# Irrigation Networks in the Western Himalaya:

# Methodological and Conceptual Implications for Public Administration Theory

(June 1995)

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Abstract

Interconnected gravity flow irrigation systems *(kuhls)* in the western Himalaya provide fertile ground for developing methodologies and conceptual frameworks useful for analyzing public organization networks. This paper integrates resource dependence theory with insights drawn from the new institutionalism and population and human ecology to generate a model which suggests that under conditions of common environmental vulnerability, interconnectedness can become a resource which reduces the risk and uncertainty associated with unpredictable environmental perturbations. This proposition is tested by developing an empirical indicator of the structure of interconnectedness between kuhl irrigation systems and examining the relationship between interconnectedness and interkuhl coordination of water management activities. After analyzing the structure and effects of irrigation networks within one watershed, I examine the technical, embedded, cognitive and normative basis' for network coherence. The paper illustrates the methodological and conceptual challenges associated with moving beyond networks as metaphors for interorganizational relations to the network as a rigorous analytical construct.

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## Introduction

Networks of interorganizational relations within uncertain and unpredictable organizational environments are not new objects of inquiry within organizational theory.[1] However the current and increasing concern regarding the functioning of public organizations under conditions of increasing heterogeneity, network embeddedness, and external regulatory control, combined with declining resources and public confidence, has pulled the network concept from the wings onto the center stage of organizational analysis. Researchers and practitioners have welcomed this shift, as it promises to illuminate the heretofore unexplained effects of increasingly dense and complex webs of interorganizational relations on organizational behavior and outcomes.[2] Yet the project is beset with such conceptual, analytical and methodological obstacles that LaPorte has argued that public organization theory is experiencing a "growing relative ignorance" (1994:6).[3] These obstacles include empirical challenges associated with accurately assessing the extent and shape of interorganizational networks and measuring network density and linkage strength, and the conceptual challenge of developing theoretical frameworks which achieve the analytical rigor required of a robust generalizable theory.

This paper uses data collected during two years of field research on the thirty-nine gravity flow irrigation systems *(kuhls)* that flow from the Neugal River in District Kangra, in Himachal Pradesh, India, to methodologically and conceptually contribute toward understanding the structure and function of interorganizational networks. The paper's key contributions are, 1) to

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[1]See Benson's (1975) early call to study interorganizational networks as "emergent phenomena" in their own right. Regarding uncertain and unpredictable organizational environments see Emery and Trist's (1965) categorization of organizational environments into placid-randomized, placid-clustered, disturbed-reactive and turbulent, and Terreberry's (1966) argument that organizational environments are becoming increasingly turbulent.

[2]This paper restricts its focus to implications for public organization networks. However the network aspect of business organizations, in contrast to the market hierarchy spectrum with its concomitant hybrid forms of organization (Williamson 1975), is increasingly prevalent. See Powell (1990) for examples of business and economic networks and for analysis of the conditions under which network forms of economic organization would be expected to emerge.

[3]See LaPorte (1994a:8) for a more complete listing of the internal and external conditions within which U.S. public organizations currently function, and LaPorte (1994b:3) for an extended discussion of the analytical shortfalls of current attempts to theorize network properties, function, structure and effects.

develop a conceptual framework which suggests how, within a context of shared environmental vulnerability, interdependent exchange relations between interconnected organizations can reduce the risks associated with environmental dependence, 2) to present one example of an empirical indicator of environmental interconnectedness within the context of irrigation systems and to use the indicator to differentiate kuhls by their degree of interconnectedness, and 3) to explore the relationship between interconnectedness and interdependent relations between kuhls for coordinated water management.

The paper has four sections. The first section briefly describes kuhl structure and function, the spectra across which kuhls vary, and the annual rhythm of activities associated with kuhl management. The second section analyzes the interkuhl network from the perspective of a "net rider" (LaPorte 1994b), an individual within the network, also conceived as "someone who is trying to work within and through a set of relationships with other actors, in pursuit of both individual and collective objectives" (Hanf and O'Toole 1992:163). This section examines how the interkuhl network operates to reduce the risk and uncertainty individuals face regarding water supply within a context of common vulnerability to recurring environmental shocks, i.e. floods, earthquakes and drought. I draw on resource dependency theory for conceptualizations of environmental dependence. However, I separate environmental dependence from organizational interdependence and suggest that under some conditions interdependence between organizations may be an asset rather than a discretion-reducing liability as resource dependence theory usually maintains. The third section analyzes the interkuhl network at the network, rather than "node" level. Assuming the perspective of a "net thrower" (LaPorte 1994b), i.e. an external analyst or policy maker, I describe, analyze and explain the structure of the interkuhl network within the study watershed. I present empirical indicators of the degree of interconnectedness between kuhls and relate the degree of interconnectedness to evidence of interdependent relations for water management between kuhls. The fourth section explains the coherence of interkuhl networks. In addition to the physical nature of kuhl interconnectedness stemming from the technical constraints of gravity flow irrigation, I argue that core institutional norms such as reciprocity, the degree to which interkuhl networks are embedded in broader social relations (Granovetter 1985), the cognitive notions of community reproduced within kuhl rituals, and the

common vulnerability of kuhls to environmental shocks such as floods, promote kuhl network coherence. Finally I synthesize the papers methodological and conceptual contributions and discuss the broader relevance of the study's results as well as its implications for public policy implementation.

**The Setting**

Some of the densest and most physically and socially diverse gravity flow irrigation systems in the western Himalaya are located in Kangra Valley in District Kangra in the eastern portion of Himachal Pradesh. The Kangra Valley spreads southwards from the base of the steeply rising Dhaula Dhar range towards the low lying and erosive Sivalik Hills. The valley is roughly forty-five kilometers long from west to east and ten to twenty kilometers wide. The elevation of the valley ranges from 4,500 feet at the foot of the Dhaula Dhar to 2,500 feet where it meets the Sivalik Range. The Dhaula Dhar dominate the landscape from any point in the valley. They rise 10,000 feet above the valley floor to an average height of 14,000 feet within a distance of less than three miles. The valley itself is a series of alluvial fans and riverine terraces deposited by the mountain streams and torrents originating in the Dhaula Dhar. These streams flow from the Dhaula Dhar south across the valley and eventually join the Beas River, one of the five major tributaries of the Indus River. Based on the density of kuhl irrigation networks, I chose one of these mountain streams, the Neugal, and studied the 39 kuhls that originate from it.

In Kangra Valley, approximately 715 major kuhls and more than 2500 minor kuhls[4] irrigate more than 30,000 hectares of terraced agricultural fields.[5] Kuhls range in size from

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[4]*A* major kuhl has a perennial water source and irrigates two or more villages. This information comes from the *Riwaj-i-Abpashi* (Book of Irrigation Customs) which was originally compiled in 1874 and later revised during the third land revenue settlement of District Kangra from 1913-1919.

[5]Dependence on kuhl water for irrigation peaks during the dry season just prior to the onset of the monsoon. During the dry season, kuhl water, originating as snow melt from the Dhaula Dhar range, is used to facilitate field preparation for the rice crop and to keep the terraced fields flooded following rice sowing. Kuhl water is also used to irrigate the primary winter crop, wheat, as well as the relatively recently introduced potato. However, in addition to providing irrigation water, kuhls also used to meet all the water needs of the villages they flowed through. This was especially true during the hot, dry pre-monsoon season when local springs were low or dry. Kuhl water satisfied all domestic water needs such as cooking, washing (utensils, persons and clothes), and watering livestock, and the small kitchen garden invariably found near the domestic compound. Members of the Doumna (basket making) caste soaked split bamboo and reeds in small pools filled with kuhl water prior to weaving them. Members of the Kumhar (potter) caste used kuhl water to turn their pottery making wheels. Most kuhls powered at least one, and as many as twenty, water mills used for husking and grinding grain.

command areas of only a few hectares to single systems that irrigate more than four thousand hectares. Their length varies from less than 100 meters, to greater than 40 kilometers, and the number of villages within a single kuhl's command area varies from one to over fifty. The organizational forms that have evolved to manage these systems also vary tremendously. Layers of complexity range from simple collective arrangements among farmers with little or no role specialization, to elaborate and refined organizations that have formal kuhl committees with elected officers and extensive written records, sophisticated methods for measuring water flow and several designated watermasters, one of whose primary tasks is to mobilize the necessary labor for kuhl maintenance and repair.[6]

The elevational differences between the agricultural fields within most villages create the topographic conditions necessary for networks of overlapping kuhls. The more fertile rice and wheat growing fields that lie just above the riverine cliffs are known as *har*. The less fertile maize growing upper fields on top of the sloping alluvial plateau are known as *larh*. I will refer to larh as upper fields and to har as lower fields. Most farmers cultivate both upper and lower fields.[7] Due to the elevational differences between upper and lower fields, the kuhls that irrigate upper fields must begin ten to fifteen kilometers upstream of those that irrigate the lower fields. Often a kuhl that irrigates upper areas in village (B) will irrigate the lower areas of an upstream village (A), while another kuhl which irrigates the lower areas in village (B) will also irrigate the upper area of a downstream village (C), and so on. This creates a situation in which the upper fields of a farmer in village (B) may be at the tail end of a kuhl originating in village (A) while his lower fields may be at the head end of a kuhl which also irrigates the upper fields of village (C). At the basin level, the pattern of multi-village kuhls and multi-kuhl villages creates a

[6]For a detailed description of the organization of kuhl maintenance and repair activities, the responsibilities of the watermaster, local irrigation practices including water measurement and distribution, and cropping patterns and practices, see Baker (1994:101-145).

