). Intake structures on systems in all classes are generally constructed from boulders, stones and brushwood located appropriately to ensure easy diversion of water; rights to water withdrawal are fairly well established within systems and water distribution among appropriators are governed by commonly understood sets of rules; and maintenance of physical structures, especially the intakes, during high floods require significant resource mobilization (Parajuli 1999, Ostrom 1992). In addition to this, another way that Nepali irrigation systems have been classified is on the basis of how they are governed. Systems that are owned, developed and managed by farmers are known as Farmer Managed Irrigation Systems (FMIS) and those owned and governed by the State are referred to as Agency Managed Irrigation Systems (AMIS) (Pradhan, 1989). The Agency managed systems are further subdivided into three components - agency managed, jointly managed with farmers, or farmer managed - to further distinguish ownership and control rights over the systems (Shukla & Sharma, 1997). The combination of these two classification methods results in 12 classes of irrigation systems. Thus, an irrigation system can be located either in the hills, river valleys, or in the terai and it can also be either farmer managed or agency managed. If managed by an agency then ownership and control can lie either entirely with the agency, or can be shared with farmers, or can also lie entirely with the farmers if the systems have been turned over to them. The irrigation systems studied for the purposes of this dissertation are mostly Terai based Farmer Managed Irrigation Systems.

ANALYSIS OF IRRIGATION SYSTEMS IN CHITWAN

CHITWAN

Chitwan is one of the 75 districts of Nepal. It covers an area of 2510 square kilometers. Three quarters of Chitwan district constitutes flat lands that have high agricultural potential. Khageri River divides the valley into two parts - Eastern and Western Chitwan respectively.

Land Use

Forest, agricultural lands, pasture/grazing lands, settlements and wastelands constitute the major land use types in Chitwan district. Land use consists of 47,192 ha. of cultivated land, 125,150 ha of forest land, 6895 ha. of grazing land and 184 ha. of roads and settlements. Water bodies, rock outcrops and unproductive land consists of 40,714 ha.

Demography

Chitwan is a valley that has been settled very recently. Owing to malarial infestation this valley remained densely forested and was left uncultivated for a long period of time. It was only after the eradication of malaria in the 1950s that an influx of migrants came to this valley from the adjoining hill districts of Gorkha, Lamjung, Tanahu, Baglung and Dhading. The estimated population of Chitwan is 355,000 and the annual growth rate is 3.52 %. Because of the migration from many parts of the country the population structure in Chitwan is multiethnic in composition.

Irrigation Development In Chitwan

There is government built as well as community built irrigation systems in Chitwan. It is reported that eastern Chitwan alone has nearly 100 community built and managed irrigation systems. Some of the systems are reported to be as old as 250 years and still in operation (Pradhan, 1987). Government built irrigation project includes the Chitwan Irrigation Project comprising the Narayani Lift Irrigation project (8,600 ha), the Khageri Irrigation scheme (6,000 ha) and the Panchkanya Irrigation Scheme (600 ha). Pithuwa is also a Government built system but managed by farmers.

Apart from the government schemes there are numerous farmer-developed systems which exist in the valley. A major concentration of these farmers managed irrigation systems (FMIS) are located in East Chitwan. Existence of at least 86 independently managed FMIS has been reported in the 1990 study carried out by independent consultants (DOI / Nippon Koei / SILT). In an assessment made by the feasibility study of the East Rapti Irrigation Project (DIHM/ADB/, 1986) total irrigable area under farmer managed irrigation systems in east Chitwan was estimated to be 4,000 ha during monsoon and about 1,300 ha during the dry season. IMSSG estimates of 1993, however, indicate that the total irrigable area under farmer managed irrigation system had gone up to nearly 10,995 ha.

Irrigation Resources of Chitwan Valley

Rapti River and its tributaries are the major water resources in Chitwan. Important tributaries are described in the following sections. Some systems also originate from springs and ponds that are either perennial or seasonal in nature.

Rapti River

This is a non-snow fed river that originates from the southern slopes of the Mahabharat range. However, as it traverses Eastern Chitwan the flow is from east to West and the gradients are gentle. Among the rivers of Eastern Chitwan this is the longest as well as the largest river and is a perennial river. The mean monthly wet season discharge (August) lies in the range between 90-500 m3/s and the mean monthly dry season discharge (April) ranges between 7-29 m3/s. Water released from the Kulekhani power plant also supplements the natural runoff from this river. During the monsoon the river transports large boulders and loose aggregates. As a result, the riverbed is rising each year and despite the presence of a dyke from Piple VDC to Kumroj VDC inundation of agriculture land is always a serious threat.. Degradation of the watershed upstream is reported to cause high peak floods and low dry season discharge. Ten irrigation systems reportedly draw water from this river.

Lothar River

Lothar originates from the Mahabharat ranges, flows North to South, has a steep gradient and ultimately drains into Rapti River about 2 Km below Lothar Bazaar. The river flows on the eastern boundary of Chitwan dividing it from Makwanpur district. The mean monthly wet season discharge (August) lies in the range between 7-55 m3/s and the mean monthly dry season discharge (May) ranges between 1.4 – 2.7 m3/s. Four irrigation systems draw water from this river. Although a perennial river, the volume of water diminishes significantly during the dry season.

Budhi Rapti

This is a perennial stream that originates from Kuchkuche forest located along the north bank of Rapti River in KATHAR VDC. The stream flows in an East-West direction parallel to the Rapti River. Again, the gradients are gentle and there is a low sediment load. Seven systems are reported to draw water from this river.

Dhongre Khola

This river is an important source of irrigation in East Chitwan. It is a perennial river and due to the gentle slope of its topography the flow is steady. The supply in Dhongre includes natural runoff from Lothar River and the drainage from Rapti irrigation system. A total of 18 irrigation systems draw water from this river.

Kair Khola

Although KK is a perennial source its water volume diminishes during the drier periods and the river is known to change course. This river too originates from the Mahabharat hills and flows in a North/South direction and is approximately 44 kilometers in length. The mean monthly wet season discharge (August) lies in the range between 7-55 m3/s and the mean monthly dry season discharge (April) ranges between 0.089 – 2.56 m3/s. Nine systems originate from this river.

Pampha Khola

This is a seasonal stream that first flows from North to South and then later from East to West. During the dry season the N-S course is reported to go dry but water can be seen in the E-W course. Farmers report that this is because water from the Dhongre irrigation system drains into this river which is utilized downstream. Nine irrigation systems rely on this river.

Other Rivers

Budhi Khola: This river is a distributary of Kair Khola. Seven systems are dependent on this river for their water source.

Chatra Khola: This is a seasonal stream originating from the Churia hills and flows in a N-S direction before joining Pumpa Khola. Five systems are reported to draw water from this river.

Dudh Koshi: This is a seasonal stream. It originates from the foothills of Churia and flows in the N-S direction. Four systems receive their supply from this stream.

Martal Khola: This is a seasonal stream and water flows only during the monsoon (May-September). Farmers report that the water volumes are diminishing over the years due to deforestation and uncontrolled settlements in the upstream watershed. Two irrigation systems draw water from this river.

Dhusari Mools: A number of systems receive their water supply from ponds and natural springs.

Service Area

The average service area of the 63 farmer managed systems is 136 hectares ranging from a low of 7 hectares (Khairghari Irrigation System) to a high of 1072 hectares (Rapti Pratappur). The service areas of government constructed systems are larger for instance The Narayani Lift irrigation Scheme has a service area of 8025 hectares and Khageri 5000 hectares.

Inter Irrigation System Water Use

Inter irrigation systems water use is a common practice. As many as 11 systems acquire and 12 provide water to systems other than their own. There are multiple bases for such water acquisition: a) contributions of cash and labor during system repair and maintenance, b) resource contribution during initial construction, c) mutual consensus based on genuine demand, and d) payment of a fixed sum of money. There are 9 systems that utilize the drainage water which flow into its systems after use elsewhere. Due to the nature of the porous sub soils there appears to be a strong hydrologic inter-linkage between irrigation systems particularly in south Chitwan. It is reported that the water flow in Dhongre Khola is resumed in the spring after Rapti Pratapur and Sisabas begin irrigating their lands.

Development History

Of the 63 systems 82% are more than 25 years old and 22% have been in operation since the past 75 years. Only about 18% of the systems came into operation in the last 25 years. Most of the systems were initiated and constructed by the farmers. Government interventions in these systems occurred mostly after the 1970s. Interventions were mostly targeted at system rehabilitation and improvement.

Age of Irrigation Systems – Chitwan

	number	percentage
Earlier than 1900 (> 100 years)	6	9.5
1900-1925 (75-100 years)	8	12.7
1925-50 (50-75 years)	7	11.1
1950-75 (25-50 years)	31	49.2
1975 and after < 25 years	11	17.5

The Tharu communities, who are the indigenous people of Chitwan, initiated most of the older systems. Migrant Pahadiya communities who started settling in Chitwan only after the 1950s are credited with having initiated most of the newer systems. The NIIS database indicates that of the 65 systems 57 were constructed by farmers, 5 by government agencies and 3 by NGOs.

Resource Mobilization For The Initial Construction

The users themselves are reported to have made substantial investments for the development of the irrigation systems in most cases. Support from government agencies and local political institutions are also mentioned but they are few in numbers. Resource mobilization by the local community has included cash and labor in most cases. In some instances food grain was collected to pay for the hired laborers. Cash and labor resources have been mobilized either on a household basis or in proportion to the size of the land owned in the command area.

Resource Mobilization For System Rehabilitation And Improvement

In more recent times many external agencies such as the DIO, FIWD, SFDP, Care-Nepal, DOR, and VDCs have been involved in various types of maintenance work. They continue to be an additional source for resource mobilization in addition to the resources generated by the community themselves. Many of the systems report receiving assistance in some form or another from external agencies.

Physical Properties Of Resource System

Headwork: The major types of headwork in the systems include the temporary brushwood check dams (32), gabion boxes used as a semi-permanent diversion structure (2), and permanent cement concrete gated diversion weirs (4). Most of the irrigation systems with permanent structures have been constructed with external assistance and are of recent origin.

Canal Length: An assessment of the distribution system by the length of the main canal reflects that there are only 9 systems that have a length greater than 5 km. Main canal lengths of the remaining systems are: 4-5 km (7), 3-4 km (11), 2-3 km (15), 1-2 km (15) and less than 1 km – (5). The system with the largest main canal (22.5-km) is the Government constructed Khageri irrigation system, and the one with the shortest (200 m) is Dudh koshi. The highest number of branch canals (17) is reported for Madhavpur Kulo and lowest (0) in Khairghari. There are 31 systems, which have less than 5 branch canals, and 11, which have, greater than 10 branch canals.

Canal Lining: The main and the secondary canals in a majority of the systems are unlined. 46 systems do not have any lining, 16 are partly lined and 1 is completely lined. The main canal of Pumpa Kulo is completely lined.

