The Use of Geographic Information Systems with the Study of Common Property Resources; applications with two farmer-managed irrigation Systems in Nepal.

by

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Paper Presented at The Workshop for Political Theory and Policy Analysis Colloquium, Monday, October 28, 1991

This paper aims to serve as an introduction to Geographic Information Systems (GIS) to scholars of common property resources. GIS is a relatively new computer technology. Its first applications were in the late 1950's in Canada and with advances in personal computer technology is now available to anyone with interests in research issues that have spatial characteristics.

The first part of the paper will briefly deal with GIS itself and will be followed by a discussion of possible uses and application of GIS in common property research. The last part of the paper will deal with applications to the study of two farmer-managed irrigation systems in Nepal, Kanchi Kulo in Argali and Thulo Kulo in Chherlung, in Nepal's Palpa district.

An introduction to Geographic Information Systems

With the rapid technological growth in the computer industry over the last two decades, spatial related problems and issues have found their way into computer-based systems used to store and manipulate geographically referenced data. These systems which are commonly referred to as geographic information systems (GIS) have become widely established in many disciplines. The term GIS is used to describe computer systems which store and combine map information with descriptive data about the map's spatial features. This type of information could be about people, property, rules which govern society or anything which describes and affects spatial features on the earth's surface. A GIS has the ability to automate geo-referenced data digitally into a computer file which can be stored, retrieved, manipulated and analyzed to answer spatially related problems and issues.

A map is a representation of the earth's spatial features as it exists at a specific point in time. Maps along with descriptive data (tabulations, reports) forms the basis of a GIS database. The spatial features are first digitally recorded into a GIS by their "xy" coordinates. This includes both physical and non-physical features along with data which describes them. Dependant on scale, features on a map are represented by points, lines, and polygons. Physical features can be seen on the earth's surface. They include road intersections (points), rivers, (lines) and forest stands (polygons) to name a few. Non-physical features include delineations which cannot be seen on the earth's surface but are generally established by man. Political boundaries are common non-physical delineations.

Once the data are recorded into GIS, its manipulation and analysis of complex, multiple spatial and non-spatial data sets will allow it to integrate and generate new spatial information about a defined geographic location. It is those capabilities which sets the computer-based GIS from other related graphics oriented systems. Other non-GIS systems such as CAD are not GIS since they do not have any analytical capabilities or means to assign or store attribute data to its spatial features. Since maps in a computer-based GIS are digitally recorded, maps with different themes, but same geographic location, can be easily combined to analyze new spatial patterns. Other common GIS functions include creating buffers around specified features; calculating lengths, perimeters and areas; defining relationships among spatial features (topology); land-use planning, determining optimal site locations, geocoding; managing natural resources; and routing and allocating resources along a network. All of those functions, however, can be done manually, but they can not be done as accurately and efficiently as with an automated GIS. It is the automation which reduces human error when large amounts of spatial data are handled and process to address location related problems.

A GIS is also flexible enough to produce and make changes for a variety of maps at different scales along with pertinent tabular data reports. When spatial data changes do occur, corrections or updates can be easily made to a map's digital file. This process is virtually impossible when a database is not digitally recorded; in other words, you have to make a new map. Without an automated file, entire maps would have to be recreated at a great loss of time and effort. Along with the relative ease of updating and generating maps, descriptive data in the form of tables or written reports can be retrieved from a GIS's tabular attribute files. The output capabilities of a GIS allows the user the opportunity to explore quickly several mapping options which would meet a project's need.

When addressing related spatial problems and issues, a GIS is the best means to store, retrieve, manipulate and analyze spatial data. Since there are continual changes on the earth's surface, maps must always be updated or recreated. When maps are stored in a GIS, its spatial features and attributes can be updated in a timely manner. The computerized GIS process allows spatial data to be manipulated and analyzed accurately and efficiently at speeds unmatched by any manual approach.

Applications of Geographic Information Systems to research on irrigation and other common property resources

Common properties represent definable spatial areas. Whether the common property is a fishing area, a pasture, a forest, an aquifer, or an irrigation system, a common feature of all these properties is their spatial character. There may be a non-spatial common property but it is difficult to conceptualize. Generally, however, we can say that common properties are spatial; they can be represented and stored by GIS then as "coverages."