[7]In general the lower terraces receive a more assured supply of water and are more fertile than the upper terraces. Residential hamlets are located adjacent to upper fields in order to maximize productive use of the lower terraces. During periods of peak agricultural activity draught animals are kept in sheds near the lower fields, and often farmers will sleep there to prevent illicit water use, especially during times of water scarcity.

network of interconnected irrigation channels which links upstream and downstream water users. Figure 1 shows the overlapping kuhl networks in the Neugal River watershed.[8]

The kuhls of Kangra Valley are subject to destructive, recurring environmental shocks such as floods and earthquakes. Floods caused by intense periods of monsoon rainfall are the most common environmental shock.[9] They are particularly destructive when a temporary landslide dam blocks the river until the rising water eventually breaches the mud dam and floods the downstream areas.[10] Depending on the severity of damage, kuhls destroyed by flooding may be repaired within several weeks, months or years. Sometimes a severely damaged kuhl is never be repaired. Although less frequent, earthquakes can also inflict substantial damage on kuhls. The high degree of risk and uncertainty associated with periodic environmental shocks represents a considerable challenge to farmers who seek to maintain assured and predictable supplies of irrigation water.[11]

**The Salience of Intel-connectedness for Individual Kuhl** Systems

During the monsoon of 1952 a mudslide caused by a particularly intense period of rainfall temporarily dammed the Neugal River just upstream of where it leaves the narrow canyon in the Dhaula Dhar mountains and flows across the fertile, cultivated Kangra Valley. The swollen

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[8]The pattern of overlapping kuhls flowing downhill on either side of a perennial river is not entirely unbroken. Due to topographic variation some villages do not have upper fields while others do not have lower fields.

[9]For example, within one twenty-four hour period in July 1976 more than 53 mm of rainfall was recorded at the Palampur weather station near the foot of the Dhaula Dhar.

[10]Although less severe flooding occurs more frequently, the last two times a temporary mudslide dammed the Neugal River were in 1944 and 1952. Landslide dams followed by destructive floods occur throughout the Himalaya (Agarwal and Chak 1991:55). The 1904 Kangra earthquake, in addition to wreaking havoc throughout the district, caused such extensive damage to the kuhls in Kangra Valley that the colonial government mobilized the army to help repair them and thereby avert a localized famine by saving the rice crop.

[11]In addition to environmental shocks, the unprecedented expansion of the nonfarm employment sector is a second environmental factor affecting the ability of kuhl regimes to maintain their integrity. Although the primarily subsistence agricultural economy of Kangra District has always been supplemented by nonfarm income, the number of individuals engaged in full time nonfarm employment has increased dramatically during the last forty years (Baker 1994:85). The expansion of the market economy has decreased reliance among some segments of the population on agriculture as the primary mode of subsistence. The socially differentiated declining dependence on agriculture has weakened institutions which manage common property resources. In the context of kuhls, this manifests as declining farmer participation in kuhl maintenance and repair, increasing inequality in the distribution of the burden of kuhl maintenance, the declining authority of the watermaster, and in some areas shifts in cropping towards less water intensive crops and sowing methods. Analysis of the impacts of increasing nonfarm employment on kuhl regimes, and explanations of the differential responses of kuhl regimes involve the degree of caste and class differentiation among a, kuhl's irrigators, the nature and extent of reliance on kuhl water, and the scale and scope of coordination required for kuhl management may be found in Baker (1994:180-234).

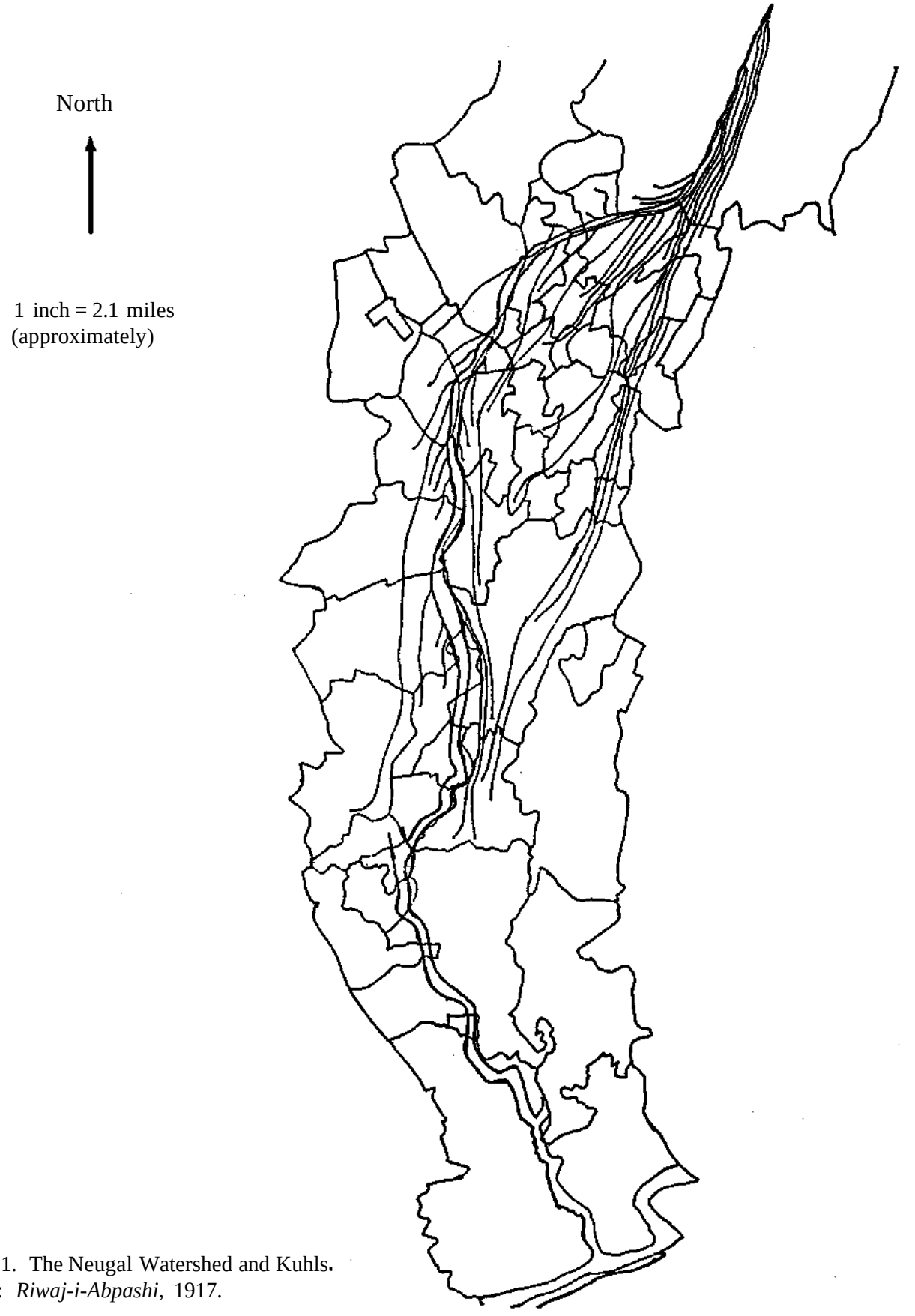


Figure 1. The Neugal Watershed and Kuhls.
Source: *Riwaj-i-Abpashi*, 1917.

Neugal River, blocked by the dam, became a churning reservoir until the water's force eventually burst the dam sending a wall of water, boulders, mud and trees hurtling downstream. The ensuing flood destroyed riverside terraced fields, altered the course of the river, and wiped clean any sign of the labor intensive diversion structures and cliffside channel sections of all the kuhls in its path. One of these was a kuhl known as Menjha Kuhl. In addition to totally destroying the kuhl, the Neugal River changed its course in a manner which necessitated relocation of the kuhl's diversion structure approximately 50 meters upstream of its previous location. Surveying an appropriate new location for the diversion structure, constructing it, and carving another channel into the riverside cliff to carry water to the fields required years of effort on the part of the irrigators who depended on the kuhl's water for both domestic and agricultural purposes. Patnuhl Kuhl just upstream of Menjha Kuhl was much less severely damaged. The irrigators of both Menjha and Patnuhl Kuhls coordinated their efforts, and within a few weeks they were able to repair Patnuhl kuhl. For the next three years until the repair and reconstruction of Menjha Kuhl was completed, the watermasters of the two kuhls coordinated a water sharing arrangement in which Menjha Kuhl received water from Patnuhl Kuhl. When Menjha Kuhl was operational, the watermasters concluded the water sharing arrangement between the two kuhls, and the kuhls were again managed independently of each other as they had been prior to the flood.

Do theories of interorganizational relations, especially resource dependence theory, lead us to expect that interconnected kuhl irrigation systems will coordinate their activities as an adaptive strategy to persist in the face of recurring, unpredictable destructive environmental shocks? The underlying assumptions of resource dependence are that organizations depend on their environments for critical resources, and that as these resources become scarce, interorganizational competition for them emerges (Galaskiewicz 1985:282). Organizations survive and prosper to the extent that they successfully compete for resources (Aldrich 1976:420). Uncertainty within this framework is important because to a great extent the nature of uncertainty regarding a critical resource determines the degree to which it constitutes an environmental contingency which the focal organization must manage. A key aspect of the resource dependency model is organizational management of environmental dependence, "organizations seek to manage their environments so as to reduce dependencies and

uncertainties" (Aldrich 1976:420). Thompson, following Emerson's (1962) work on power and dependence, argues that an organization's dependence on an element within its task environment is directly related to the organization's need for the resource the element provides and is inversely related to the presence of alternative sources of that element (1967:30). Thompson's work suggests that there are two types of resources on which organizations depend; material and exchange resources. Material resources are the primary inputs such as raw materials or budget allocations which organizations require to survive. Exchange resources are the relationships through which the focal organization obtains the material resources it requires from those organizations in its task environment that control them. Organizations use negotiated arrangements to manage relations with those elements of their environment they depend on (Thompson 1967:34).

Although most kuhl systems are highly dependent on river water as a primary material resource, there are no exchange resources available to the managers of kuhls (other than ritual, see below) through which they can directly manage the unpredictably of water supply due to floods and earthquakes.[12] Thompson suggests that in order to manage environmental contingencies the focal organization will attempt to gain power by trading on its ability to reduce the constraints and contingencies other organizations face in their task environments (1967:34). While this formulation suggests that exchange resources can be deployed in an indirect manner to reduce an organization's dependence on an element within its task environment, it maintains the theory's focus on a focal organization and dyadic exchanges between it and other organizations. This restricted focus limits the theory's ability to account for interorganizational coordination when all the organizations in an organizational field are subject to the same material resource contingency. Under such conditions no one organization possesses a comparative

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[12]Scharpf (1978:355) extends this line of reasoning to create a 2x2 table with resource substitutability and resource importance as the two axes. He argues that an organization's relationship to an element in its environment will be one of high dependence when substitutability is low and importance is high, low dependence when substitutability and importance are both low or when they are both high, and independence when substitutability is high and importance is low.