Access to Water Resource: In 22 systems farmers can access water from their systems throughout the year, 7 for 9-12 months, 9 for 6-8 months and 27 for less than 6 months. Systems drawing water from perennial river sources have an advantage over those drawing from seasonal rivers.

Structures For Water Allocation

It is only a few systems that have the cement concrete proportional weirs, most rely on wooden weirs. In systems that do not have provisions for proportional weirs, use of gated outlets, piped outlets and temporary outlets are reported. The sizes of these outlets are reported to be proportional to the area irrigated. In the absence of permanent water allocation structures, farmers erect temporary checks of wooden stakes, bushes, stone and earthen materials across the main canal so as to ensure a near proportional allocation of irrigation water.

Water Allocation And Distribution

The basis for inter system water allocation at the source is reported to be by mutual consensus among the water users of the upstream and downstream systems in the majority of the irrigation systems. This norm is practiced particularly during the water deficit periods. The users from the downstream systems approach water users committee of the upstream systems through their own representatives and make informal requests for sharing water. Cases of water theft also do occur and it is a source of acrimonious conflicts.

Pithuwa and Chainpur have made special arrangements for sharing water. Since Chainpur uses the water for drinking purposes it gets to draw on this resource during the day and Chainpur draws on it during the night. This is an informal agreement between the two parties. Similarly, in the irrigation systems receiving their supply from Budhi Khola, water is allocated proportionately into seven shares according to the regular contributions made by system users for the maintenance and upkeep of the intake. All these irrigation systems share a common intake in Kair Khola.

Water Allocation Within The System

Water allocation and distribution in systems are intimately integrated. Whereas assignment is the principle of entitlement, distribution is the implementation of the allocation principle. Different principles are in practice depending upon the constraints of the physical resources. During the water adequate period majority of systems adopt a continuous supply method, as there are no limitations to the amount of water that is available. However, for the water scarce periods there are different combination of rules that come into force.

12 systems allocate water on the basis of genuine demand, and 31 systems use a combination of continuous and demand based supply. There are a few systems that suffer from water scarcity even during the monsoon season due to the ephemeral nature of the streams. Five systems drawing water from such sources have adopted relatively strict rules for the allocation of water. Panchkanya is an example of one such system that allocates water depending upon the type of land to be irrigated.

The water deficit months are generally from October to May. May is also the time when Spring paddy is cultivated in systems that have adequate access to water. During this period farmers are known to formulate more restrictive set of water allocation methods to ensure equity in allocation. Typically, water is shared proportionally on the basis of the number of branches or secondary canals that need to be supplied. There are 24 systems that practice this method of water allocation during the dry periods. Another technique practiced in an equal number of systems is based on the allocation principle of a time and area relationship. Farmers in some systems also allocate water on the basis of the time required by their stream to saturate a given unit of land area. In the absence of permanent water measurement structures various techniques such as the above are used to allocate water between appropriators. Other allocation variables are i) number of outlets ii) political units (ward, blocks) iii) location within a service iv) time of delivery of irrigation water and iv) number of users.

A total of 16 different types of water allocation methods are reported in the Chitwan area. However, the most important variables that govern water allocation techniques involve time, land area, discharge, canal net work, location and number of outlets, number of users, types of land to be irrigated and shape of command area.

Some systems are reported not to have any formal methods of water allocation. The reasons for this are either the system has adequate water for the users or there is no users committee to coordinate allocation.

Distribution Of Irrigation Water

Rotation of water supply starting from head reach to tail reach of the system is reported to be the most popular water distribution schedule. There are, however, a few systems which have adopted a rotation system in an alternate manner between the head and the end reach to ensure equitable distribution of water. In order to make rotation of water supply more systematic, farmers have been adopting increased delivery time to the given supply when moving towards tail reach for the same size of land taking into account the time elapsed and losses in conveyance of water. Other distribution schedules reported are time slot allotment to individual user, distribution from one field to another and delivery of water in the tail and head end at day time and night time respectively.

In systems where water is to be distributed by share or by time rotation based on the proportion of land in the irrigated area, wooden or concrete proportional weirs (also called jhyal), piped outlets and gated outlets are fixed in the canals so that users can monitor the flow of water. In the absence of permanent water distribution structures, users utilize the locally available materials like wooden stakes, bushes and soil slices in order to maintain almost constant depth of flow in the main canal at branch bifurcation points for proportional release of water in different branches. In case of outlets directly connected to the main canal, the width of outlet is inspected and adjusted by the water user functionaries or water monitors as and when required allowing a defined volume of water to be released.

Annual Repair And Maintenance

Annual maintenance activities include de-silting of the major branch canals, repair of intake structures and strengthening of canal dikes. For most perennial systems the de-silting activity takes place twice a year, once in Feb-March (spring rice season), and once in May-June (monsoon rice season). In the seasonal systems de-silting takes place once prior to the monsoon (April-May).

Emergency Repair And Maintenance

Emergency repairs typically involve repair of the diversion structure and main canal embankment. Since the diversion structures are made of brushwood they tend to be swept away often during the floods and require attention. The irrigation systems drawing water from the Rapti and the Lothar Rivers are reported to require more number of emergency repairs. Although the Dhongre and the Budhi Rapti are also perennial rivers incidences of flooding are lower here because of the steady flows. In the irrigation systems drawing water from the seasonal streams the incidence of flash floods are higher and the maintenance frequencies are higher too.

Preventive Repair And Maintenance

Preventive maintenance activities are reported only in the main and the branch canals mainly to protect the canal embankment in order to prevent the caving in of the canals. The responsibility for maintaining the canals generally belongs to those users owning land along the canal embankment.

Resource Mobilization For Repairs And Maintenance

Cash as well as labor resources are mobilized to carry out repair of intake structures and de-silting of canals. Most systems generate these resources internally. The basis for cash or labor resource mobilization appears to differ for activities relating to the intake structure, main and secondary canals and for emergency repair and maintenance. For the maintenance of headwork cash and labor resources is mobilized on the basis of households and landholding. For the main canal it is based on the land holding. Similarly, for emergency repairs the household again appears to be the basis for mobilization. The system of "Jharahi" wherein all able-bodied men of a household contribute labor during repair and maintenance is practiced in systems operated by the Tharus especially for maintenance activities in the headwork and main canal.

The nature of resource mobilization in the irrigation systems is reported to be changing over time. Wherein a decade back it was the norm for all water users to contribute labor during the annual maintenance, the practice now is shifting towards the water users sending a proxy laborer or paying cash for the labor charges. This form is practiced more in the Pahadia managed systems than in the Tharu managed systems. In some systems the annual repair and maintenance work is contracted out to external parties.

Rules And Regulations

Rules and regulations in all systems are linked to the allocation and distribution of water, resource mobilization for repair and maintenance, charging fines for being absent during repair and maintenance, and penalties for the defaulters. 60% of the systems in Chitwan have written rules and regulations. 70% of the Tharu managed systems have no formal written rules and regulations. Rule following nevertheless is reported to be highest in the Tharu managed irrigation systems.

Violations of rules attract a variety of sanctions. If someone violates the labor obligation rule or becomes absent during annual repair and maintenance work, monetary fines are imposed on the defaulters. In the majority of the cases, the amount fined (kardari) is equivalent to the prevailing daily labor wage rate in the particular area. In some systems, where the availability of the labor is scarce defaulters are required to pay an amount higher (Rs 5-10) than the daily labor wage. Sanctions can take any of the following form i) no fine, ii) monetary fine, iii) cessation of water turn, iv) removal from water users committee, and v) any combination of the above.

Sanctions are imposed by the water user functionaries, guards or by fellow appropriators depending on the nature of the sanction imposed. Sometimes, in cases of water thefts severe social sanctions are also imposed.

Conflict Management

Inter-system as well as intra-system conflicts occur from time to time. The inter-system conflicts relate to issues of water sharing violations between systems and intra-system conflicts result from disagreements in water allocation and distribution methods especially during the water deficit periods. Although there are a reasonable number of conflicts that arise only two cases have been serious enough to warrant external intervention from the district administration. Normally conflicts are resolved locally.

Quite often the conflict between upstream and downstream systems occurs in water deficit periods when water sharing agreements are violated resulting in the breakage of diversion structures. Representatives from both WUOs routinely resolve such conflicts informally. Conflict among users within systems occurs mainly due to water pilferage or violation of the water rotation rule during water deficit periods particularly during paddy transplantation seasons. The number of conflicts in a system tends to increase with number of appropriators. Conflicts tend to be settled by imposing sanctions on violators.

DATA ANALYSES

A subset of the Nepal Irrigation and Institutions and Systems Database (NIIS) encompassing all of the irrigation systems from Chitwan District was examined to explore relationships between irrigation performance measures and heterogeneity variables. Although the total number of cases examined was 74, effectively 65 and less could only be used for statistical analysis due to data gaps.

The approach to data analyses involved a) identifying and developing composite irrigation performance measures b) using these measures to specify a regression model to explore relationships between performance and heterogeneity and c) examining further associations between irrigation performance and different institutional variables. The first task was accomplished utilizing the structural equation modeling approach where the specified model was validated through a confirmatory factor analysis. The latent variables in the model were then subsequently used to explore associations between irrigation performance and various physical and institutional variables. The methodology employed is similar to the one used by Lam (1996).

Confirmatory Factor Analysis

The theoretical arguments for choosing a multi-dimensional measure for irrigation performance has been well laid out by Lam (1996). He suggests that measures of irrigation performance have to capture the following ideas a) the physical condition of the irrigation system, b) the ability to deliver water and c) agricultural productivity. Following his methodology I first attempted to check whether these measures would still be valid for my data set. Unable to validate the three dimensional model for my data set, I built a two dimensional model and results are reported for this model in the subsequent sections.

The two *LATENT FACTORS* specified are PHYSICAL CONDITION and AGRICULTURAL PRODUCTIVITY. The first variable attempts to capture how well an irrigation system is maintained i.e. the canals and the head-works. The quality of the infrastructure is a reflection of the collective maintenance efforts as well as the degree of social organization of the group. The second variable agriculture productivity attempts to broadly capture the productive potential of the group resulting from their collective efforts. The *INDICATORS* that are believed to measure the latent variable Physical Condition are a) CONDITION AND b) ECONEFF. Similarly, METRICTON, HEADINT and TAILINT measure Agriculture Productivity. A brief description of the variables is as follows:

CONDI: Attempts to measure overall how well maintained the irrigation systems are. Response to the statement, "the physical condition of the system is as well maintained as is economically feasible given the terrain and technology available to farmers" generates four categories of response which are: 1= Very bad Condition 2 = poor, 3 = good, and 4= excellent
ECONEFF: Attempts to measure short-run economic technical efficiency. Response to statement " the costs of operating and maintaining this system are less than the benefits obtained from operation and maintenance" generates four types of responses: 1= highly inefficient, 2=inefficient, 3=efficient, 4=highly efficient
MTON: Attempts to capture the quantity of agriculture produce per hectare per year.
HEADINT: Cropping intensities at the head end of the canal. Three crops a year would mean a cropping intensity of 300%. Intensities can vary from 100% - 300%.
TAILINT: Cropping intensities at the tail end of the canal.