Second, the distribution of resources over a spatial area is important in the analysis of common properties and their institutions. Some areas will produce more of a given resource and some areas will produce less and it is possible to register this information on a map. In fisheries, this may mean displaying the location of the best fishing grounds relative to areas that are not so productive. In pastures, it would mean the better grazing areas vs. areas that are less productive of grass. In irrigation, it might be the classic division between the head-end and tail-end of an irrigation system where the head has a surplus of water and the tail has a paucity of water. These data can be stored and displayed with GIS.

Third, resources are not simply distributed over a surface in varying degrees, but are differentiated by type as well. For example, fisheries may be composed not just of one type of fish but of several, which may exist in different levels of the same two dimensional area. With regard to irrigation systems, the area may be differentiated according to, for example, groups holding differing rights to water, different ethnic groups, the fertility of land or the ability of land to hold water, and not simply the availability of water. The distribution of "types" of resources within a CPR can also be stored as a coverage in GIS.

Fourth, there are temporal and dynamic aspects of spatial phenomena that are important in common property research. Migration of fish through an area over a period of time, the different use of lands in irrigation systems over an annual cycle and the respective rights to water during those times are examples.

Fifth, a common property will likely be composed of different property rights that may be bundled together in a variety of ways. Schlager and Ostrom, for example, suggest that property is not defined simply by a right to alienation (ownership) but also according to rights to exclude other from a resource, rights to manage the resource, and rights to access to the resource and withdraw from it. The configuration of these different property rights and the distribution of them within a CPR are important considerations in both the fashioning of CPR institutions and doing research on them.

Sixth, the relative location of the resource with regard to places of residence is important and can be shown with GIS. That is, some villages have a locational advantage in a common property resource; a village might be strategically located for monitoring of a resource so that appropriation of resource units from it will be easily and casually noticed by residents of the village. As another example, rules may specify that appropriators must reside within a certain jurisdiction in order to appropriate resources from a CPR. These spatial relations can be displayed and stored with GIS.

Seventh, all of these factors in a CPR can be addressed by GIS because geography or space is the common key between the data sets; information is linked together if it relates to the same space as does another set of information (Rhynd 1989:2). "Coverages" of the same area in question can be established with different kinds of data on each coverage. These coverages can then be overlain to show patterns, spatial associations, and change over time.

Eighth, GIS can also store important "attribute" data for points, arcs, and polygons. That is, part of a GIS program like ARC-INFO is a relational data-base program. Storage of attribute data means one can "point" to a feature, for example a rice-field, and bring up important data such as land-area, ownership, annual production, amount of water that is allocated to it, and so on. Important documents, such as written constitutions, sets of rules, maintenance work attendance books, and even pictures of key individuals and features of the system can be stored in GIS. Rules governing a CPR could be stored in GIS.

Ninth, if the area that has been "digitized" and represented in GIS on a workstation has been done so according to known latitude and longitude coordinates, "polygons" and "arcs" within the representation can be automatically calculated for real-world area, length, production, etc., in the attribute files. Determination of latitude and longitude even in remote sites such as the Kali Gandaki river valley in Nepal is available now to researchers through the use of Geo-Positioning Systems (GPS) technology.

Tenth, new GIS programs such as PROMAP offer the potential to model dynamic changes over time within an ecosystem. One GIS researcher states that "models developed under this framework will provide new research tools for modeling a wide range of environmental problems such as fire, hydrology, pest management, wildlife behavior, and human perception" (Gimblett and Ball 1990:64). Modeling with such a GIS tool may be useful for a variety of common property research.