[13]This statement is true for all kuhls during the hot and dry pre-monsoon season. However, in some areas annual streams which flow during the rainy season are diverted into kuhl channels thus reducing dependence on the perennial water source. Using Scharpf s 2x2 table this suggests that although the importance of water for kuhls remains high throughout the year, the substitutability of perennial stream water varies depending on the presence of nearby annual streams.

advantage that it can use as an exchange resource to trade with other organizations and thus reduce the contingencies both organizations face.

In order to account for observed interorganizational coordination among kuhls under conditions of common environmental vulnerability which can only be indirectly managed, high environmental dependence, and uncertain resource supply, it appears necessary to shift the level of inquiry from the level of the individual focal organization to the organizational field. This expanded focus enables examination of relations between kuhls, the extent to which a network of interkuhl relations exists, and the degree to which interkuhl networks may help reduce the environmental uncertainties related to periodic but unpredictable environmental shocks.[14] Pfeffer and Salancik use Emery and Trist's (1965) classification of an organization's environment into four categories (placid-randomized, placid-clustered, disturbed-reactive, and turbulent) depending on the nature and source of interdependence between an organization and its environment, to draw a more general distinction between a set of organizations which transact with each other and the larger social context which the set of transacting organizations is embedded within (1978:70). Pfeffer and Salancik further specify other properties that characterize the organizational field comprised of interdependent organizations. They suggest that the environment of an organizational field has three main structural characteristics, 1) the degree of interconnectedness between the set of organizations, 2) the degree of resource scarcity (munificence), and 3) the distribution of power and authority among the organizational set (concentration). They argue that under conditions of resource scarcity, relatively high degrees of interconnectedness and low concentrations of power, interdependence between organizations will increase and will produce conflict and uncertainty for individual organizations.

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[14]Warren (1967:404-406) differentiates organizational fields into four categories based on, 1) the degree to which goals are shared among units, 2) the degree to which inter-unit decision making is centralized, 3) the level at which decision making authority resides, 4) the extent to which the units are autonomously structured, 5) the level of commitment to inter-unit leadership relative to unit leadership, and 6) the degree of "collectivity orientation". Of the four types of interorganizational field contexts (unitary, federative, coalitional and social-choice), the "coalitional context" best describes the field of interkuhl relations. Individual kuhls coordinate their interactions in an *ad hoc* manner when and to the extent that their goals overlap, there is no formal organization for interkuhl decision making, authority for interkuhl coordination rests within each kuhl, primarily with the watermaster, most kuhls are autonomous from each other but they do coordinate their labor inputs for joint efforts, although norms govern the relationship between watermasters there is no commitment to a joint form of leadership or management structure, and lastly there is a minimal level of "collectivity orientation" among the irrigators of different kuhls.

Interconnectedness creates problems for organizations because the environment of a particular focal organization becomes increasingly uncertain and unstable as the degree of system interconnectedness increases (1978:69).

The image that Pfeffer and Salancik portray of "organizational environments as loosely coupled networks of clusters of organizations which are themselves more closely interconnected" (1978:70) provides a lens to examine the possible roles and importance of relations between interconnected kuhl systems vis a vis the risk and uncertainty periodic environmental shocks create for individual kuhls. However, in the case of interkuhl relations, their assumption that interorganizational interdependence resulting from increasing interconnectedness is directly related to increasing conflict and uncertainty does not hold. Rather than state the relationship as an assumption, it may be more illuminating to ask, "under what conditions does increasing interdependence resulting from environmental interconnectedness result in more or less uncertainty for an individual organization?" If, under some conditions, interdependence reduces environmental uncertainty, then it becomes important to ask how and why it does. Although Pfeffer and Salancik assume that interdependence leads to conflict, under some conditions interdependence may provide the basis for cooperative interorganizational coordination.

Astley and Van de Ven (1983) provide one way of thinking about organizational interdependence in a manner that does not assume *a priori* that it leads to conflict. They describe what they call the "collective-action" view within organization theory in the following manner,

> Rather than view organizations as pitched in a competitive battle for survival through a direct confrontation with the natural, or exogenous, environment, these authors (those who espouse the collective-action view) emphasize collective survival, which is achieved by collaboration between organizations through the construction of a regulated and controlled social environment that mediates the effects of the natural environment (1983:250-1).

A central concept of the collective-action view of organizations is the interorganizational network comprised of symbiotically interdependent organizations who together shape their environments through various types of exchange relations. These interorganizational exchange relations, Astley and Van de Ven argue, are governed by normative frameworks of expectations pertaining to codes of conduct, and rights and responsibilities. The normative framework of expectations enables the network to make collective decisions as a unit which meet the network's

collective interests as well as those of the individual member organizations. Astley and Van de Ven's discussion of symbiotically interdependent organizations broadens our analysis of interorganizational interconnectedness and suggests that interdependence may be both competitive and conflict generating, as well as symbiotic and coordination generating.[15] The role of normative frameworks in sustaining reciprocal exchange relations is one of the primary concerns of the new institutionalists (Powell and DiMaggio 1991) who also incorporate the role of cognitive frameworks in their analyses of organizational behavior and interorganizational relations.

Whether interconnectedness between organizations leads to competition or coordination hinges on whether a population of organizations is structured as an "aggregation of organizations governed by external economic forces, or viewed as an integrated collectivity of organizations governed by its own internal social and political forces" (Astley and Van de Ven, 1983:258). Embedded in this distinction between types of organizational environments are first, different conceptualizations of the term 'population' and what it signifies for the nature of relations between members of the population, and secondly, differing notions of the relative weights of economic verses social and political determinants of organizational behavior. Astley and Van de Ven discuss these differences in terms of the debate between population ecology and human ecology. They suggest that population ecologists define populations as aggregates of relatively homogenous units which share key characteristics and common traits. Population ecologists such as Hannan and Freeman (1977) argue that as a consequence of their similar characteristics members of the same population share a common vulnerability to the natural environment.[16] Human ecologists, on the other hand, view populations as defined by an internally coherent set of relations based on complementary differences between members of the population, rather than by

[15]Granovetter makes the similar and important point that the very social relations which generate trust and cooperation can also create the conditions for conflict and "enormous malfeasance" (1985:491-493). Within kuhls this is exemplified by the fact that some of the fiercest conflicts over water can occur between members of the same clan, especially when control over water is related to fraternal conflicts over the partition, ownership and cultivation of previously joint landholdings.

[16] "Natural" in the sense of natural environment here refers to parameters of the organization's environment that are not socially constructed, not enacted (Weick 1979), but rather are objective phenomena which impact an organization. This is in contrast to a "social" environment which refers to the socially and politically constituted sets of interorganizational relationships that link the focal organization to other members of the population.

a common vulnerability to environmental factors (Hawley 1950,1968). The functional interdependence which evolves between members of the same population creates a socially and politically constructed environmental network which insulates population members from the "natural" environment. Population ecologists emphasize the importance of environmental pressures and competition between organizations for scarce resources in explaining organizational behavior, while human ecologists, with their emphasis on socially constructed environments, attribute primacy to social and political forces to explain organizational behavior.

The insights of the population and human ecology approaches regarding interorganizational and organization environment relations need to be integrated in order to develop a framework able to explain the capacity of individual kuhl systems to persist within a context of recurring environmental shocks. An integrated approach entails acknowledging that there are both "natural" and "social" components to an organization's environment. Within the context of kuhls, the "natural" or "unenacted" aspect of their environment consists of uncontrollable shocks which threaten their persistence. This notion derives from the population ecology definition of a population as a set of relatively homogenous units which share a common vulnerability to the natural environment. The "social" aspect of the environment which the human ecology approach emphasizes consists of symbiotic interdependence between kuhls and the construction of a protective set of social exchange relations between them. Integrating conceptualizations of the natural and social environment enables the framework to account not only for competition, but also for coordination between organizations.

Rather than supplant the natural environment as a key determinant of organizational behavior, this synthesis argues that the socially constructed environment buffers individual members of the population set (i.e. individual kuhl systems) from uncertainty in the natural environment. The social and natural environments may be conceived of as nested entities. The socially constructed environment consisting of exchange relations between interconnected kuhl systems is nested within the natural environment and functions to inhibit the natural environment's uncontrollable and potentially destructive perturbations. This formulation implies that interdependence will be competitive and generate conflict when conditions of common vulnerability do not obtain. Conversely, when organizations do share a common environmental

vulnerability, it suggests that interdependence will constitute the basis for interorganizational coordination to shield organizations from their shared vulnerability. This helps to explain how and why the socially constructed network of interkuhl relations helps absorb the impacts of unpredictable and random shocks.

**The Structure and Effects of Interkuhl Networks**

In this section I analyze the structure of the network of interconnectedness the pattern of overlapping kuhl systems creates at the watershed level. The section switches the unit of analysis from that of the perspective of the "net rider" to the "net thrower"(LaPorte 1994b), i.e. the "pattern of linkages and interactions as a whole" which constitute the basin or watershed level of kuhl irrigation networks (Hanf and O'Toole, 1992:169).[17] Using this perspective, I examine the interconnectedness of individual kuhl regimes and explore the extent to which interkuhl coordination is related to kuhl interconnectedness.

Tables 1 and 2 show the pattern of overlapping kuhl networks for the revenue villages and kuhls on the right and left banks, respectively, of the Neugal River, in a manner that allows differentiation between sets of kuhls that are more or less tightly interconnected. From the multi-kuhl villages perspective (reading rows from left to right by village), the tables indicate that most villages are engaged with upstream kuhls that irrigate their upper area and with downstream kuhls that irrigate their lower area. For example, on the right bank Sapruhl Kuhl (no. 5) irrigates the upper fields of Village Kharot, while Pathan, Rai and Makruhl Kuhls (no.'s 6, 7 and 8) irrigate the village's lower fields. The same pattern may be observed from the multi-village kuhls perspective (reading columns from up to down by kuhl). Both tables indicate that generally kuhls irrigate lower and then upper areas of different villages as they flow downstream. For example, on the left bank Diwan Chand Kuhl (no. 2) irrigates the lower fields of three upstream villages and irrigates the upper fields of two downstream villages.[18]

[17]The approach of this section views networks as presenting "vehicles of action" (Hanf and O'Toole 1992:171) through which coordination is organized and problems solved, rather than as an analytical construct which "describes the context of, and factors leading to, joint decision making".