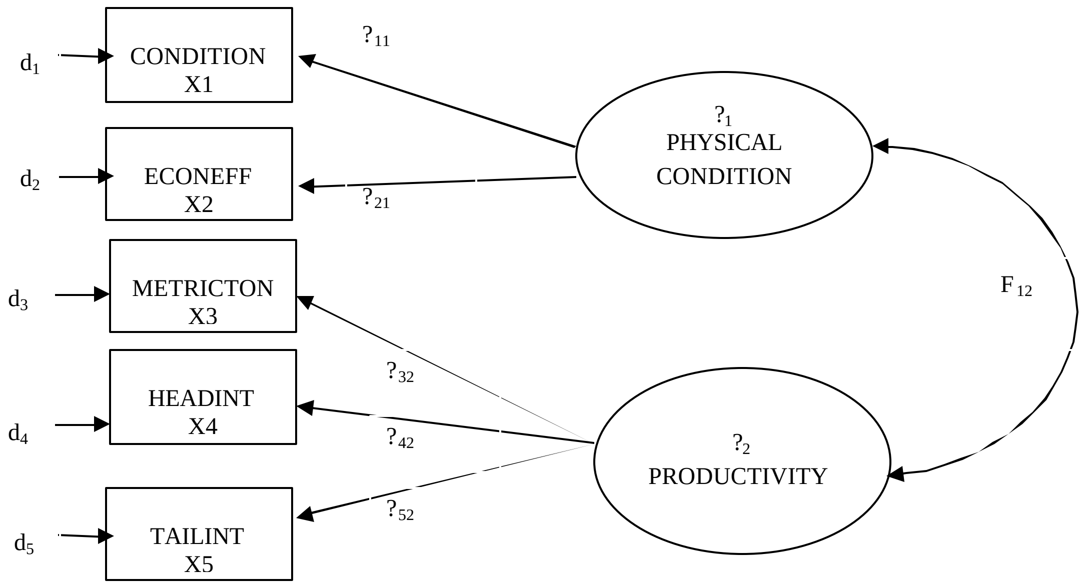
Based on the above two LATENT variables and their indicators a confirmatory factor model can be represented by the following equation and path diagram:

X = ? ? + d

Where,
X = vector of observed indicator variables

? = vector of latent factors
? = matrix of loadings that give a magnitude of the effects of ? on X
d = vector of residuals
F_{12} = Correlation between two factors

FIGURE -1 CONFIRMATORY FACTOR MODEL



A polychoric correlation matrix of the observed variables was computed using PRELIS and this matrix was the input used to estimate the confirmatory factor model employing LISREL VIII. Estimates are based on the Maximum Likelihood Estimating technique. The correlation matrixes as well as the resulting statistics are presented in the following tables.

TABLE -1

CORRELATION MATRIX

	CONDI	ECONEFF	MTON	HEADINT	TAILINT
CONDI	1.000				
ECONEFF	0.327	1.000			
MTON	0.343	0.354	1.000		
HEADINT	0.435	0.254	0.667	1.000	
TAILINT	0.344	0.226	0.741	0.786	1.000

TABLE -2

MAXIMUM LIKELIHOOD ESTIMATES

Coefficients	Standardized Maximum Likelihood Estimates	Standard Errors	T-Values
CANAL CONDITION			
$?_{11}$	0.682	0.185	3.696
$?_{21}$	0.480	0.157	3.049
PRODUCTIVITY			
$?_{32}$	0.803	0.107	7.497
$?_{42}$	0.858	0.104	8.238
$?_{52}$	0.912	0.101	9.031
CORRELATION AMONG DIMENSIONS			
F_{11}	1.000	-	-
F_{22}	1.000	-	-
F_{12}	0.622	0.159	3.911
VARIANCE OF ERRORS			
d_1	0.534[a]	0.224	2.387
d_2	0.770	0.169	4.553
d_3	0.355	0.079	4.486
d_4	0.264	0.071	3.706
d_5	0.168[a]	0.067	2.506

N= 65
$?^2 = 6.15$, df = 4, p = 0.188
[a] Not Statistically significant at he 0.05 level

TABLE -3

GOODNESS OF FIT STATISTICS FOR CFA MODELS

Model	$?^2$	df	P	RMR	NFI	CFI	IFI	GFI	AGFI
M_0	152.75	10	0.000						
M_1	9.58	5	0.088	0.062	0.936	0.966	0.967	0.943	0.830
M_2	6.15	4	0.188	0.038	0.958	0.983	0.984	0.963	0.861

df = degree of freedom, RMR = Root Mean Square Residual,
NFI = Normed Fit Index, CFI = Comparative Fit Index, IFI= Incremental Fit Index
GFI = Goodness of Fit Index, AGFI = Adjusted Goodness of Fit Index
M_0 = A baseline model which assumes no relationship
M_1 = A uni-dimensional model where Performance is the latent variable and all other are indicator variables
M_2 = proposed model

TABLE -4

FITTED RESIDUAL COVARIANCE MATRIX

	CONDI	ECONEFF	MTON	HEADINT	TAILINT
CONDI	0.000				
ECONEFF	0.000	0.000			
MTON	0.002	0.114	0.000		
HEADINT	0.071	-0.002	-0.022	0.000	
TAILINT	-0.043	-0.046	0.009	0.003	0.000

TABLE -5

STANDARDIZED RESIDUAL COVARIANCE MATRIX

	CONDI	ECONEFF	MTON	HEADINT	TAILINT
CONDI	0.000				
ECONEFF	0.000	0.000			
MTON	0.038	1.802	0.000		
HEADINT	1.510	-0.038	-1.794	0.000	
TAILINT	-1.426	-1.401	1.226	0.803	0.000

TABLE -6

R^2 Values for the Indicators

	R2
CONDI	0.466
ECONEFF	0.230
MTON	0.645
HEADINT	0.736
TAILINT	0.832

TABLE -7

Factor Scores Regressions

	CONDI	ECONEFF	MTON	HEADINT	TAILINT
Physical Condition	0.471	0.230	0.076	0.109	0.182
Productivity	0.043	0.021	0.209	0.300	0.502

Discussion of CFA Results

The fit of the model is assessed based on a number of statistics such as Chi square, Root Mean Square Residual, and different Fit indices which are summarized in Table 3. In addition the fitted residual covariance matrix and the standardized residual covariance matrices are reviewed to ensure no discrepancies (Tables 5 and 6) in the model. The model chi-square, also called discrepancy, is the most common fit test statistic. The chi-square value should not be significant if there is a good model fit, while a significant chi-square indicates lack of satisfactory model fit. That is, chi-sqaure is a "badness of fit" measure in that a finding of significance means the given model's covariance structure is significantly different from the observed covariance matrix. If the chi-square is <.05 the model is rejected. The Chi-square statistic of the model has a value of 6.15 with 4 degrees of freedom. Its corresponding P-value is 0.1888. What this means is that the sample covariance matrix and the covariance matrix predicted by the model are not statistically different or significant. Hence our test of the hypothesis that the sample covariance matrix and the covariance matrix predicted by the model is the same cannot be rejected. Another statistic the RMR for our model 0.038 is reasonably small. The closer the RMR to 0 for a model being tested, the better the model fit. RMS residuals are the coefficients which result from taking the square root of the mean of the squared residuals, which are the amounts by which the ***sample*** variances and covariances differ from the corresponding ***estimated*** variances and covariances. The NFI, CFI and IFI values for the model are respectively 0.958, 0.983 and 0.984. By convention all of these statistics should be > 0.9 to accept the model which is true in our case. The goodness of fit statistic GFI of 0.963 too exceeds the conventional threshold of 0.9. A review of Table 4 gives us a picture of the magnitude and direction of the standard errors. The standardized residuals in Table 5 further allows us to interpret these residuals. Each of the standardized residual cab be interpreted as a standard normal deviate and can be considered to be large if any of the values exceed 2.58 (Joreskog and Sorbom, 1989). None of the elements in table 5 exceeds this threshold and the model's prediction errors can be considered to be low. Further, an alternative model (a uni dimensional model) M_1 was run to see if there was any difference at all between this model and the proposed model M_2. Reviewing the comparative statistics in Table-3 we see that each of the statistics for model M_2 is better than those of M_1. On the basis of these results we conclude that the two-dimensional model best fits the sample data and that the latent variables PHYSICAL CONDITION and AGRICULTURAL PRODUCTIVITY can be used as measures of irrigation performance for further analyses.

Looking at Tables 2 and 6 we can, further, see that there are no anomalies in the parameter estimates e.g. correlations exceeding 1 or negative variances. The t-values except for one element are all statistically significant at the 0.05 level. The INDICATOR loadings ($?_{ij}$) are relatively high ranging from 0.48 to 0.912 and the R^2 values which measure the portion of variability in an indicator accounted for by the latent dimensions range from 0.23 to 0.832. Except for ECONEFF, values for the rest of the variables appear reasonable. Although the Weighted Least Square (WLS) method is recommended to be the most appropriate estimation technique for analyzing categorical data of the kind that has been analyzed, the MLE still gives consistent estimates of the parameters and can be used as approximate indicators. Since computing an asymptotic covariance matrix of the sample variance as its weight in estimation requires a large sample size (>1000) the WLS method could not be used. However, various empirical studies do suggest that WLS typically leads to similar fit statistics as maximum likelihood estimation and to no difference in interpretation. On the basis of the discussions put forward in the previous sections the two dimensional Model M2 can be considered to reasonably fit the sample data and that the factor scores for the identified latent variables can be used as measures of irrigation performance for further analyses.

REGRESSION MODEL

The purpose of conducting a regression analyses in this section is to examine primarily the relationships between performance measures and variables that represent the physical and socio-economic environments. Physical variables that are thought to influence performance are orientation, average access to water, type of headworks, type of canal lining and the size of the irrigation system (system area and canal length). Similarly, pertinent scoio-economic variables are believed to be ethnic composition, income variations among groups of irrigators, group size and alternative choices groups have vis a vis access to irrigation water.

The regression model is specified as in the following equation (1) where the two latent factors Physical Condition and Productivity from the earlier sections are the dependent variables. The equations used to compute the factor scores for these variables are derived from the model estimates from the earlier section (Table 7). It has to be noted that the factor scores have no magnitude and can be interpreted only relative to each other. Ordinary Least Squares (OLS) is used to estimate the regression model.