Eleventh, inventories or data bases of resources can be developed. GIS inventories of common property resources would be a great help for the monitoring of CPR's, for ready access to CPR's for research either on individual systems or comparative work over many systems, and for national organizations of a particular kind of common property resource. Robert Yoder has suggested that a GIS inventory would help to rationalize investments in FMIS in Nepal. That is, an irrigation department may have little knowledge of an irrigation system that is requesting assistance for headworks or canal reconstruction. A national inventory of farmer-managed irrigation systems would provide information to a department of irrigation that would inform decision makers about different systems. Such information would allow them to develop criteria for investment and select systems that offer, according to the standards they establish, the most potential. For example, information could be included in a GIS inventory that would graphically describe the physical characteristics of a system. Areas with potential for irrigation adjacent to a existing system could be designated in a GIS coverage. Inventories might also be useful to sensitize those responsible for "interventions" in CPRs. That is, the high degree of integration of some irrigation systems appears to be based on the degree of dependence all irrigators have on one another to lend a hand during annual maintenance chores. If the entire 6.5 kilometer length of the main canal of the Thulo Kulo Irrigation system in Chherlung, Nepal were lined and annual maintenance requirements were substantially reduced, the coherence of the irrigation system organization might be eroded. With farmers at the head-end less dependent on farmers in other areas for labor to maintain the system, the head-enders could more easily resist tail-ender demands for equitable distribution of water. The capability of this system to expand because of the peculiar nature of the rules that govern it would also be restricted. For Thulo Kulo, attribute data for an "arc" representing the main canal could include information about the relationship between annual maintenance of the system and coherence of the irrigation system's organization.

Twelfth, GIS can be used in conjunction with remote sensing technology. A base map can be provided by remotely sensed imagery and spatial areas of particular interest can be outlined with GIS as needed. In an inventory based on both remote sensing and GIS of irrigation systems in the Kali Gandaki Valley from Ridi Bazaar to the Naranyani River in Nepal, very broad and easily updated views of the condition of rice cultivation and irrigation can be obtained along with a much closer view of each system.

Thirteenth, patterns of social organization can be observed spatially. People who appropriate resources from common property resources do so in organized ways. For example, a farmer-managed irrigation system in Nepal is an organized activity that often requires the co-operation of many different households for annual maintenance of the canals and intake structures. How these households group together for varying purposes is of interest. Are spatial relationships observable in this regard? In Yoder's work on the Thambesi irrigation system in Nepal, he noted that the irrigation system was loosely organized. He reported that since the main canal was so short, only a few farmers were required to repair it each year; there was no need to mobilize many farmers for annual repair of the system. Farmers at the head-end were not dependent on farmers at the tail end for repair of the system. He also noted that Thambesi exists in a small watershed surrounded by steep land; the result is a quick run-off of water after rains. Farmers need to mobilize quickly to apply water to their fields (Yoder 1986). As a consequence, parma groups in this area are probably well organized. Parma groups are cooperative work gangs for the plantation and harvesting of rice in Nepal. It would be interesting to compare a number of irrigation systems which depend on water resources coming out of small watersheds with steep terrain. Are all their parma groups organized in a similar fashion? Is ready accessibility of labor important to the parma, or are kin and other social ties more important? An inventory of irrigation system in GIS, as a spatially reference data base, would offer a relatively easy means to conduct such a study.

This technology is increasingly portable and compact. To give a personal example, when the authors of this paper were thinking about what to put into it, one of the us thought that he had accurate maps for two Nepal irrigation systems that we could then compare nicely with GIS. It turned out that whereas he had highly detailed maps for one system, the maps for the other system were in Nepal, the victim of baggage limits on international air travel. The maps, he lamented, would cover the whole floor of a good sized room. With GIS, this bulk would be squeezed down into a diskette and drawn up as needed. All the separate maps that made up the system map had common boundaries and could have, with some effort, been digitized and assembled into one map in GIS. For researchers who have to fumble with maps in exotic locations, diskettes, even Bernoulli disks, can save a lot of worry and excess baggage costs.