[18]At the watershed level the pattern of overlapping kuhl networks conforms closely to Thompson's (1967:54) concept of sequential interdependence in which the parts of an organization are serially related to each other. He further defines sequential interdependence as a set of conditions in which the parts are not symmetrically interdependent, and the order of their interdependence can be determined. Thompson predicts that sequential

The number of kuhls per village can be used as a proxy indicator of the degree of interconnectedness between kuhl regimes. This indicator is based on the assumption that a kuhl which irrigates a village which no other kuhls irrigate will be less interconnected than a kuhl which irrigates a village irrigated by several other kuhls. For example, on the right bank Bhagotla Kuhl (no. 3), is the least interconnected. It irrigates only one village and it is the only kuhl which irrigates that village. In contrast to Bhagotla Kuhl, Sapruhl Kuhl (no. 5), also on the right bank, is more interconnected because from one to three other kuhls irrigate each of the three villages Sapruhl Kuhl irrigates.

Interconnectedness refers to the density of irrigation networks that a particular kuhl is engaged with. The degree of interconnectedness is a physical parameter of an individual kuhl's environment. It is primarily influenced by the elevational distribution of a village's arable land - a kuhl which irrigates a village whose arable land is dispersed across several elevational niches tends to be more interconnected than one which irrigates a village whose arable land is more concentrated in one elevational niche.[19] Interconnectedness, measured as the extent of interkuhl linkage, is a necessary but not sufficient condition for the emergence of interdependent relations between kuhls.

In discussing kuhl interdependence I use LaPorte's definition of interdependence as "an exchange relationship of at least one resource between at least two persons" (1975:7).[20] He distinguishes between three types of interdependent exchange relations that may obtain between two individuals or groups (a,b). In the first, group A may be dominant over group B, in other words B depends on A for a necessary resource. Second, groups A and B may be mutually dependent on each other for the provision of a resource both need. And third, group B may be dominant over group A.

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interdependence gives rise to coordination "by plan" which involves "the establishment of schedules for the interdependent units by which their actions may then by governed" (1967:56). The informal nature of these "schedules" matches the kinds of interkuhl coordination shown in Table 3 and discussed below.

[19] In other words, a village with only lower fields will be engaged with only one kuhl while a village with both lower and higher fields will be engaged with multiple kuhls.

[20] This definition of interdependence is consistent with and follows from Cook's definition of exchange which emphasizes resource transfers through voluntary transactions by two or more actors (1977:64). It is more restrictive than Levine and White's definition of exchange which encompasses "any voluntary activity between two organizations (1961:120).

Table 3 shows the kinds of interdependent relations between kuhls I observed during field research, and the kuhls which engaged in them. There are four kinds of interdependent relations between kuhls: 1) sharing the same diversion structure, 2) having a joint watermaster for both kuhls, 3) joint water guarding, and 4) water sharing. Water sharing arrangements between kuhls were the most common kind of interdependent relation. During the period of field research three clusters of from two to seven kuhls were sharing water and one pair of kuhls had recently shared water. Water sharing arrangements between kuhls typically involve temporary water transfers from an upstream kuhl to a flood damaged downstream kuhl for the duration of the repair work. For example, during the 1993 monsoon the Neugal River flooded and washed out the shared diversion structure and cliffside section of the main channel for Mahang and Loharal Kuhls. The watermaster for Mahang and Loharal Kuhls arranged a water sharing arrangement with the watermaster of the next upstream kuhl, Raniya Kuhl. Throughout the 1993 summer agricultural season water from Raniya Kuhl was diverted into a gully that carried it to the main channels of Mahang and Loharal Kuhls. By the end of the year the repairs were still not complete and the water sharing arrangement with Raniya Kuhl continued.

Interkuhl water sharing arrangements occasionally also emerge during drought or during the hot and dry, pre-monsoon season. Shri Ranvir Singh, a former watermaster of Pangwan Kuhl who is now President of the Pangwan Kuhl Committee, recounted that during his tenure as watermaster a severe water shortage combined with upstream diversions left no water in the Neugal River. In order to receive the minimum water necessary for pre-monsoon field preparation, Ranvir Singh was able to negotiate with the watermasters of the next five upstream kuhls to not divert water for a twenty-four period. On the designated day all five kuhls were shut down, water flowed downstream to Pangwan Kuhl where the readied diversion structure diverted it to the fields for a single flood irrigation.

At first glance interkuhl water sharing arrangements appear to conform to the first type of interdependent relationship (A dominant over B). An upstream kuhl (A), is dominant over the downstream kuhl (B), because until kuhl B is repaired it depends on kuhl A for water. Similarly, during a period of low water availability Pangwan Kuhl was dependent on the actions of upstream kuhls in order to receive even a minimal supply of water. However, when a longer

time frame is used to analyze interkuhl relations the structural positions of dominant and subordinate kuhls can shift back and forth. Because the occurrence of floods and their effects, in terms of which kuhl(s) will be damaged and to what degree, is random and unpredictable, there is no assurance that a kuhl which at time *t* is requested to temporarily provide water to a damaged downstream kuhl, will not at time *t+1* itself be damaged by a flood and forced to request a water transfer from the next upstream kuhl.[21] In order to preserve its future option to request water from an upstream kuhl, it will transfer water to a downstream kuhl in the present. In this manner the structural positions of dominant and subordinate shift over time in an unpredictable manner. This shifting dependence encourages cooperative responses from kuhls which occupy a temporarily dominant position.[22]

Introducing time into the analysis of interkuhl water transfers helps to explain why an upstream kuhl would share water with a temporarily damaged downstream kuhl with no possibility of direct reciprocation. Scharpf acknowledges the importance of time and the broader structure of interorganizational relations when examining a specific interorganizational interaction. He writes,

> Many interactions (interorganizational), however, are not of a one-shot nature. They occur in the context of more stable relationships with their past histories and their expectations of future transactions. Within this broader context, individual interactions which, taken by themselves, would be disadvantageous to one party might still be acceptable (1978:353).

Although the structural relationship between two kuhls may conform to unilateral dependence (A dominant over B), their observed behavior more closely approximates that expected from organizations engaged in a mutually dependent interorganizational relationship. Over time, within a context of shared environmental vulnerability, structural relations of unilateral

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[21]In this respect the kuhl environment conforms to Emery and Trist's (1965) definition of a turbulent environment in which unpredictable phenomena over which the focal organization has no control reduce the capacity of the organization to achieve its goals.

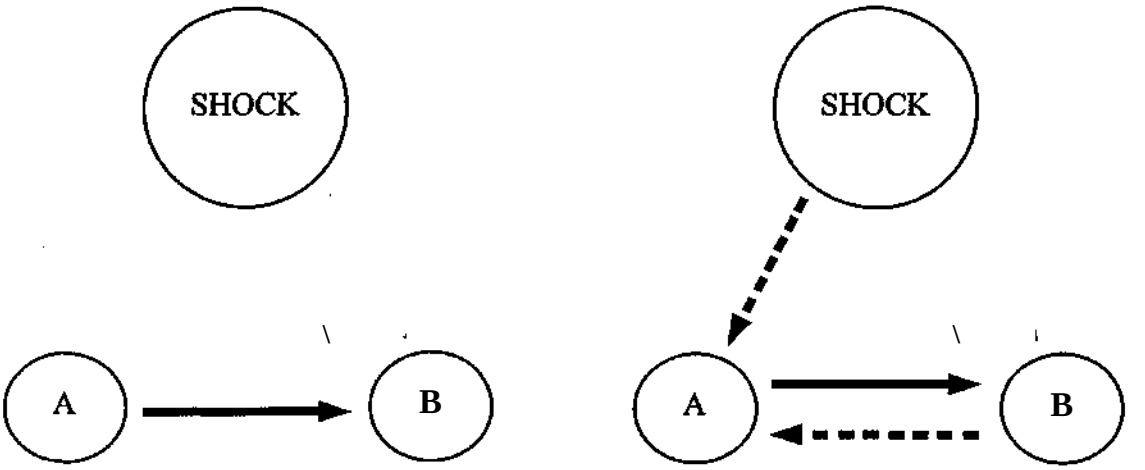
[22]In order for past actions to affect present inter-kuhl exchanges and for present inter-kuhl exchanges to affect the possibility for future inter-kuhl coordination, a long term and collective memory of the past is a necessary condition. This condition is more likely to be met in settings with stable communities and populations than in other organizational settings with less historical continuity. Within kuhls the institutionalization of the position of kohli (watermaster), i.e. the formal position is continuous through time and independent of any particular individual (Zucker 1987:455), increases the likelihood that past events will influence present decisions and that future ramifications, even if subsequent to an individual's tenure as kohli, will influence present choices.

dependence assume the behavioral characteristics of mutual dependence. Figure 2 illustrates how structural unilateral dependence can display the behavioral characteristics of mutual dependence when the context of past relations and potential future relations is considered. Diagram 2a shows kuhl A dominant over kuhl B when B suffers an environmental shock at time *t* without considering the broader context of past exchanges and potential future exchanges. Diagram 2b takes into account contextual relations - the dashed lines indicate that A has been or could be vulnerable to the same environmental shock as B, in which case it may depend on B for resources. The common environmental vulnerability of both A and B to similar environmental shocks thus transforms unilateral into mutual dependence.[23]

The second kind of interdependent relation shown in Table 3 is the sharing of the same diversion structure, generally between two adjacent kuhls. Sometimes reconstructing a destroyed diversion structure and upper channel section is more difficult than creating a permanent water sharing arrangement between two previously independently managed kuhls. For example, Taruhl and Chamruhl Kuhls (left bank kuhls 10 and 11) originally had separate diversion structures. The *Riwaj-i-Abpashi* (Book of Irrigation Customs) states that at some time in the past, presumably following a flood or earthquake, the diversion structures were combined.[24] Since that time these two kuhls have shared the same diversion structure which irrigators from both kuhls jointly repair and maintain. Approximately .5 km below the diversion structure the single common channel splits into the two original channels and the water is divided into two equal parts. This kind of interkuhl relation conforms to the second type of interdependence in which at least two groups are mutually dependent upon each other for a resource they both desire. Other examples of this type of mutual interdependence include kuhl clusters which share

[23]Wellman reports an analogous dynamic in his analysis of networks of personal communities in Toronto, Canada. Using the concept of "network balance" (1988:170), he shows that general reciprocity at the network level always exceeds that between two network ties (nodes). He attributes network balance to the structural embeddedness of ties, and the tendency for reciprocal relations between individuals to reach an equilibrium at either high or low levels of exchange. In his analysis, network balance emerged by expanding the spatial scale of analysis, among kuhls network balance emerges by expanding the temporal scale of analysis. In either case the result is the same: "Do unto others as you would have your network do unto you" (Wellman 1988:171).