PERFORMANCE MEASURES (*Physical Condition & Productivity*) = a + $ß_1$ * Orientation + $ß_2$ * Income Variations + $ß_3$* Ethnic Composition + $ß_4$* Alternatives + $ß_5$* Lining + $ß_6$ * Headwork + $ß_7$* Number of Appropriators + $ß_8$* System Area + $ß_9$* Average Access to Water + $ß_{10}$* Canal Length ………………………….. (1)

Orientation =	A dichotomous variable, 0 if system is located on East-West flowing river and 1 if located on North-South flowing river.
Income Variation =	Dichotomous Variable, 0 if variance of average annual income across families is low and 1 if moderate or high.
Ethnic Composition =	dichotomous variable, 0 if heterogeneous, and 1 if homogenous
Alternatives =	dichotomous variable, 0 if alternative water source not available 1 if available
Lining =	dichotomous variable, 0 if no lining, 1 if partial or complete lining
Headwork =	dichotomous variable, 0 if permanent (gabion) and 1 if temporary (brushwood)
Number of Appropriators =	continuous variable
System Area =	continuous variable (hectare)
Average Access to Water =	continuous variable (months)
Canal Length =	continuous variable (meters)

Discussion of Regression Results

Regression results are presented in the following Table.

TABLE - 8

OLS Regression Results

Independent Variables	Dependent Variables	
	Physical Condition	Productivity
Constant	74.864 (11.383 ***)	201.63 (11.124***)
Orientation	-11.301 (-2.889 ***)	-31.243 (-2.899***)
Income Variation	-4.973 (-1.858 *)	-13.632 (-1.848*)
Ethnic Composition	2.401 (0.952)	6.467 (0.930)
Alternatives	-3.336 (-1.243)	-9.271(-1.254)
Lining	2.497 (0.800)	6.871 (0.799)
Headwork	-2.132 (-0.763)	-6.109 (-0.793)
Number of Appropriators	.010 (0.705)	0.027 (0.709)
System Area	.009 (0.766)	0.026 (0.755)
Average Access to Water	1.186 (2.419 **)	3.218 (2.381**)
Canal Length	0.000 (-1.042)	-0.001 (-1.046)
Adjusted R^2	0.439	0.435
Number of Cases (N)	64	64

* $p < 0.1$, ** $p < 0.05$, ***$p<0.01$

Orientation appears to be the most statistically significant (0.01 level) variable that influences performance. Moreover, the sign of the coefficient estimates are negative. What this indicates is that systems located on North-South flowing rivers under perform in comparison to systems located on East-West flowing rivers. This result is consistent with our observations of the Nature of the rivers in that region. Rivers on a North-South route in Chitwan valley are generally seasonal rivers, have higher gradients, transport lots of sediments and often change course. Hence everything else remaining equal irrigation systems located on N-S Rivers have less volume of water per year available for their crops. The regression results bear this out. Not only do N-S systems under perform in terms of productivity but also the maintenance of irrigation systems appear to be poorer. Another variable that significantly influences the performance measure is the number of months appropriators can access water from the rivers (significant at 0.05 level). The sign of the coefficient is positive indicating that systems that access water for more number of months are more productive and have better maintained infrastructure. Income variation too appears to have a significant effect at the 0.1 level and its sign is negative. If the annual income variation among groups is high then this appears to have a negative impact on both performance measures. This result is a little different from Lam's result which shows that *income inequality* is significantly and negatively related to productivity but not significantly to the physical condition of the system. However, the results do tend to support both Bardhan (2000) and Dayton–Johnson's results where they show *wealth inequality* is significantly and negatively associated with canal maintenance. The regression results further indicate that ethnic composition, the type of headwork, canal lining, system area, number of appropriators and irrigation alternatives tend to have no significant association either with productivity or physical condition of the infrastructure. Although the coefficients signs for head-works (-ve) and canal lining (+ve) are similar to those reported by Lam, unlike his finding, here these variables appear not to be statistically significant. An interesting result relates to ethnic composition. There are studies which indicate that that class differences can cripple efforts at organizing for collective action in the villages due to mistrust and lack of mutual understanding and also results (Wade, 1994) that show groups can overcome socio-cultural barriers and cooperate. In Chitwan socio-cultural differences appear not to be a factor that affects performance though the +ve sign indicates advantages for the homogenous group.

Performance Measures and its Association with Different Variables

Performance and Physical Variables

A review of table 9-12 suggests that there are 22 irrigation systems located on E-W Rivers and 42 on N-S. Further, systems on E-W Rivers have better maintained infrastructures and higher productivity. These results are statistically significant and underscore the importance of physical properties of a given natural resource. This idea is again reinforced by the numbers in Table-12. All of the 22 irrigation systems on E-W Rivers have access to water for more than nine months on the average whereas only 11 out of 42 systems have such access on N-S Rivers. The availability of water appears to have a positive impact not only on the productivity but also on infrastructure maintenance. The greater benefit to cost ratio that can potentially be achieved in systems located on E-W Rivers probably provides stronger incentives to organize and keep the infrastructure well maintained.

TABLE-9 SUMMARY OF PERFORMANCE MEASURES

	Mean	Standard Deviation	Minimum	Maximum	Number of Cases
Physical Condition	73.73	13.21	36.41	90.75	64
Productivity	197.82	36.27	95.98	243.24	64

TABLE -11 RELATIONSHIPS BETWEEN ORIENTATION AND PERFORMANCE MEASURES

	N	Systems on East - West running Rivers (N=22)	Systems on North- South Running Rivers (N=42)	F	p
Physical Condition	64	85.15	67.74	40.94	0.00
Productivity	64	229.12	181.43	40.62	0.00

TABLE-12 RELATIONSHIPS BETWEEN AVERAGE ACCESS, ORIENTATION AND PERFORMANCE MEASURES

	Systems on East – West running Rivers	Systems on North- South Running Rivers
Access to water less than 9 months	0 (0%)	31 (74%)
Access to water greater than 9 months	22 (100%)	11 (26%)
	22	42
	100%	100%
Chi^2 = 31.49, p = 0.000		

	Access to water less than 9 months (N=31)	Access to water greater than 9 months (N=33)	F	p
Physical Condition	65.1	81.83	42.4	0.000
Productivity	174.2	220	41.95	0.000

Performance and Labor Contribution

Investigating whether higher productivity and better maintenance on E-W systems compared to those in N-S systems are results of labor contribution we see in Table 13 that this is not the case. Although measures such as average number of labor days spent in system maintenance, labor days/hectare, and labor days/household are higher in East – West River systems they are not significant at the 0.1 level. Hence the explanation for better performance measures have to be sought else where.

TABLE- 13 RELATIONSHIP BETWEEN LABOR CONTRIBUTION AND ORIENTATION

	Systems on East – West running Rivers (18 cases)	Systems on North- South Running Rivers (41 cases)
Average number of labor days spent in system maintenance (Labor days)	1380.83 (1823.35)	825.26 (1217.7)
F = 1.9, p = 0.173		
Average number of labor days spent in system maintenance per hectare of land area (Labor days/ha)	12.2 (18.6)	9.12 (9.8)
F = 0.694, p= 0.408		
Average number of labor days spent in system maintenance per household (Labor days/household)	14.21 (25.26)	7.19 (8.54)
F = 2.545, p = 0.116		

Performance, Leadership and Cooperation

Table -14 exhibits the response to the question, "has any member of the group invested notable amounts of money and or time in an effort to coordinate appropriators' strategies?" Similarly, Table-15 is a response to the question " Is there any evidence presented in the documents that these appropriators have engaged in cooperation in other activities besides the management of this resource?". It is observed that more leadership activities take place in E-W systems than in N-S systems and there has been more cooperation in other arenas in E-W systems than in N-S systems. Further, leadership qualities and cooperation in other arenas is seen to be strongly associated with irrigation performance measures - productivity and physical condition.

TABLE 14 - RELATIONSHIPS BETWEEN LEADERSHIP OR ENTREPRENEURIAL ACTIVITIES, ORIENTATION AND PERFORMANCE MEASURES

	Systems on East - West running Rivers	Systems on North- South Running Rivers
No Leadership activities	3 (18%)	24 (60%)
Presence of some level of such activities	14 (72%)	16 (40%)
	17	40
	100%	100%
Chi^2 = 8.58, p = 0.003		

	No Leadership activities (N=26)	Presence of some level of such activities (N=28)	F	p
Physical Condition	68.65	79.99	14.9	0.00
Productivity	183.88	214.96	14.7	0.00

TABLE -15 RELATIONSHIPS BETWEEN COOPERATION IN OTHER ACTIVITIES BESIDES IRRIGATION, ORIENTATION AND PERFORMANCE MEASURES

	Systems on East - West running Rivers	Systems on North- South Running Rivers
No cooperation	3 (18%)	27 (71%)
Some cooperation	14 (82%)	11 (29%)
	17	38
	100%	100%
Chi^2 = 13.51, p = 0.000		

	No cooperation (N = 30)	Some cooperation (N = 25)	F	P
Physical Condition	70.07	78.36	6	0.018
Productivity	187.82	210.45	5.9	0.018

Performance and Institutional Variables

More Appropriators in E-W systems tend to be rule followers than in N-S systems, however, the infraction level in N-S systems are lower than in E-W systems. Both the results are statistically significant at the 0.07 level. Rule following appears to have a stronger association with productivity than physical condition yet both are statistically insignificant at the 0.1 level. The degree of infraction on the other hand, appears to have similar strengths of association though again both relationships are insignificant at the 0.1 level. These results are reflected in Tables 16 and 17. It is surprising to note that rule following and breaking does not have a strong association with the performance measures.

TABLE -16 RELATIONSHIP BETWEEN RULE FOLLOWING PRACTICES, ORIENTATION AND PERFORMANCE

	Systems on East - West running Rivers	Systems on North- South Running Rivers
Low/Moderate level of rule following	8 (42%)	32 (80%)
High level of rule following	11 (58%)	8 (20%)
	19	40
	100%	100%
Chi^2 = 3.185, p = 0.074		

	Low/Moderate level of rule following (N=13)	High level of rule following (N=41)	F	P
Physical Condition	73	78	0.978	0.327
Productivity	210	195	1.867	0.178

TABLE-17 RELATIONSHIP BETWEEN LEVEL OF INFRACTIONS, ORIENTATION AND PERFORMANCE

	Systems on East - West running Rivers	Systems on North- South Running Rivers
Low level of rule breaking	15 (83%)	34 (97%)
High/moderate level of rule breaking	3 (17%)	1 (3%)
	18	35
	100%	100%
Chi^2 = 3.24, p = 0.071		

	Low level of rule breaking (N=45)	High/moderate level of rule breaking (N=3)	F	p
Physical Condition	74.6	79.24	1.804	0.185
Productivity	200.24	212.78	1.867	0.178

Comparison of Irrigation Systems Drawing Water from North-South and East-West Flowing River Systems of Chitwan

Rivers flowing East-West vs River flowing North South

Classification of Irrigation Systems in Nepal are based on the topography of the terrain traversed by the rivers. Systems that tap into rivers whose gradients change rapidly as they flow downhill are called Hill Irrigation Systems, those that draw water from rivers that cut across valleys with gentle gradients are termed River-Valley Irrigation Systems, and those that draw water from relatively large rivers flowing across the flat Terai lands are called Terai Irrigation Systems (Pradhan, 1989). The physical characteristics of a river – rate of change of gradient, discharge, suitable locations for constructing diversions, rate of sediment deposits on river bed, frequency of change in watercourse etc. – very often determine the starting conditions i.e. amount of efforts required to operate an irrigation system. Irrigation systems located close to each other on the same river may very well face significantly different beginning conditions. Differences in the resource conditions introduce heterogeneities.