Finally, as the technology become more friendly and more transportable, farmers, fisherman, foresters, and pastoralists will use GIS and Remote Sensing to aid in the design of their institutions and use of common properties. This might be especially important in the area of native claims to land and resources. At the recent IASCP conference in Winnipeg, Canada, I saw a number of papers having to do with uses of resources by indigenous peoples living in fairly remote areas. The methods central and provincial governments in Canada, Norway, and other countries used to assess resource use and produce policy almost wholly neglected informal subsistence economies and local knowledge. Yet people in the north in Canada, for example, would depend on resources appropriated from land central governments considered vacant or unused. Carl Hrenchuk mapped uses of such lands and discovered that they were hardly "wilderness" but "home" to native peoples in the area (Hrenchuk 1991). They depended on foraging activity in an area approximately 35,000 square kilometers in size, lands that had been designated as "unoccupied crown lands" (Hrenchuk 1991). Terry Tobias reported on Pinehouse, a village of 700 Cree Metis, located on the Churchill River in norther Saskatchewan. He stated that the informal sector of Pinehouse had been virtually entirely ignored in provincial planning documents. The village economy was characterized ad depending almost entirely on transfer payments while returns from fishing and hunting were almost non-existent. tobias worked with people in the area to document harvesters' knowledge in the resource use. While provincial government documents indicated less than 20 kilos fish caught per capita per year, Tobias' data indicated that over half the died of the people of Pinehouse came from fishing.

GIS can be useful with regard to Native claims. Not only is it a convenient device for the establishment of an inventory of resources and their use, but it is a relatively advanced computer graphic technology. It offers a visual product that can convey a great deal of information very quickly. It is a persuasive, even glitzy, means to present information to policy makers.

The use of overlays in GIS; an example with Kanchi Kulo

The following maps of Kanchi Kulo are an example of the use of overlays in GIS, along with the capacity to store spatially referenced data, perhaps the most important feature. The concept of a base map, coordinate systems, attribute files, and overlays along with particular features of Kanchi Kulo irrigation system will be discussed text on the maps. All of the maps, including the text, were drawn by a pen-plotter.