[24]For a more complete description of the *Riwaj-i-Abpashi*, its contents, manner of compilation and significance for water management see Baker (1994:166-170).




2a. A one shot view of an interkuhl exchange. 2b. A multi-shot view of an interkuhl exchange.

Figure 2. A diagramatic illustration of how unilateral interkuhl exchange from a synchronic perspective (2a) can become bilateral from a diachronic viewpoint (2b).

the same watermaster, or engage in joint water guarding, the third and fourth kinds of interkuhl relations shown in Table 3.

Table 3 also gives a quantitative indicator of the kuhl interconnectedness. The indicator, a rough measure of the density of the interkuhl network each kuhl is embedded within, is the ratio of the number of other kuhls which irrigate each of the villages the kuhl irrigates to the number of villages the kuhl irrigates. In order to determine if their was a relationship between a kuhl's interconnectedness and interdependent relations for coordinated water management, I classified the ratios into three categories; ratios less than one represent low interconnectedness, ratios greater than or equal to one but less than two represent medium interlinkage, and ratios greater than or equal to two represent high interconnectedness.

When the measure of interconnectedness is examined in conjunction with the extent and kind of interdependent relation between kuhls, the table shows that almost all interdependent kuhl relations occur between kuhls that are highly interconnected. Of the nineteen different kuhls engaged in at least one interdependent relation, sixteen are highly interconnected, two are moderately interconnected and only one is minimally interconnected. All five of the kuhls which were/are involved in two or three kinds of interdependent relations are highly interconnected. The one minimally interconnected kuhl (Ghran Kuhl, left bank no. 1) shared a diversion structure with the next downstream kuhl (Diwan Chand, no. 2). However, this arrangement did not last. Following a relatively brief period during which the diversion structure was shared, separate structures were again constructed. While I probably did not identify all the coordinated water management arrangements that occur within the basin, the examples provided here do support the proposition that interdependent interkuhl relations are positively related to, if not dependent on, the extent to which kuhls are interconnected.

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[25]Two pairs of kuhls (Mahang and Loharal, Taruhl and Chamruhl) within the study watershed each have one watermaster who manages the kuhls jointly. One pair of kuhls (Kathul and Sapruhl) shares the responsibility for guarding, maintaining and repairing a shared twelve kilometer long main channel section during the pre-monsoon dry season.

[26] Raipur and Sulah Villages, (left bank) are irrigated by tightly interlinked kuhls but for which I do not have examples of watersharing arrangements. Most of the kuhls in Sulah are very small, irrigating five hectares or less and are informally organized with no watermaster. Water sharing may occur between these small kuhls, but it may be so informally organized as to be almost invisible to an outsider. Alternatively, water sharing may not occur because the kuhls are so small that repairing them after a flood may be easier than coordinating a water transfer between them. My fieldwork in Raipur was less intensive than elsewhere in the study basin because I focused most

**Explaining The Coherence of Network Structure**

Understanding how and why networks of interkuhl relations cohere over time requires not only examining interkuhl networks as "emergent phenomena" (Benson 1975); it also involves exploring their cultural and historical components (Scott 1983), their social embeddedness (Granovetter 1985), and the extent to which the technical characteristics (LaPorte 1994b) of gravity flow irrigation systems constitute the basis for interkuhl exchange and coordination.

The technical constraints of gravity flow systems, in conjunction with the topographic variation found within most villages, produced the dendritic pattern of main kuhl channels within the Neugal watershed shown in Figure 1. The network of kuhl channels constitutes a technologically determined template of interconnectedness which offers the possibility for interdependent interkuhl exchange relations to emerge. Figure 3 illustrates how the dendritic patterns of kuhl networks differ in four watersheds adjacent to the Neugal watershed. In the Awah watershed the pattern of multi-kuhl networks is relatively dense and thus, like the Neugal, provides a template of physical interconnectedness which could be the basis for various kinds of interkuhl interdependent relations.[27] In contrast to the kuhl network found in the Awah basin, those of Mand and Poon basins are much less dense, and in Chahan Khad, it is virtually absent. In these watersheds truncated patterns of kuhl networks created by the interaction of local topography and the technical constraints of gravity flow irrigation thus limit the extent to which interkuhl exchange and coordination is possible.

The embeddedness of kuhls within "ongoing structures of social relations" (Granovetter 1985), in addition to the physical template of kuhl interconnectedness, helps to explain the

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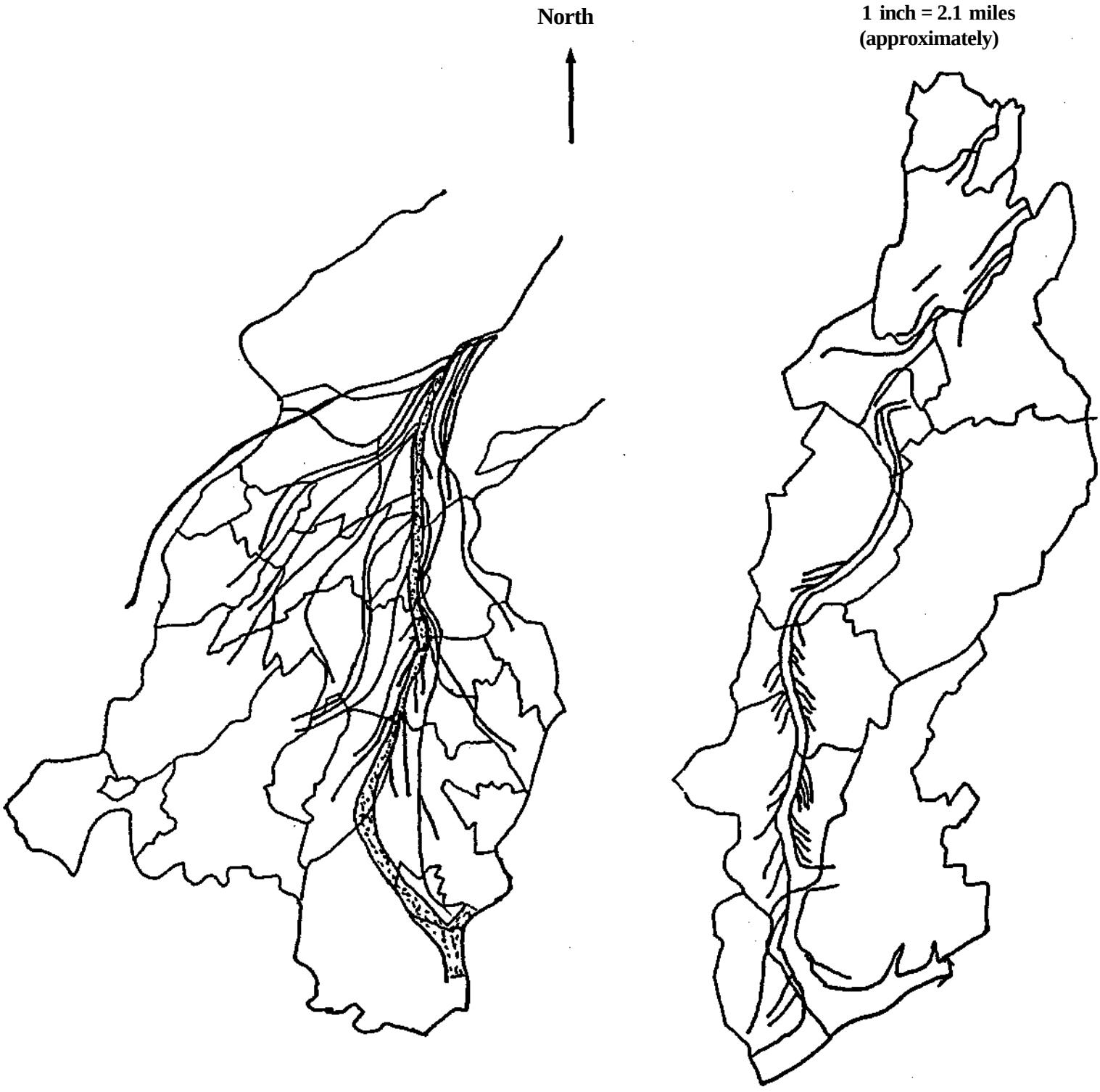
of my research attention on nongovernment kuhls and all but one of the six kuhls in Raipur has been managed by the Irrigation and Public Health (IPH) Dept. since the 1970's. Resource dependence theory predicts that coordinated strategies between the kuhls in Raipur should exist. This may have been the case prior to IPH control, however the IPH Dept. generally takes a kuhl by kuhl approach to water management in Kangra, so it is unlikely that long term water sharing arrangements would exist between these kuhls. If water sharing does occur in Raipur, it will be coordinated by employees of the IPH Dept., not the farmers themselves. Farmers do not have the right to distribute water within or between IPH managed kuhls.

[27]This assumes that similar network patterns will exhibit similar behavioral characteristics, an assumption espoused by the formalist school within structural analysis (Wellman 1988:25).

[28]Perhaps it is more accurate to say that without a well developed template of interconnectedness, interkuhl exchange and coordination will assume different forms from those observed in the Neugal watershed. Water transfers could be managed by coordinating water flows at the diversion point rather than between main kuhl channels. Because this study was restricted to the kuhls within the Neugal basin, I can only speculate on this point.