There are two distinct types of river systems in Chitwan, those that flow North to South and those that flow East to West. The rivers that flow from North to South (Kair Khola, Pumpa Khola, and Lothar) originate from the Mahabharat hills and are characterized by i)steep gradients ii) seasonal flows, iii) changing river courses, iv) low discharge volumes, and v) flow through difficult terrain. Irrigation systems drawing water from these rivers are located immediately on the foothills of the Mahabharat Hills and share the characteristics of both Hill and River-Valley Irrigation Systems. Such irrigation systems tend to have longer canals, landslide zones, narrow cross sections, frequent flash floods, longer idle lengths, and diversion weirs need frequent maintenance. In contrast the rivers that flow from East to West (Rapti, Dhongre, Boodi Rapti) traverse flat terrains where gradients are mild, flows are perennial and discharges are high. Irrigation systems drawing water from these rivers share the characteristics of Terai Irrigation Systems. In such systems intake construction is crucial and resource mobilization considerable as they tap into powerful rivers. However, since river gradients are negligible and the canal irrigates flat farmlands canal maintenance efforts are lower.

Although there are physical and institutional differences between these systems there are similarities too (Pradhan 1989, Ostrom, 1992). Intake structures on systems in all classes are generally constructed from boulders, stones and brushwood are located appropriately to ensure easy diversion of water; rights to water withdrawal are fairly well established within systems and water distribution among appropriators are governed by commonly understood sets of rules; and maintenance of physical structures, especially the intakes, during high floods require significant resource mobilization (Parajuli 1999, Ostrom 1992).

Irrigation Systems off N/S vs. E/W Flowing Rivers

Reflecting on the differences in the general characteristics of the rivers that flow from North to South and those that flow from East to West, we can expect irrigation systems drawing water from the former to have more difficulties at system maintenance (terrain, landslides, changing river course) and more conflicts between systems to assert water rights (low mean monthly discharges). Similarly, we can expect to see more cooperative efforts exerted at the intake and less inter system conflicts over water rights on systems drawing water from the latter type of rivers.

TABLE -18 Discharge From Different Rivers

RIVER	Mean monthly discharge – Dry season May (cu mecs)	Mean monthly discharge – Wet season August/ cumecs	Mean monthly average over years (least and max)	Catchment Area (Sq Km)	River Length (Km)	Number of Irrigation Systems	Estimate of Water use cumecs
LOTHAR (N-S)	1.4 – 2.7	7-55	*	169	14	4	4.96
RAPTI (E-W)	7-29	90-500	13 –184 (April/Aug)	1884	65	10	4.35
BOODI RAPTI (E-W)	0.17-3	3-123		184		11	1.43
KAIR (N-S)	0.089 – 2.56	8-37	1.05 – 18.52 (April/Aug)	79.7	44	9	2.77
PUMPA (N-S)	0.2	35	*	*	*	5	1.29
DHUNGRE (N-S)	1.09	49.2	*	*	*	22	5.38

Irrigation Systems off N-S flowing rivers

Kair River

Three irrigation systems – Jyamire, Baheri Paschim and Belsi/Hajipur - were examined on this river (TABLE-19). Among these Baheri Paschim was the only irrigation system that was functioning during the time of survey in July 2003. Its intake and the canals were in good condition and water was flowing in the system. However, the changing river course and the flood waters had destroyed the intake of Jyamire flooding not only its fields but those of neighboring systems resulting in its closure in 2000. A Gabion stone wall had to be erected at the intake area to stop flooding. Unable to locate a suitable intake site either upstream or downstream this system has been dysfunctional for over three years. The effect on the Belsi/Hajipur system due to the changing river course (one month prior to survey) has resulted in a dry intake area. A new intake needs to be constructed further up and into the river course. Preparations were underway to raise money and organize manpower to reconstruct the intake during the time of the survey.

Jyamire used to be located upstream of Baheri Paschim and Belsi/Hajipur is located downstream. This is a case that underscores the importance of the physical location of intake vis a vis the river course. Relative positions on a river matter but the advantages on a river that changes course often is untenable.

TABLE- 19 Irrigation Systems off KAIR River

	Jyamire	Baheri Paschim	Belsi/Hajipur
Relative Location on River	Head	Mid	Tail
Location	Chainpur VDC 2, irrigates land North of E-W Highway	Chainpur VDC 1, irrigates land North of E-W Highway	Ratnanagar, Chainpur VDC 1,2, irrigates land North as well as South of Highway
Service Area (Ha)	55	50	100
Number of Households	100	110	500
Year initially Constructed	1964	1954	1908
Constructed by	Pahadia	Pahadia	Tharu
Ethnic Composition	Brahmin/Chettris	Brahmin/Chettri – 55% Tharu – 32% Darai 13%	Tharu – 50% Brahmin – 30% Newar/Magar/Gurungs - 16% Kami – 4%
Land Holding (Ha)	Majority ~0.23ha	70% own > 0.67	75% < 0.67
ERIP intervention	No	Yes	No
Average Water access (months)	0	8	7
Canal	Mud- lined	Mud lined + partial cement lined	Mud-lined
Note	Flood/ had to close. Non-functional since last 3 years.	15% land owned by Tharu but cultivate 75% of land, absentee landlords	Although irrigates 4 villages Bansi and Bhokahana do not cooperate in maintenance, unique topography.

Jyamire Irrigation System: This is a system located in Chainpur VDC 2 north of the East-West highway. It irrigated 55 hectares of land belonging to 100 households. It was originally constructed in 1964 by the migrant families. The total length of the canals is approximately 10 Km and it had a temporary headwork. After its closure due to unmanageable flooding conditions in 2000 farmers have either switched over to irrigating their fields through pump sets or rely on drainage water from the upstream systems. The majority of the landowners are Brahmins and Chettris.

Baheri Paschim: This is a system initially constructed in 1954 which serves an area of 50 hectares north of the highway belonging to 110 households. It is located in Chainpur VDC-1. It has a permanent gate and parts of the canals are cement lined. This is a system that was supported by the East Rapti Irrigation Project. The ethnic composition of the group is Brahmin/Chettri – 55%, Tharu – 32%, Darai – 13%. Because there are many absentee landlords over 75% of the land is tilled by the Tharu and Darai households under different sharecropping arrangements. Although the Tharus and Darai own only 15% of the total land they manage and maintain the canals. Maximum land holding is 2.5 Ha, minimum 0.25 Ha, and the majority 1 Ha. (avg access 7 months)

Belsi/Hajipur Kulo: This system irrigates 100 Ha of land belonging to 500 households. More than 75% of the households own land less than 0.67 Ha. Fifty percent of the total households are Tharu, 30% Brahmin, 16% Newar, Magar and Gurungs, and 4% Kami and Sarkis. The system was constructed by the Tharus in 1908 and is one of the oldest systems in the Kair river. The main canal is approximately 4 Km in length and the three main branches add up to 3 Kms. The canals irrigate the villages of Hajipur, Belsi, Bansi and Bhokahana. However, villagers of Bansi and Bhokahana do not cooperate in canal maintenance because the drainage water has to pass through their fields because of the topography though they are located at the tail end of the system. Villagers are increasingly supplementing their water needs through pump-sets. Villagers report that the intake has had to be changed 2 times already in the past 2 years due to the changing river course. There has been no ERIP intervention in this scheme and all the canals are mud-lined. Avg access (7 months)

Pumpa Khola

Four irrigation systems – Pumpa, Kyampa, Baireni/Pakhdibas, and Surtani - were examined on this river(Table -20). Only Baireni/Pakhdibas among these four systems was not functioning during the time of survey. A landslide had washed away more than 400 meters of the main canal which needed to be constructed all over again. Also scouring of the river bed had left the intake at a higher elevation which needed to be shifted to another appropriate location. On this river system Pumpa is located at the head end, followed by Kyampa (30 m below pumpa), Baireni/Pakhdibas and Surtani. Although the relative location among these four systems places Surtani at the tail end it enjoys an advantage over the others because the drainage waters from the Lothar river systems drain into the Pumpa at about this location providing it access to water round the year. Systems both above and below Surtani are water deficit.

TABLE-20 Irrigation Systems off PUMPA River

	Pumpa Kulo	Kyampa Kulo	Baireni/Pkhdibas Kulo	Surtani Kulo
Relative Location on River	Head	300 m below Pumpa	Mid	Tail
Location	Birendra Nagar Ward 1,5 irrigates land North of E-W Highway	Birendra Nagar Ward 1, irrigates land North of E-W Highway	Khairehani Ward 2, Birendra nagar 6, irrigates land North of Highway	Khairahani Ward 2, irrigates land both North and South of Highway
Service Area (Ha)	70	100	100	60
Number of Households	140	120	180	90
Year initially Constructed	1968	1969	1932	Unknown
Constructed by	Pahadia	Pahadia	Tharu	Tharu
Ethnic Composition	Brahmin/Chettris – 60% Gurung – 22% Magar – 11% Tamang – 7%	Brahmin/Chettri – 70% Gurung – 20% Magar 10%	Tamang– 51% Tharu – 36% Brahmin/Chettri - 13%	Tharu – 54% Brahmin – 36% Magar/Kami/Damai – 20%
Land Holding (Ha)	75%< 0.67ha	80% own < 0.67	84% < 0.67	70%<0.67 ha
ERIP intervention	Yes	Yes	No	Yes
Average Water access (months)	9	8	2	12
Canal	Cement - lined	Mud lined + partial cement lined	Mud-lined	Mud lined + partial cement
Note	Canal in top condition, water right conflicts with neighbors Kyampa and Chipleti	Has an agreement with Pumpa to acquire sufficient water for its wheat crop	Intergroup conflict. Tamangs who came in 1958 forcibly used system.	Receives supplemental water from Lothar.