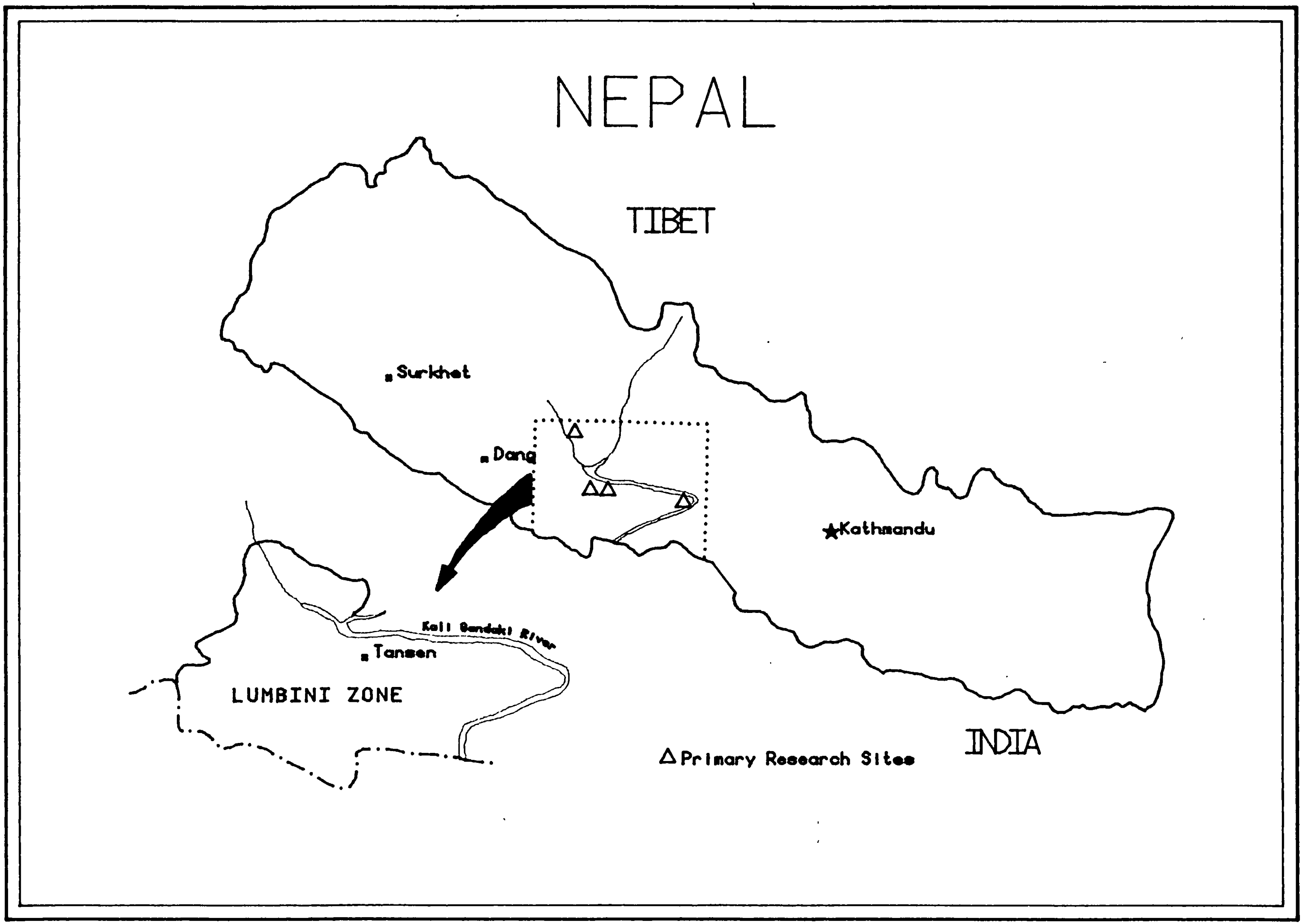
Map of Nepal

Nepal is a Himalayan country about the size of Wisconsin on the northern border of South Asia. Nepal is generally described as having three areas of habitation: the high Himals, the middle hills, and the Terai. The Himals are, of course, the worlds's tallest mountains. The continuing collision of two tectonic plates have created the Himalayas and Nepal shares with Tibet (China) one half of the world's highest peak, Mt. Everest. The border with India on the south, called the Terai, is relatively flat and low, around 100 meters in elevation in the eastern portion. Most of the people of Nepal still live in the middle hills although the population in the Terai is growing faster.

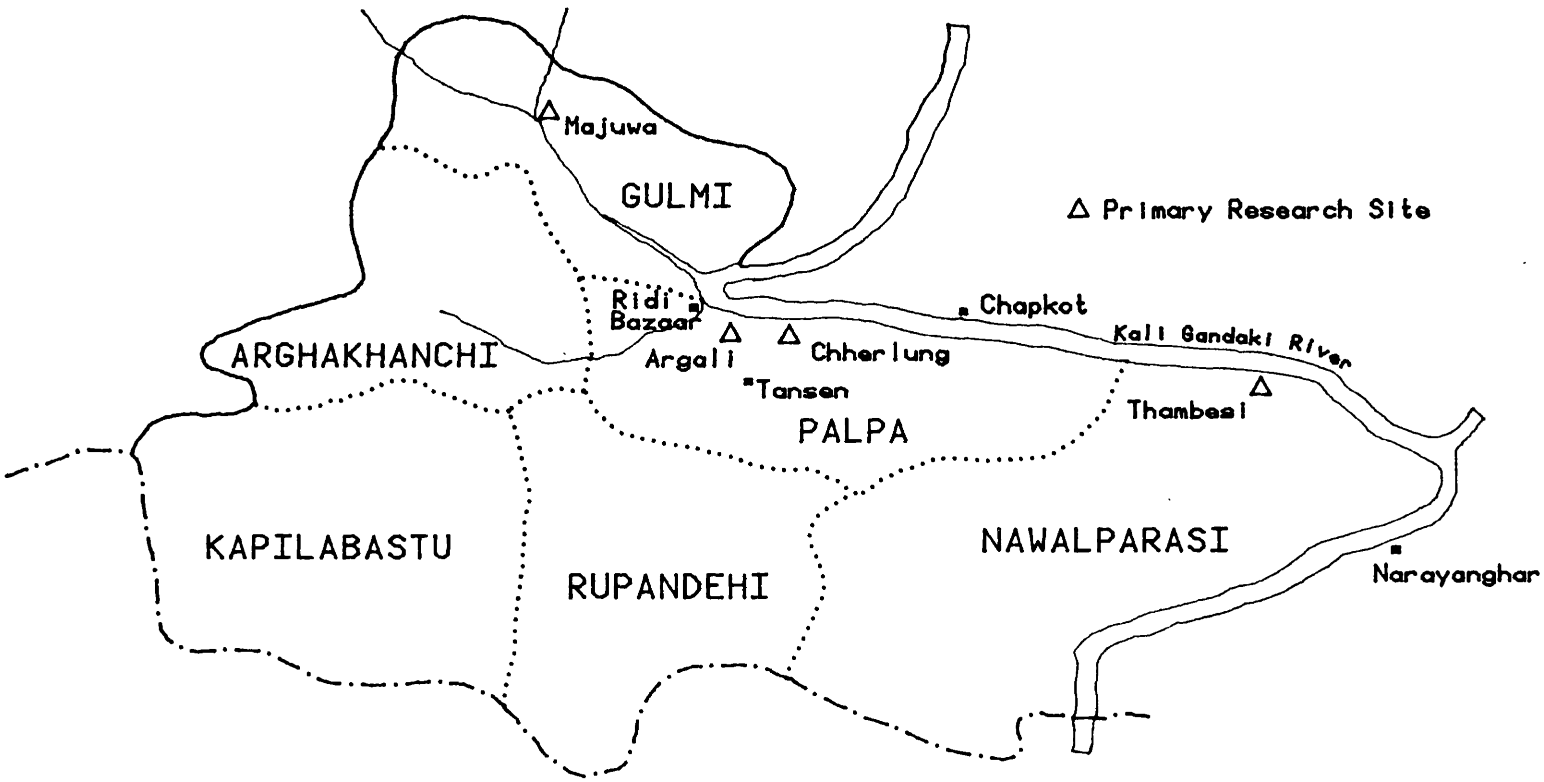
The southwest monsoon brings copious amounts of rainfall for four months of the year from June through September to South Asia and especially to Nepal. Some rainfall stations record more than five meters of rain per year although most are considerably less than that. At any rate, although Nepal is a relatively poor country, it is fairly wealthy in water resources. In this paper, we will talk about water resources used to irrigate farmer's fields in farmer-managed irrigation systems.