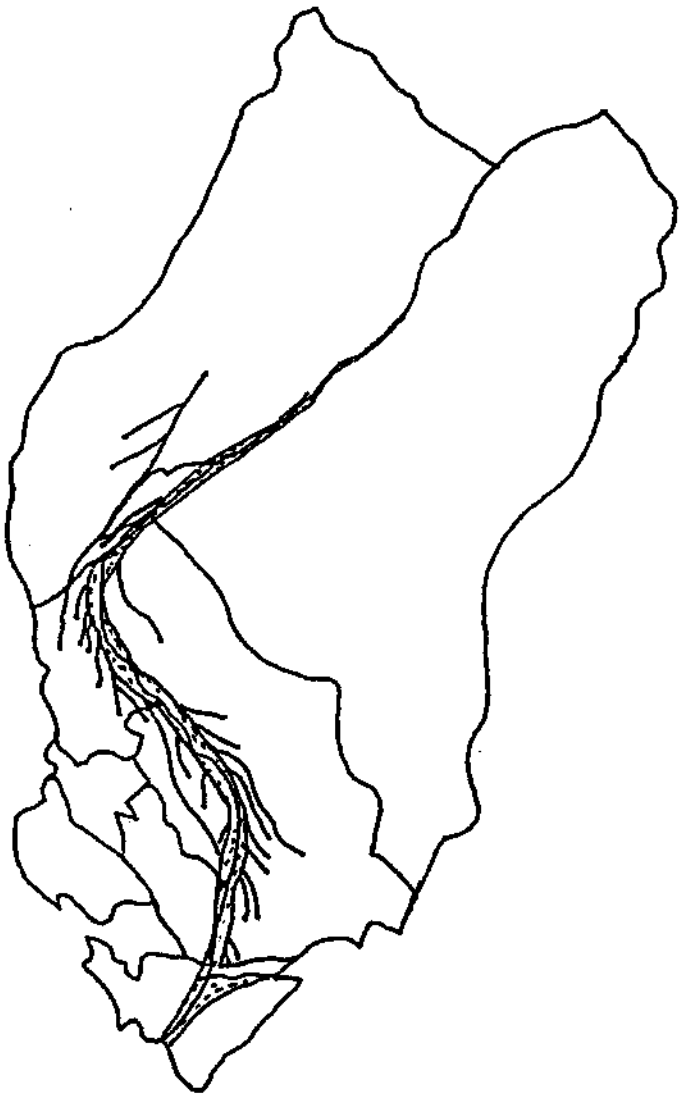

3a. Awah Khad Watershed

3b. Mand Khad Watershed

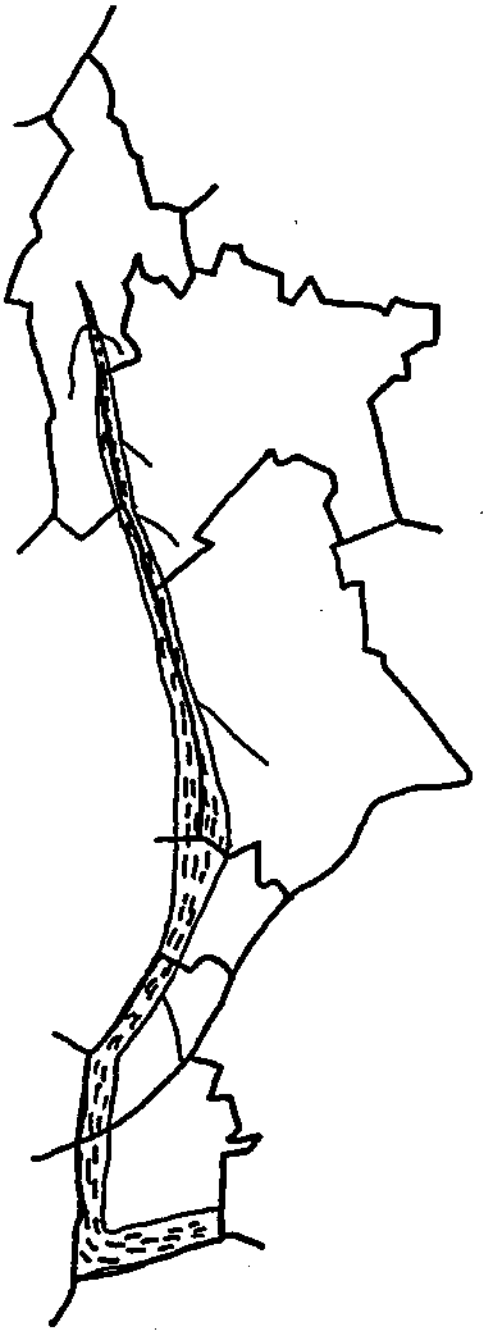
**Figure 3. Four watersheds of Kangra Valley Illustrating different patterns of irrigation networks ranging from most dense (3a Awah) to least dense (3d Chahan). Each diagram shows the stream running from north to south, the irrigation systems which divert water from the stream, and the boundaries of the villages (revenue) within the catchment basin. Source: *Riwaj-i-Abpashi,* 1917.**

North

1 inch = 2.1 miles
(approximately)



3c. Poon Khad Watershed



3d. Chahan Khad Watershed

transformation over time of asymmetric dependence into mutual dependence, which enables water sharing exchanges at time *t* to occur. The embeddedness argument emphasizes how networks of personal relations which link individuals, rather than institutional arrangements or moral sentiments, foster trust and minimize "malfeasance". Granovetter argues that interpersonal trust and malfeasance are directly and indirectly related, respectively, to the density of the network of social relations between individuals.[29] Although I did not collect robust enough data on social networks to empirically test this proposition, I did observe that the irrigators of interconnected kuhls were embedded within denser networks of social relations than irrigators of non-interconnected kuhls, and that this positively affected the degree of interkuhl coordination.

Assuming that the degree of interconnectedness between kuhls is positively related to the density of the network of social relations linking the irrigators of different kuhls, we can use the embeddedness argument to account for why the shared diversion structures between Mahang and Loharal Kuhls and Taruhl and Chamruhl Kuhls (left bank kuhls, no.'s 8,9,10,11), has persisted while that between Ghran and Dewan Chand Kuhls did not. As the embeddedness argument predicts, the irrigators of the first two pairs of kuhls are engaged in more dense networks of social relations than are those of Ghran and Dewan Chand Kuhls. The two pairs of kuhls which have continued to share diversion structures have relatively equal command areas, each pair has one watermaster who manages both kuhls, most irrigators have plots of land irrigated by both kuhls of each pair and hence participate in the maintenance of both kuhls, and most irrigators of all four kuhls reside in the same or adjacent hamlets and are bound by norms of reciprocity that exist in social arenas other than irrigation. Conversely, Ghran Kuhl is much smaller than Dewan Chand Kuhl. It carries water 5 kilometers and irrigates 60 hectares in Gaddi (settled nomadic herders) dominated hamlets. Dewan Chand Kuhl transports water more than 25 kilometers and irrigates 185 hectares in a Rajput dominated area. The kuhls have separate watermasters and are managed independently of each other. Neither are these two groups of irrigators bound by other shared allegiances such as marital alliances or material exchange networks. The lack of shared

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[29] Similarly, Aldrich and Whetten (1981:391) argue that the "ultimate predictor" of network stability is the presence of multiple linkages between network members which reduce the probability that any link will fail. These multiplex organizational relations include "exchanging multiple resources, communication between multiple boundary spanners, friendship or kinship ties, and overlapping boards of directors" (1981:391).

interest combined with the asymmetries between the irrigators of these two kuhls suggests that, in contrast to the other two pairs of kuhls, they are not engaged in a dense network of shared social relations. As the embeddedness argument would predict, separate diversion structures were constructed for Ghran and Dewan Chand Kuhls following the 1905 earthquake while Taruhl and Chamruhl Kuhls, and Mahang and Loharal Kuhls, continue to jointly manage their shared diversion structures.

Normative and cognitive frameworks also contribute towards the coherence of interkuhl exchange networks. The influence of norms and values on interorganizational coordination is a common theme throughout much of the literature on interorganizational relations. Although Selznick (1957) was one of the earlier theorists to emphasize the importance of norms and values in understanding organizational behavior, more recent contributions focusing on interorganizational relations include Aldrich (1976) who argues that "perceived cooperation" positively affects interorganizational coordination and suggests that values and sentiments be integrated into the resource dependence model. Similarly Astly and Van de Ven argue that over time mutually beneficial patterns of interorganizational behavior assume the character of general norms which "take on the character of autonomous social forces, directing and regulating collective action" and thus structure relations within symbiotic networks (1983:263).[30]

In order to follow Zucker's admonition to avoid the use of "underspecified" terms such as norms (1987:460), and Meyer et. al.'s critique of the explanatory use of the category "culture" as a residual box containing vague consensual values (1994:17), I show how the norm of diffuse reciprocity is institutionalized within Kangri culture. Reciprocal relations between individuals in

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[30]Other theorists who acknowledge the importance of norms in interorganizational networks include Benson (1975) and Pfeffer and Salancik (1978:147). One particularly forceful norm in Kangra is the prohibition against women participating in any communal aspect of kuhl management. The example of Samruhl Kuhl illustrates an institutional transformation which occurred as a result of violating this norm. In the early 1980's the kuhl committee for Samruhl Kuhl initiated a system of fines in an attempt to slow declining absenteeism for kuhl repair and maintenance. The system was quite unpopular because in a few women-headed households there were no males to contribute labor. The women had no alternative but to contribute their own labor for communal kuhl cleaning. This contravened the strong taboo against female participation in any communal aspect of kuhl management and created adequate incentive for changing the mobilization of resources for kuhl maintenance from a labor to a cash based system. Rather than contribute labor, each household is now required to contribute cash in a fixed proportion to their cultivated land. This money is kept in a fund to pay local laborers to clean and repair the kuhl as required throughout the year. Although women do not participate in the communal portions of kuhl management, they do manage kuhl water and maintain irrigation channels on their own land. Furthermore powerful women can be members of the kuhl committee - two presidents of different kuhl committees were women.

Kangra are strongest between members of a sub-clan living in the same house cluster.[31] Blood ties combined with proximity lead to frequent interaction and generate joint interests (Parry 1976:136-139). During elections an entire sub-clan will often form a political faction, or a sub-unit of a faction composed of the whole clan, which votes as a block. All the households in a single house-cluster will send a representative to join the marriage party of a groom of the clan when it leaves to bring the bride to the groom's natal village. Sub-clan members share in the preparations required for the major life cycle rituals, they engage in reciprocal exchanges of gifts of cloth and money at these occasions, and they are expected to observe some degree of mourning restrictions after the death of a member of the house cluster.