Pumpa Kulo: This system which was initially constructed in 1968 irrigates 70 Ha of land belonging to 140 households. The ethnic mix of this group is: Brahmin – 60%, Gurung – 22%, Magar – 11%, and Tamang – 7%. The total canal length including the two branches is about 6 Km. Unlike any other systems part of the intake of this system includes permanent concrete work. This has been the reason why Pumpa has been involved in an extensive legal battle over water rights with its neighbor Chipleti and Kyampa. Tremendous efforts including the construction of a 50 m tunnel through hard rock have gone into constructing a kilometer stretch of the canal through very difficult mountain terrain. The canal is in top condition and the group has very elaborate and well understood rules for maintaining the canals. Average water access from the canal is reported to be about 9 months and 75 % of the households own land less than 0.67 hectares.

Kyampa Kulo: This system constructed in 1960 has its intake just 30 meters down from Pumpa's intake. The canal passes through similar terrain as its neighbor and irrigates 100 Ha of land belonging to 120 households. Since it is located immediately downstream from Pumpa it is dependent upon an agreement with Pumpa, reached after substantial conflicts, that it would release sufficient water to irrigate its wheat crops. The majority of the households own less than 0.5 hectares of land and Brahmins are the dominant ethnic group.

Baireni/Pakhadibas: This is one of the oldest systems on this river constructed by the Tharus in 1932. At present its irrigation command area is 100 Ha belonging to 180 households. Ethinic composition of this group constitutes 51% Tamang, 36% Tharu and 13% Brahmins/Chettris. The total length of the main canal is over 11 Km where the first 2 Km stretch passes through difficult terrain. Since it is located about 2 kilometers downstream from the Pumpa/Kyampa.Chipoleti intakes there is very little water in the river as it reaches the intake of this system. The problem is further compounded by conflicts between the Tharu and the Tamang groups. Migrant Tamangs who settled in the area only after 1958 are reported to have forcibly started using the system resulting in a deep mistrust between the groups. Construction of new irrigation systems upstream (pumpa, chipleti), difficult terrain, and intergroup conflicts has resulted in poor performance of the system. This system on average can access only for two months in a year.

Surtani Kulo: This system irrigates 60ha belonging to 90 households. The ethnic composition of the group is 54% Tharu, 36% Brahmin, and 20% -Magar/Kami/Damai. A little more than 70% of the households own less than 0.67 ha of land where maximum holding is 3.3 Ha. The system has a gabion diversion dam and a permanent check gate and the intake has remained in the same place for many years. Although located downstream it is at an advantageous position because its intake is at a location where it can tap supplemental water from the Lothar River. This system has a continuous water supply to all branches round the year.

Lothar Khola

Three irrigation systems – Madhavtar Kulo, Bagar Kulo, and Dubichaur Kulo – were examined on this river system. Mahadevtar is located at the head end of the river and is the first irrigation system drawing water from it. Although Bagar's intake is physically located after Madhevtar its water rights are second to Dubichaur's which is located at the end. All of the systems were in working condition in March 2003.

TABLE-21 Irrigation Systems off LOTHAR River

	Madhavpur Kulo	Bagar Kulo	Dubichaur kulo
Relative Location on River	Head	Mid	Tail
Location	Piple 6, irrigates south of highway	Piple 6, irrigates land North of E-W Highway	Piple 4, irrigates land South of Highway
Service Area (Ha)	130	10	100
Number of Households	135	25	150
Year initially Constructed	1943	1994	1958
Constructed by	Pahadia	Pahadia	Pahadia
Ethnic Composition	Brahmin/Chettris > 90%	Brahmin/Chettri – 95%	Tamangs– 45% Brahmin/Chettris – 27% Praja - 18% Damai/Kami – 10%
Land Holding (Ha)	Majority < 0.67ha	70% own > 0.35	75% < 0.67
ERIP intervention	No	No	Yes
Average Water access (months)	12	9	12
Canal	Mud- lined, Permanent Gate	Permanent Gate	Mud-lined, partial cement, permanent gate
Note	Water sufficient, inactive WUA, strongly defended water rights	June-Feb water use, cannot cultivate spring paddy	Strict rules governing water use.

Madhavpur Kulo: This is the oldest irrigation system in the Piple area constructed in the early 1990s. It services about 130 hectares of land belonging to 135 households in ward number 6 of Piple VDC. There are three major branches each roughly 1.5 Km in length. All of the canals are mud lined and there has been no intervention by ERIP. The dominant ethnic group is Brahmin and majority land holding is less than 0.5 hectares. Located at the very head end of the river this system has adequate water round the year.

Bagar Kulo: This is a new system constructed in 1994. Land area irrigated is approximately 10 hectares belonging to 25 households. Majority own land less than 0.35 hectares, the canal length is 1 Km and Brahmin/Chettris constitute the major ethnic group. The farmers from Bagar were able to construct this canal only after a protracted struggle with farmers from Dubichaur and Mahadevtar. A negotiated settlement has resulted in an arrangement where it can be operated from June-February for 9 months. This prevents them from cultivating Spring Paddy.

Dubichaur ko Kulo: This system irrigates 100 hectares belonging to 150 households. It was first constructed in 1958. It has one main canal (1.5 Km) and two branch canals (1.5, 0.5 Km). The ethnic composition of the group is Tamangs – 45%, Brahmin/Chettris – 27%, Praja 18%, and Damai/Kami – 10%. During the spring season water is on short supply and there are strict rules governing water use within the system.

Irrigation Systems off E-W flowing rivers

Rapti River

Janakalyan "Ka" and Janashakti: This is a relatively large irrigation system drawing water from the Rapti River. After 200 meters from the intake, water is distributed between ward number 1 and ward numbers 9 and 8. One part of the water is allocated for the settlements of Kushana and Gadauli in Ward number 1 and two parts for settlements of Pidrahani, Kumrattha, Soondi and Gaida of Wards 9 and 8. The total distance of Janakalyan "Ka" from the head to the tail is approximately 13 Kms. Janashakti is another canal system drawing water from the Rapti River. Its waters mix into the Janakalyan Canal at Pidrehani of Ward 9. However, the water of Janashakti is allotted entirely for Soondi and Gaida of Ward number 8. The entire Janakalyan "ka" kulo irrigates approximately 423 hectares of land belonging to over 500 households. Around 150 households share the waters of Janashakti. Janakalyan "ka" was constructed in 1983 and Janshakti in 1993. For recording purposes with the government, Janshakti is considered a branch canal of Janakalyan and both the systems are referred to as Janakalyan "Ka".

Boodi Rapti and Dhongre

Badgaon Pipra Kulo: This irrigation system services two settlements (Badagaon and Pipara) of Ward number 6. This system draws water from two sources - Boodi Rapti River and Dhongre River. When it was initially constructed in 1932 the intake source was only Boodi Rapti, Dhongre was added later on. The main canals transporting water from these two different river systems mix and flow for about a kilometer before they are distributed through the branch canals. Average width of the irrigation canal after the merger is 5 meters. There are 9 major branch canals on this system servicing 182 hectares of land area. Distribution of the water is based on the land area that is irrigated. The longest branch canal is about 2.5 Km and the shortest 0.2 km. There are 200 households using the system and the ethnic composition is 50% Tharu and 50% Bahun /Chettri. Most of the land areas in this system produce three major crops.

Kuckuchhe Forest

Amrit Kulo and Janakalyan "Kha"): The source of Amrit Kulo is the stream that originates from the Kanteswori Forest but its intake is located on the outskirts of Khuckuche forest. Although this system services about 75 hectares of land it is not entirely through the waters from the Kanteswori streams. Waters from Kanteswori is able to irrigate only about 25 hectares of land, the remaining 50 hectares is irrigated through the waters of the Jana Kalyan "Kha" kulo. The Jana Kalyan "kha" kulo's source is the Rapti River. The households of ward numbers 5 and 7 constructed this system jointly and water is shared between them on a 3: 2 ratio. The head canal of Janakalyan passes through the Kuchkucche forest. As it comes out of the forest, it is roughly parallel to the Amrit Kulo where it releases Amrit's share of the water via a side canal. After releasing ward number 7's share of the water the Janakalyan traverses across ward number 7 transporting water further west to ward number 5. The joint waters of Amrit kulo service

100 households where its ethnic composition is: 76% - Brahmin/Chettri, 14% - Tamang, and 10% - Damai. Amrit Kulo has been in service since 1961 but Janakalyan was constructed only in 1983. Amrit Kulo is about 3 Km in length and has 9 branches.

Kharkhutte Tallo Kulo (ward #7): The source of this canal is the Boodi Rapti River, which originates from the jungles of Kuchkuchhe. It irrigates approximately 60 hectares of land in ward 7 belonging to 70 households. The ethnic composition of the households is: Tharu – 29%, Darai – 17%, Brahmin/Chettri – 54%. This system has been in operation since 1958. The average length of the main canal is 3 Km and there are 7 branch canals in this system.

Information in the previous paragraphs are summarized in Table-22.

TABLE-22 Irrigation Systems Off E-W Flowing Rivers

	Rapti River Janakalyan "Ka & Janashakti	Boodi Rapti and Dhongre Badgaon/Pipra Kulo	Kuchkuchhe Amrit and Janakalyan "Kha"
Location	Wards 1,9,8 Kathar VDC	Kathar Ward 6	
Service Area (Ha)	423	182	75
Number of Households	500	200	100
Year initially Constructed	1983, 1993	1932	1961, 1983
Constructed by	Pahadia	Tharu	Pahadia
Ethnic Composition	Bahun/Chettri - Majority Darai Tamang	Tharu – 50% Bahun/Chettri – 50%	Bahun/Chettri – 76% Tamang – 14% Damai – 10%
Land Holding (Ha)	Majority <0.67 ha	Majority <0.67 ha	Majority <0.67 ha
ERIP intervention	Yes	Yes	Yes
Average Water access (months)	12	12	12
Canal	Mud- lined, Partially cement, Permanent Gate	Mud- lined, Partially cement, Permanent Gate	Mud- lined, Partially cement, Permanent Gate
Note	Water shared between 1 and 9,8 – 1:2, Janshakti services 150 HH exclusively in 8.	Draw water from two sources, two villages use a common canal.	The canals of Amrit convey water to ward 5, another system.

Comparing systems off N-S flowing rivers

Amongst the rivers flowing in the N/S direction Pumpa River has the lowest discharges and tends to dry up at lower stretches during the dry seasons of April/May. Further, there aren't too many suitable points where the intakes can be located. Except for Surtani none of the systems in this river can access water round the year. Average access ranges from 3 – 8 months. Given the nature of the river one can expect irrigation systems drawing water off this river to be very sensitive about their water rights. This is underscored very well by the conflicts that Pumpa, Kyamapa and Chipleti irrigation systems have had in the past (see Shukla et al, 1996 for details). The source of conflict amongst these systems has been the location of their intakes which are relatively close to each other and the construction of a semi-permanent intake by Pumpa system increasing its ability to divert more water for itself. Understandably the conflict is over the volume of water accessible to systems in a seasonal river characterized by diminished discharges. Despite the intersystem conflicts each of these systems is able to access water for an average of 7 months since cooperation within systems is strong. This strength is physically reflected by well maintained canals and also elaborate agreed upon rules governing system maintenance and water allocation. All the systems have similar ethnic mixes like Pumpa. There are at least 4 ethnicities reflected in each group dominated by Brahmin/Chettris.

Further downstream, terrain difficulties and reduced flows compounded by inter group conflicts between the Tharus and the Tamangs in the Baireni/Pakhdibas system is slowly pushing it to a state of disrepair. Also wealthier farmers are opting out of the system by putting up their private pump sets.

In contrast to the above mentioned systems Surtani located further downstream enjoys a peculiar locational advantage enabling it to access water round the year. Canals are well maintained and a relatively heterogeneous group of farmers have well designed rules to ensure equitable distribution among their members.

Though Kair is a bigger river than Pumpa, the water volumes, like Pumpa, reduces significantly in the dry months. This river is also known to change water course frequently rendering intakes useless on a regular basis. Most systems on this river on an average access water between 7-8 months annually.

The relative location of the irrigation intakes on this river is at significant distances unlike in Pumpa and is not at all a cause for conflict. Rather, the inability to manage floods and to find a suitable alternative point to locate its intake has resulted in the demise of Jyamire. Incessant floods threatened not only its own but fields of neighboring systems as well and there was intense pressure to permanently close the intake site through the construction of a gabion wall. Although it is a relatively small system (55ha) with a homogenous group (mainly Brahmins/Chettris) it was not able to put together sufficient resources to develop an alternate site. Farmers report that the group size was just to small (100 HH) to generate the required resources for an alternative site. Households in this system at present either rely on drainage water from other systems or on their own pump sets. Another system of similar size, Baheri Paschim, however, has been fortunate to be located at a point where floods have not affected it severely. Despite ownership of significant land by absentee landlords irrigation canals are still well maintained. Tharus and Darais, who till land under various sharecropping arrangements, operate this system. Belsi/Hajipur, one of the last systems located on this river, exhibits an interesting case. Not only does it have to cope with washed out intakes and floods but also a unique topography in its fields where any drainage water has to flow through the fields located at the tail end in this system. An unwillingness to negotiate first use rights by head-enders during stressful times has resulted in a situation where the farmers at the tail-end from Bansi and Bhokahana refuse to cooperate knowing fully well that drainage water during plentiful times will flow their way anyway. Also increasing use of pump-sets in the area is exerting a strain on the collective action efforts of the group. Although 50% of the group comprises Tharus collective efforts are not at levels that ought to be possible.

Lothar, another river system that flows from N/S, is a little different from Pumpa and Kair in that it is a perennial river and does not change its course before draining into the Rapti. Though discharges diminish during the dry season there has always been sufficient round the year water for Madhevtar Kulo which is located absolutely at the head end. Two other systems – Bagar and Dubichaur - draw water from Lothar but it is not adequate to yield two rice crops.

The behavior of water users in the plentiful Madevtar system is different from those in Bagar and Dubichaur. Since it is the first of the three systems drawing water and because its intake is located at a very suitable point requiring only minimal efforts to divert water relative collective efforts are insignificant and often neglected. The water users committee is nonfunctional, water distribution and canal maintenance rules are very loose and aren't enforced, and water users association is not registered. However, water is plentiful round the year. This is reflected by the overflowing canals and the number of fish ponds in the command area. Despite the apparent negligence the first use rights are strongly defended and the group is reluctant to regulate its wasteful water use practices for the benefit of systems downstream. It is also unwilling to include Bagar, a small 10 Ha system, in its fold. The ethnic composition of this group is homogenous comprising mostly of Brahmins. Although the second system off Lothar is Bagar it has the most inferior water use rights. This is because this piece of flood land was reclaimed only very recently by new settlers. Only after years of struggle with Dubichaur and Madhevtar were they able to negotiate a settlement and open up an intake on Lothar. However, their contract prevents them from accessing water for spring paddy. Dubichaur, located at the tail end is relatively water stressed during the dry season. It has elaborate water apportioning and maintenance rules and their canals are well maintained. The group consists of at least four ethnic groups. Paddy and Maize are cultivated on a 50/50 basis during the spring.

TABLE-23 SYSTEMS OFF N-S FLOWING RIVERS

PUMPA	KAIR	LOTHAR
Lowest discharge among the three rivers, lower stretches dry up, not too many points to locate intakes, difficult terrain. Water sharing conflicts between Pumpa, Kyampa and Chipleti Faces difficult terrain, has multiple ethnic groups but strong cooperation in all three systems embroiled in conflict. Canals are well maintained, presence of strong rules. Baireni/Pakhdibas faces similar conditions but cannot cooperate, ethnic conflicts persist. Soortani – Locational advantage	A bigger river than Pumpa yet water volumes reduce in dry season. Frequent change in water course, terrain not as difficult as Pumpa. No intersystem conflicts as relative intake locations are further apart Inability to manage floods – Jyamire's demise. Baheri Paschim – good location, sharecropping arrangement by absentee landlords with Tharus – homogenous group – well maintained canals. Belsi/Hajipur: affected by changing river course, peculiar topography giving advantage to tail end – inability to cooperate despite 50% of Farmers are Tharus.	A perennial River, does not change course, diminished volumes but sufficient water, easiest physical terrain. Madhevtar: non-functioning water users committee, majority Brahmins a homogenous group Bagar: second in line but inferior water rights to Dubichaur Dubicahur: Relatively Water stressed during dry season, ethnic composition diverse, strong water allocation rules.

Comparing systems off E-W flowing Rivers

Unlike rivers flowing in the N-S direction, the E-W Rivers have higher discharge volumes, lower gradients and are perennial rivers. Most systems that draw water off these rivers, therefore, do not tend to have inter - system conflicts because water is in plentiful supply. Also, since the rivers have gentler gradients and do not frequently change course there are far greater numbers of points where intakes can be suitably located. Idle canal lengths are shorter, larger command areas are irrigated, canals traverse through easy terrain, average access is round the year, and canal maintenance efforts are significantly lower. The concern, rather, is on dealing with floods which wash away intakes multiple times in a year. Most efforts at canal maintenance are exerted at the intake which consumes the majority of man-hours expended on system operation.

Rapti, Dhongre and Boodi Rapti typically exhibit the above mentioned characteristics than the systems of Kuchkuchhe. Systems drawing water from the Kuchkuche forest springs face even easier physical conditions.

Probably due to plentiful resource conditions more inter-system cooperation is seen. For instance Amrit Kulo and Janakalyan Kha, Jana Kalyan "Ka" and Janshakti, and Badgaon-Pipara systems are examples of intersystem cooperation. Farmers from ward number 5 use the canals of Amrit Kulo (ward 7) to transport the Rapti water to their fields. Similarly, in the Badgaon-Pipara system Badgaon's canals are used to convey waters from two different rivers Boodi Rapti and Dhongre.

The ethnic composition of groups in all of the systems examined show that they are not homogeneous and comprise of at least three different ethnic groups. Cooperation among group members in all of the systems appears to be enduring. Water users associations are registered and active, there are specific written rules governing the apportioning of water and maintenance of the systems which are commonly well understood, records of labor contributions are documented and sanctions are enforced. All of the systems examined have a cropping intensity of 300% (2 paddy and 1 winter crop) and only minor differences are reported in yields between head and tail end within a system reflecting successful water management rules. More maintenance efforts are reported to be required for intake maintenance in the Rapti than in other Rivers.

Preliminary Observations on Heterogeneity and collective action

Unpredictable resource flows and terrain determine the amount of collective efforts that are required to bring about tangible improvements on the status quo. If there is very little scope of feasible improvement and if required efforts far outweigh the expected benefits to be derived then cooperation may be difficult. Resource attributes, however, are one part of the equation. Whether people cooperate is also a function of attributes of the resource users. If there is a common understanding among resource users, if they consider the resource to be salient and if there is trust then the chances of cooperating are high. Cooperation again can be affected by locational asymmetries, inequalities in wealth, ethnic dissimilarities and exit options. In the subsequent section I will try to summarize how some of these factors play out in Chitwan.

Initial resource conditions, in Chitwan, appear to be a big factor that sets the stage for cooperation. Irrigation systems located on N-S flowing rivers face more uncertainties than systems located on E-W flowing rivers. Accordingly, more cooperation difficulties are observed in the former systems than in the latter. However, despite the difficulties faced various levels of efforts at cooperation can be observed since agriculture is the major livelihood of the local population and water is a salient resource. All of the systems have been able to tackle their locational asymmetry problem by devising a set of water allocation rules that create incentives for all group members to join the cooperative effort. Belsi/Hajipur is an obvious exception. Although cooperation problems have been observed the inability to get along with each other due to ethnic differences appears not to be a major factor. Such a problem of mistrust was seen only in one case that of Baireni/Pakhdibas system. Pumpa, which faces similar resource conditions as Baireni, unlike Baireni, has been able acquire significant resource units through collective efforts. The type of headwork, canal lining, system area, number of appropriators and irrigation alternatives also tend not to be significantly associated either with productivity or physical condition of the infrastructure. Variation in income, however, does appear to have a significant impact on performance. Systems with lower income variance tend to perform well both in terms of productivity and infrastructure maintenance. There are wealthy farmers in each of the systems who sometimes own 20 times more land than the smallest farmer. However, the majority of farmers fall in the less than 0.5 ha category and constitute a critical mass promoting cooperation. Leadership roles and past cooperation in other arenas tend also to be strongly associated with irrigation performance measures. Introduction of technology i.e. private pump-sets, and the employment opportunities in a foreign labor market does provide some exit options but their impact on the whole appears to be negligible. Pump-sets consume fuel and fuel adds to production costs. Hence pump-sets are still used as a back up and supplemental source. Similarly, movement of the labor force to a foreign market is insignificant, a family member may be employed outside but the remaining family members still depend on farming for their livelihoods.

Most of the farmer managed irrigation systems in Chitwan are functional and in good condition. They have been able to get out of the cooperation dilemma by providing themselves with a self-governing institution.

REFERENCES

Acheson James. 2000. “Varieties of Institutional Failure”. Presented as the Keynote Address at “Constituting the Commons: Crafting Sustainable commons in the New Millenium”, Eighth Conference of the International Association for the Study of Common Property, Bloomington, Indiana, USA, May 31-June4.

Acheson James. 1989 “Management of Common Property resources”. In, Stuart Plattner, ed., Economic Anthropology. Stanford: Stanford University Press.