Activities within other social spheres also serve to reproduce the reciprocal relations between sub-clan members. At major life cycle rituals such as marriage and death, communal work parties are organized to fell, split, and transport the wood required to cook food for the meals at which large numbers of guests will be fed over a three to five day period. Those who contribute labor during these events receive a free meal, and most importantly, the right to call upon communal labor at some unspecified future time.

Sharing water between kuhls *"bhai bandi se"* (literally, through brotherhood) is also rooted in the notion that the merit achieved through gift giving accrues only when nothing is received in return.[32] A striking example of unilateral exchange in Kangri culture is the tradition of *kanya dan* ('the gift of a virgin'). Although prevalent across all castes, this mode of exchange is most developed in the tradition of hypergamy between the hierarchically structured Rajput clans. Parry (1976:208) demonstrates that social prestige and religious merit accrue to the wife-givers only when the family receives no material compensation from the wife-takers.[33] While

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[31]In Kangra corporate multi-caste villages are much less prevalent than in, for example, the Indo-gangetic plains. Most settlements consist of single-caste house clusters *(narar)*, which after their founding by a common ancestor, partitioned and increased in numbers through patrilocal marital arrangements. See Baker (1994:76-80) for a description of the relationship between house clusters, hamlets and revenue villages and the effect of the British colonial administration on the social and economic significance of these groupings.

[32]The phrase *"bhai band se"* (through brotherhood) was invariably used by watermasters and farmers in discussions of informal interkuhl water sharing arrangements. The term implies that there is no expectation of direct reciprocity, nor even an assurance of compensation in the future. It implies a sense of community, "brotherhood", that binds those engaged in watersharing within a common ethical order.

[33]The ideology of *kanya dan* extends the obligation to give to the wife-taking family without receiving any material compensation to not only the natal households of the wife and mother, but also to those of the father's mother's brother and mother's mother's brother. The asymmetrical flow of gifts from the wife-giver's family to the wife-

the tradition of *kany a dan* is a more extreme example of unreciprocated exchange than that which occurs between kuhls, it does indicate the centrality of asymmetrical reciprocity to social relations in Kangra and thus helps explain the cultural basis for the coherence of interkuhl exchange networks.

Religious ceremonies *(puja)* which have arisen in response to the common vulnerability of all kuhls to their natural environment exemplify the role of cognitive frameworks in fostering network coherence. Two main objectives of kuhl rituals are to ensure that adequate water will flow into the kuhl during the dry season, and to protect the kuhl from destructive floods during the monsoon. To ensure adequate water flow the kuhl's *mata* (mother), also referred to as the feminine deity which inhabits the kuhl, is propitiated.[34] The watermaster conducts the puja to the kuhl's mother at the diversion structure or a nearby designated large boulder, usually immediately after the kuhl's annual maintenance and repair when most of the irrigators are present. The watermaster will call out to the feminine spirit of the kuhl to bless the farmers with her presence in the upcoming dry season. *Prasaad* (any offering of food to a deity, in this case a cooked sweet dish or sweet bread), is offered to the goddess and then shared amongst all those present.

To ward off destructive floods the watermaster conducts puja to the river in its omnipotent and potentially destructive masculine manifestation, known as *Qua]a Pir.*[35] Puja to Quaja Pir supplicates the deity to bypass the kuhl in its destructive fury by shifting its course to the side of the riverbed away from the kuhl (and quite possibly towards another kuhl). Puja to

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taker's family often continues for three generations. The belief that receiving any form of compensation will cancel the merit accrued by giving the gift prevents the wife-giver from ever accepting food in the wife-taker's house, and at the top of the Rajput hierarchy has resulted in the forbidding of other forms of marriage exchange that do not conform to this "unilateral ideal" (Parry 1976:209). Although the practice of *kanya dan* tends to be more rigidly adhered to among higher castes, as ideology it is all pervasive. See Bodeman (1988:208) for an analogous example from southern Italy in which familism operates primarily within upper class families but is nevertheless an important ideological construct across all classes.

[34]In some cases the object of the puja is more personalized. In the case of Raniya di kuhl, (queen's kuhl, left bank no. 7), the local hill queen who provided the funds for constructing the kuhl in the late 18th century is herself propitiated. For a more complete description of the rituals associated with kuhl management, including their social significance, how they vary among kuhls and speculation concerning the absence of any basin level ritual, see Baker (1994:123-130).

[35] *Pir* is a Muslim saint. *Quaja* is also probably a Persian term and thus helps establish the link between Kangra and the peoples and cultures to the northwest and into Central Asia.

Quaja Pir is generally performed at the same time as to the kuhl's deity. Prasaad will be offered to Quaja Pir and then distributed to all those present.[36]

The ritualistic elements of kuhl management that puja embodies strengthen and reproduce the group of irrigators as a community. Offering prasaad to the deity and then distributing, sharing and consuming the blessed offering simultaneously marks, makes and strengthens community among those individuals who participate. The production of community continues as the watermaster, while walking home after performing the puja, distributes prasaad to all whom he encounters on the way. The symbols, actions, and relationships that kuhl puja employ are those repeated in daily domestic rituals, at every trip to a shrine or temple, and at all life crisis ceremonies. The constitutive aspect of puja exemplifies the point made by the new sociological institutionalists (Meyer and Rowan 1977, Scott 1983, 1994, Zucker 1987, Powell and DiMaggio 1991, Meyer et. al. 1994) that institutions reflect and embody cognitive as well as normative elements of their environments. Scott argues that "cognitive elements include widely held beliefs and taken-for-granted assumptions that provide a framework for everyday routines...." (1994:81). The cognitive elements embodied within kuhl puja contribute towards the social construction of actors as community members, and the various components of kuhl puja are (re)enactments of broader "institutional scripts" (Meyer et. al. 1994:10) which play out in a variety of everyday contexts and thus serve to increase the institutionalization of kuhls.

The coherence of interkuhl networks can therefore be explained as constructed around a template of technologically determined interconnectedness, embedded in broader networks of social relations, and grounded in mutually reinforcing cognitive and normative structures of identity and reciprocity, respectively. Interdependent relations between irrigation systems help to buffer environmental shocks. Actions or policies which weaken the basis for interkuhl coordination reduce the resiliency of the irrigation network. For example, since the mid-1970's the Irrigation and Public Health (IPH) Dept, of the State of Himachal Pradesh has managed nine

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[36]If the puja to the kuhl's deity was effective, if adequate snow fell on the Dhaula Dhar the previous winter, and if the monsoon is not delayed, then puja to the kuhl's deity will be done only once every year. If however, water scarcity threatens the paddy crop, then another puja to the kuhl's deity will be performed at the diversion structure. As before, the watermaster will preside, but rather than offer *prasaad* of a sweet dish, a goat will be sacrificed, offered to the deity, cooked on the spot and distributed to all those present. The kuhl's irrigators will make voluntary contributions to cover the cost of the goat. Stories abound of past watermasters with unusual powers, who, during times of great water scarcity were able to bring more water into their kuhls after performing this puja.

of the most socially complex and longest kuhls which irrigate mostly higher elevation, less fertile land.[37] The IPH Dept. has adopted a kuhl by kuhl approach to water management. Managing each kuhl as an autonomous unit without considering the network of interkuhl relations it was previously embedded within has reduced interkuhl coordination between IPH and village managed kuhls and has eliminated it among IPH managed kuhls. While this may make no difference to the persistence of these systems during periods of non-stress, when environmental shocks do occur, the weakened basis for interkuhl coordination will reduce the network's ability to buffer the effects of the shock. With fewer possibilities for interkuhl water exchanges following a destructive shock, kuhls which sustain severe damage will be less likely to be rebuilt and/or they will become increasingly reliant on state resources for their repair and maintenance.

**Conclusion**

Interdependent relations between kuhl irrigation systems for coordinated water management can reduce the risks and uncertainty associated with recurring environmental shocks. Although resource dependence theory provides a deductively based entree to understanding relations between a kuhl regime and its environment, contrary to what the theory leads us to expect, interconnectedness between kuhls is not a problem to be managed or a liability to be controlled, but rather constitutes a resource which promotes kuhl persistence in the face of destructive environmental shocks. Using this inductively derived insight as a guide, I broadened the scope of inquiry from the more narrow focus on the relation between an individual kuhl and its source of water to include relations between interconnected kuhls. I synthesized insights from population and human ecology and proposed a conceptual framework which distinguishes natural from social environments. The framework suggests that under conditions of common environmental vulnerability, organizations within the same population construct social environments based on symbiotic interdependence which shield themselves from perturbations in the natural environment.

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[37]For analysis of the historical roles of the pre-colonial, colonial and post-independence states in kuhl management, culminating in the relatively recent assumption of management responsibility for some kuhls by the IPH Dept. and the impacts thereof, see Baker (1994:157-174). For a model which predicts the extent and nature of state involvement in kuhl management given salient social and ecological characteristics of individual kuhls, see Baker (1994:216-226).

While the framework emerged from a detailed ethnographic study of 39 irrigation systems within the same watershed in North India, it would appear to have more general applicability for the study of interorganizational relations in contexts whose conditions approximate those of the study, i.e. symbiotic interdependence between organizations which share a common vulnerability to an element within their environment. Situations which approximate these conditions include, for example, intergovernmental coordination between the U.S. Forest Service, the California Dept. of Forestry and County governments for fire prevention and fire fighting, coordination among federal and state disaster relief agencies following natural calamities, and coordination between federal and state natural resource management agencies in the face of declining resources and diminishing decision making discretion due to increasing control by external regulatory bodies. To the extent that the organizations and agencies in these situations are symbiotically interdependent and share a common environmental vulnerability, the framework leads us to expect some form of interorganizational coordination.

The specific characteristics of the interorganizational coordination, the framework suggests, will depend upon the nature of the interconnectedness of the involved organizations. Analysis at this level involves shifting to the perspective of the "net thrower" in order to analyze the nature, form and strength of the network of interorganizational relations, and to evaluate the nature of network coherence. This study employed a relatively simple indicator which measured network density and the degree of interconnectedness among kuhls within the Neugal watershed. Appropriate indicators will vary by context, but they might include the frequency and nature of interorganizational interaction, resources allocated towards achieving joint objectives, subjective perceptions regarding the strength and importance of interorganizational linkages, and the presence of formalized procedures for interorganizational coordination.

The basis for network coherence is likely to incorporate technological, social, normative and cognitive elements. The coherence of irrigation networks was shown to be a combination of technically derived interconnectedness based on the determinants of gravity flow water distribution systems, the embeddedness of kuhl networks in broader social relations, and cognitive and normative frameworks which reproduce notions of community and norms of reciprocity. Self-organizing networks, such as those examined in this paper, will probably

exhibit quite different properties than externally-organized networks which tend to have more hierarchical control elements. Hierarchical elements within interorganizational networks often result from legislative and regulatory constraints imposed by government. Examples of the latter might include networks of interorganizational relations produced through EPA regulation of toxic waste storage facilities and the impacts on Federal and State agencies of the Endangered Species Act.

Insofar as interconnectedness and resulting interorganizational networks constitute an asset or resource during periods of crisis or shock, any action, policy or program which weakens the basis for interorganizational coordination may in the long run weaken the organization(s) themselves, or create large, unanticipated social and ecological consequences. I showed how the Irrigation and Public Health Department's kuhl by kuhl management approach weakened the resilience of interkuhl networks, possibly threatened the long term integrity of non-state managed kuhls and increased dependence on state aid following environmental shocks. In an analogous manner weakened capacity for interorganizational coordination for fire prevention and fighting in California due to severe budget cuts may not be acutely felt during periods of relative low fire frequency. However, the declining ability of the interorganizational system to respond quickly and effectively during a severe conflagration will, at some point, result in large private, public and ecological costs. The integrative framework developed in this paper for analyzing the technological, social and environmental components of networks, the methods used for charting the degree of interconnectedness between kuhl irrigation systems, and the analysis of the beneficial aspects of interdependence under conditions of shared environmental vulnerability, advances efforts to understand the properties and benefits of interorganizational networks.

Lastly, this study illustrates the research and methodological challenges associated with moving beyond networks as metaphors for interorganizational relations to networks as "a specific set of links among a defined set of individuals" (Hanf and O'Toole 1992:171). Charting kuhl interconnectedness and examining the relationship between interconnectedness and interkuhl coordination required detailed ethnographic information concerning the nature and extent of interkuhl coordination, and empirical data regarding the structure of kuhl interconnectedness. Information concerning local cognitive and normative frameworks required

for ascertaining the various basis' of network coherence only became apparent to this researcher after an extended period of emersion in the fieldwork study area. Moving from networks as descriptive metaphors towards a more rigorous and analytically sound conceptualization of networks as a model of interorganizational relations requires substantial investments of researcher time and effort, as well as theoretical frameworks which can account for the pervasive forms of interorganizational coordination we observe around us.

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| Village Name | Kuhls (by number) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Kandi | L | L | | | | | | | | | | | | | |
| Bhagotla | | | L | | | | | | | | | | | | |
| Lalla | | | | U | L | | | | | | | | | | |
| Paror | | | | U | U | L | | | | | | | | | |
| Kharot | | | | | U | L | L | L | | | | | | | |
| Panapar | | | | | | | L | L | L | L | L | L | | | |
| Gaggal | | | | | | | L | | | | | L | L* | | |
| Dhera | | | | | | | U | | | | | | | L | L* |
| Nora | | | | | | | U | | | | | | | | |
| Purba | | | | | | | UL | | | | | | | | |

**Table 1 Revenue Villages (by name) and Kuhls (by number) of the Neugal Basin, Right Bank. L= lower fields, U= upper fields.**

Kuhls are arranged upstream to downstream as follows: 1) Bhradi, 2) Chanogi, 3) Bhagotla, 4) Kathul, 5) Sapruhl, 6) Pathan, 7) Rai, 8) Makruhl, 9) Samruhl, 10) Pangwan, 11) Sonia, 12) Gagruhl, 13) Majettli, 14)Bal, 15)Natyrya.

* Indicates the kuhl is independent of others in the same revenue village.

| Village Name | Kuhls (by number) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Bandla | L* | L | L | L | L | L | | | | | | | | | | | | | | | | | | |
| Ghugar | | L | L | | L | L | L | | | | | | | | | | | | | | | | | |
| Sidhpur Rani | | | | | | U | U | L | L | L | L | L | L | | | | | | | | | | | |
| Sidhpur Sarkari | | | U | | | | | U | L | L | L | L | | | | | | | | | | | | |
| Khlet | | L | L | L | | L | | | | | | | | | | | | | | | | | | |
| Menjha | | | | | | | | L | | | | L | U | L | | | | | | | | | | |
| Battu Palam | | | U | | | | | L | | L | L | | | | | | | | | | | | | |
| Jasun Samola | | | L | | | | | L | | | | L | | L | | | | | | | | | | |
| Raipur | | | L | L | | L | L | | | | | L | | L | | | | | | | | | | |
| Henja | | | | L | | | | | | | | | | | | | | | | | | | | |
| Aria | | | U | | | L | | | | | | | | | | | | | | | | | | |
| Saloh | | | U | | | | L | | | | | | | | | | | | | | | | | |
| Sulah | | | | | | | | | | | | U | | | L | L* | L* | L* | L* | L* | L* | L* | | |
| Paror | | | | | | | | | | | | | | | L | | | | | | | | | |
| Garla Sarkari | | | U | | | | | | | | | U | | L | | | | | | | | | | |
| Garla Dei | | | U | | | | | | | | | | | L | | | | | | | | | | |
| Bhawarna | | | | | | U | | | | | | | | | | | | | | | | | | |
| Ninaon | | | | | | | | | | | | | | U | | | | | | | | | L | |
| Daroh | | U | | U | | | | | | | | | | | | | | | | | | | L | L |
| Ghar Jamula | | | | | | U | | | | | | | | | | | | | | | | | | |
| Mundi | | U | | | | U | | | | | | | | | | | | | | | | | | L |
| Bandahu | | | | | | U | | | | | | | | | | | | | | | | | | |

**Table 2 Revenue Villages (by name) and Kuhls (by number) of the Neugal Basin, Left Bank. U=upper fields, L=lower fields.**

Kuhls are arranged upstream to downstream as follows: 1) Ghran, 2) Diwan Chand, 3) Mia Fateh Chand, 4) Dai, 5) Ghughrul, 6) Kirpal Chand, 7) Raniya, 8) Mahang, 9) Loharal, 10) Taruhl, 11) Chamruhl, 12) Patnul, 13) Menjha, 14) Sangar Chand, 15) Masanol, 16) Spein, 17) Sulah da Cho, 18) Saldian, 19) Macchlena, 20) Kami, 21) Rein da Cho, 22) Bouru da Cho, 23) Upperli, 24) Buhli.

* Indicates that the kuhl is independent of others in the same revenue village.

| Kuhl Name | Kind of Interkuhl Interdependent Relation | | | | Interlinkage Measure |
|---|---|---|---|---|---|
| | Water Sharing | Shared Diversion Struc. | Joint Water Master | Joint Water Guarding | |
| Bhradi (r) | | | | | 2/1 (H) |
| Chanogi (r) | | | | | 2/1 (H) |
| Bhagotla (r) | | | | | 0/1 (L) |
| Kathul (r) | | | | $X_1$ | 3/2 (M) |
| Sapruhl (r) | | | | $X_1$ | 6/3 (H) |
| Pathan (r) | X! | | | | 5/2 (H) |
| **Rai** (r)* | $X_1$ | | | | 10/6 (M) |
| Makruhl (r) | $X_1$ | | | | 8/2 (H) |
| Samruhl (r) | $X_1$ | | | | 5/1 (H) |
| Pangwan (r) | $X_1$ | | | | 5/1 (H) |
| Sonia (r) | $X_1$ | | | | 5/1 (H) |
| Gagruhl (r) | $X_1$ | | | | 6/2 (H) |
| Majettli (r) | | | | | 1/1 (L) |
| Bal (r) | | | | | 1/1 (L) |
| Natyrya (r) | | | | | 1/1 (L) |
| Ghran (1)* | | $X_1$ | | | 1/1 (L) |
| Dewan C. (1)* | $X_2$ | $X_1$ | | | 16/5 (H) |
| Mia Fateh (1)* | | | | | 30/11 (H) |
| Dai (1)* | | | | | 15/5 (H) |
| Ghughrul (1)* | | | | | 8/2 (H) |
| KirpalC.(l)* | | | | | 26/10 (H) |
| Raniya (1) | $X_3$ | | | | 17/4 (H) |
| Mahang (1) | $X_3$ | $X_2$ | $X_1$ | | 21/5 (H) |
| Loharal (1) | $X_3$ | $X_2$ | $X_1$ | | 12/2 (H) |
| Taruhl(l) | | $X_3$ | $X_2$ | | 15/3 (H) |
| Chamruhl (1) | | $X_3$ | $X_2$ | | 15/3 (H) |
| Patnuhl (1)* | $X_4$ | | | | 26/7 (H) |
| Menjha (1) | $X_4$ | | | | 10/2 (H) |
| Sangar C. (1)* | | | | | 15/6 (H) |
| Masanol (1) | | | | | 1/2 (L) |
| Spein (1) | | | | | 1/1 (L) |
| Sulah (1) | | | | | 1/1 (L) |
| Saldian (1) | | | | | 1/1 (L) |
| Macchlena (1) | | | | | 1/1 (L) |
| Kami (1) | | | | | 1/1 (L) |
| Rein (1) | | | | | 1/1 (L) |
| Bouru 0 | | | | | 1/1 (L) |
| Upperli(l)* | | | | | 3/2 (M) |
| Buhli (1) | $X_2$ | | | | 5/2 (H) |

**Table 3 Degree of Interlinkage and Nature and Extent of Interdependent Relations for the Kuhls Originating From the Neugal Khad. (r) and (1) = right and left bank respectively. * = currently managed by Irrigation and Public Health Department. $X_n$ identifies which kuhl clusters are engaged in the interdependent relation. Interlinkage measure for kuhl "a" = ratio of the number of other kuhls which irrigate each of the villages "a" irrigates to the number of villages "a" irrigates. When the ratio (y) < 1 interlinkage = low (L), when 1≤ y < 2 interlinkage = medium (M), when > 2 interlinkage = high (H).**