Agrawal, A. 2002. “Common Resources and Institutional Sustainability”. In “Drama of the Commons”. National Academy Press, Washington D.C.

Axelrod, R. 1984. “The Evolution of Cooperation”. New York: Basic books.

Baker, J.M. 1997. “Common Property Resource Theory and Kuhl Irrigation Systems of Himachal Pradesh, India. Human Organization 56:199-208.

Baland. J. and J. Platteau. 1994. “Halting degradation of natural resources: Is there a role for rural communities?”. Namur, France: Universitaries Notre-Dame de la Paix, Facultes des Sciences Economiques et Sociales. Oxford University Press. Forthcoming.

Bardhan, P. 1993 “Symposium on Management of Local Commons”. Journal Of Economic Perspectives 7 (4): 87-92

Bardhan, P. K. 2000 Irrigation and Cooperation: An Empirical analysis of 48 Irrigation Communities in South India. Economic Development and Cultural Change 48:847-865.

Bardhan, P. and Dayton-Johnson 2002 “ Unequal Irrigators: Heterogeneity and Commons Management in Large-Scale Multivariate Research”. In The Drama of the commons. Edited by Ostrom et al. National Academy Press, Washington DC.

Berkes, F., 1989 “Common Property Resources: Ecology and Community-Based Sustainable Development. London:Belhaven Press.

Bloomquist, A. 1992. “Dividing the Waters: Governing Groundwater in Sothern California”. San Francisco: ICS Press.

Bloomquist W., E. Schlager, S. Tang. 1994 “Regularities from the field and possible Explanations”. In Ostrom, Gardner, Walker ed., “Rules, Games, & Common-Pool Resources” (University of Michigan Press), pages 301-16

Bloomqvist, A. 1996. “Food and fashion. Water Management and Collective Action among Irrigation Farmers and Textile Industrialists in South India. Linkoping, Sweden: The Institute of Tema Research, Department of Water and Environmental Studies.

Bromley, D. W., Editor. 1992 “Making the Commons Work”. San Fransisco, CA: Institute for Contemporary Studies.

Cason, T.N., and F.Kahn,.1996. “A Laboratory Study of Voluntary Public Goods Provision with Imperfect Monitoring and Communication.” Working Paper. Department of Economics, University of Southern California, Los Angeles.

Cernea, M. 1988. “User Groups as Producers in Participatory Afforestation Strategies.” World Bank Discussion Papers no. 70. Washington, DC: The World Bank.

________1981 “Land Tenure Systems and Social Implications of Forestry Development Programs”. World Bank Staff Working Paper No. 452. Washington, D.C.: The World Bank.

Chambers, R., N.C. Saxena and T. Shah. 1989. “To the Hands of the Poor: Water and Trees. London: IT Publications.

Coward, E.W, G. Levine. 1987. “Studies of farmer Managed Irrigation Systems: Ten Years of Cumulative Knowledge and Changing research Priorities. In Public intervention in Farmer Managed in Farmer Managed Irrigation Systems, IIMI, 1987.

Dayton – Johnson, J. 2000 “ Choosing Rules to Govern the Commons: A model with evidence from Mexico. Journal of Economic Behavior and Organization 42:19-41.

Demestz, H. 1967 “Toward a Theory of Property Rights”. American Economic Review 57:347-59.

Easter K.W., and K. Palanisami. 1986. “Tank Irrigation in India and Thailand: An Example of Common Property Resource Management,” Department of Agricultural and Applied Economics Staff Paper, University of Minnesota.

Farrel, J. 1987. “Cheap Talk, Coordination, and Entry.” Rand Journal of Economics 18(spring):34-9

Feeny, D., Hanna, S. and McEvoy, A.F. 1996 “Questioning the Assumptions of the “Tragedy of the Commons model of fisheries”. Land Economics 72(2):187-205

Gordon, H. S., 1954 “ The Economic Theory of Common-Property Resource: The Fishery. Journal of political Economy. 62(April): 124-142

Gibson, C., M. McKean and E. Ostrom. 2000. “People and Forests; Communities, Institutions, and Governance.” MIT Press, Cambridge, Massachusetts.

Hackett, S.C. 1992 “Heterogeneity and the Provision of governance for common-pool resources.” Journal of theoretical politics 4:325-342.

Hardin, G. 1968. “The Tragedy of the Commons”. Science 162:1243-1248

Issac, R., and James Walker. 1991. “Costly Communication: An experiment in a Nested Public Goods Problem.” In Laboratory research in Political Economy, ed. Thomas R. Palfrey. Ann Arbor: University of Michigan Press. Pages 269-86.

Jayaraman, T.K. 1981. “Farmers’ Organizations in Surface Irrigation Projects: Two Empirical Studies from Gujarat,” *Economic and Political Weekly*, vol. 16 (39), 1981.

Johnson, N., G. Libecap. 1989 “Contracting Problems and Regulation: The Case of the Fishery”. American Economic Review, December, 72:5, 1005-22.

Kanbur, R. 1991 “ Heterogeneity, Distribution and cooperation in Common Property Resource Management.” Background paper for the 1992 World Development Report, World bank

Lam Wai Fung. 1998 “Governing Irrigation Systems in Nepal: Institutions, Infrastructure and Collective Action”. Institute of Contemporary Studies, Oakland California.

Larson, Bruce A,; and Daniel W. Bromley. 1990. “Property Rights, Externalities, and Resource Degradation: Locating the Tragedy.” Journal of Development Economics 33(2):235-62

Leach, E.R. 1961 “ Pul Eliya: A village in Ceylon.” Cambridge, Eng: Cambridge University Press.

Martin, E.D., R. Yoder. 1983. “Review of Farmer-Managed Irrigation in Nepal”. Water Management Seminar, Nepal, 1983.

McCay, B. J., and J.M. Acheson 1987 “Human Ecology of the Commons” in The Question of the Commons. Tucson:University of Arizona Press.

McKean Margaret. 2000. Common Property: What is it, What is it good for, and what makes it work, In Gibson et al, eds, People and Forests.

McKean, Margaret. 1992. “Success on the Commons: A comparative examination of Institutions for Common Property Resource Management.” Journal of theoretical Politics 4(July):247-82.

Molinas, J.R. 1988 "The impact of inequality, gender, external assistance and social capital on local level cooperation." World Development 26:413-431.

Ostrom, Elinor, Roy Gardner. 1993 "Coping with Assymetries in the Commons: Self-Governing Irrigation Systems Can Work". Journal of Economic Perspectives – Vol 7, Number 4, Pages 93-112.

Ostrom, E., R. Gardner, J. Walker. 1994. "Rules, Games and Common-Pool Resources". Ann Arbor, Mich., U.S.A.: University of Michigan Press.

Ostrom Elinor. 1990. "Governing the Commons. The Evolution of institutions for Collective Action." Cambridge University Press.

Ostrom E., 1998 "Self Governance of Common Pool Resources". The New Palgrave Dictionary of Economics and the law. Edited by Peter Newman.

Ostrom, Elinor. 1998. "Self-Governance and Forest resources". Workshop in Community Based Natural Resource Management (CBNRM). Washington DC, May 10-14, 1988

Ostrom, E. 2001. "Reformulating the Commons". In ed., J. Burger et al. Protecting the Commons: A Framework for Resource Management in the Americas. Island Press, Washington D.C.

Ostrom Elinor. 1999. Context and Collective Action: Four Interactive Building Blocks For a Family of Explanatory Theories, Workshop In political Theory and policy Analysis, IU.

Ostrom, Elinor. 1992. "Crafting Institutions for Self Governing Irrigation Systems". ICS, San Francisco.

Ostrom, E. 1999. "Institutional Rational Choice: An assessment of the Institutional Analysis and Development Framework." In Paul A. S. Sabatier's, Theories of the Policy Process, ed, Westview Press.

Parajuli, U. N. 1999. "Agro-Ecology and Irrigation Technology: Comparative Research on Farner-Managed Irrigation Systems in the Mid-Hills of Nepal". PhD. Dissertation, Wageningen.

Pradhan, P. 1989 "Patterns of Irrigation Organization in Nepal" A comparative Study of 21 Farmer Managed Irrigation Systems". Country paper No. 1, IIMI, Colombo, Sri Lanka.

Palit, S. 1996 " Comparative Analysis of Policy and Institutional Dimensions of community Forestry in India and Nepal". MNR series No. 96/4, ICIMOD

Ramussen L.N. R. Meinzen-Dick. 1995 "Local Organization for natural Resource Management: Lessons from Theoretical and Emperical Literature". International Food Policy Research Institute, Washington D.C.

Runge C.F. 1981 "Common Property Externalities: Isolation, assurance and resource depletion in a traditional grazing context." Ameriacn Journal of Agricultural Economics 63:595-606.

_________ 1984 "Institutions and the Free Rider: The Assurance Problem in Collective Action". Journal of Politics 46:154-181.

Sally, D. 1995. "Conservation and Cooperation in Social Dilemmas. A Meta-Analysis of Experiments from 1958-1992." Rationality and Society 7(January):58-92.

Schlager, Edella. 1990. "Model Specification and Policy Analysis: The Governance of Coastal Fisheries." Ph.D. diss., Indiana University.

Shiwakoti, G., E. Ostrom. 2002. "Improving Irrigation Governance and Management in Nepal". ICS Press, Oakland, CA.

Shukla, A. et al. 1993. "Irrigation Resource Inventory of East Chitwan." IMSSG, Institute of Agriculture and Animal Science Rampur, Chitwan, Nepal.

Tang, S.Y. 1991 " Institutional Arrangements and the Management of common Pool Resources". Public Administration Review 51:42-51

Tang, S.Y. 1992 " Institutions and Collective Action: Self-Governance in Irrigation. Sanfrancisco:ICS.Press.

Uphoff, Norman, M.L. Wickramasinghe, C.M. Wijayaratna. 1990 " Optimum Participation in Irrigation Management: Issues and Evidence from Sri lanka". Human Organization 49 (1): 26-40.

Vaidyanathan, A. 1986 "Water control Institutions and Agriculture: A Comparative Perspective. Indian Economic Review 20:25-83.

Varughese, George. 1999. "Villagers, Bureaucrats, and Forests in Nepal: Designing Governance for a Complex Resource". Workshop in Theory and Political Analysis.

Varughese, G., and E. Ostrom 2001 " The contested role of heterogeneity in collective action: some evidence from community forestry in Nepal". World Development 29 (5): 747-765

Wade, Robert. 1988 "Village Republics: Economic Conditions for Collective Action in South India". Cambridge University Press.

Wade, R. 1994. "Village Republics: Economic conditions for Collective Action in South India. San Francisco, CA: ICS Press.-

Yoder, Robert D. 1986. "The Performance of Farmer-Managed Irrigation Systems in the Hills of Nepal". Ph.D. Dissertation, Cornell University.