Map of Palpa and Nawalparasi Districts

This map shows the districts, or Jilla in Nepali, of Palpa and Nawalparasi. There are 75 districts in Nepal; a district is comparable in size to a county in states east of the Mississippi in the U.S. Palpa is a hill district while part of Nawalparasi in the hills and part is in the Terai. Both of these districts are bordered on the north by one of the great Himalayan rivers, the Kali Gandaki. Flat terraces call tar in Nepali sit 80 to 150 meters above the Kali Gandaki River and it is on these terraces that farmers have constructed many irrigation systems. This paper will describe two irrigation systems in this area.


NEPAL
TIBET
Surkhet
Dang
Kathmandu
Kali Gandaki River
Tansen
LUMBINI ZONE
INDIA
Primary Research Sites

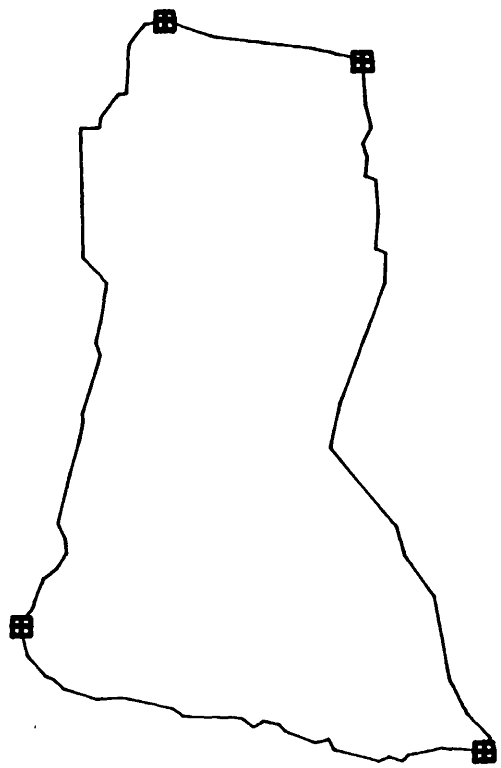
Lumbini Zone, Nepal



Map of Argali

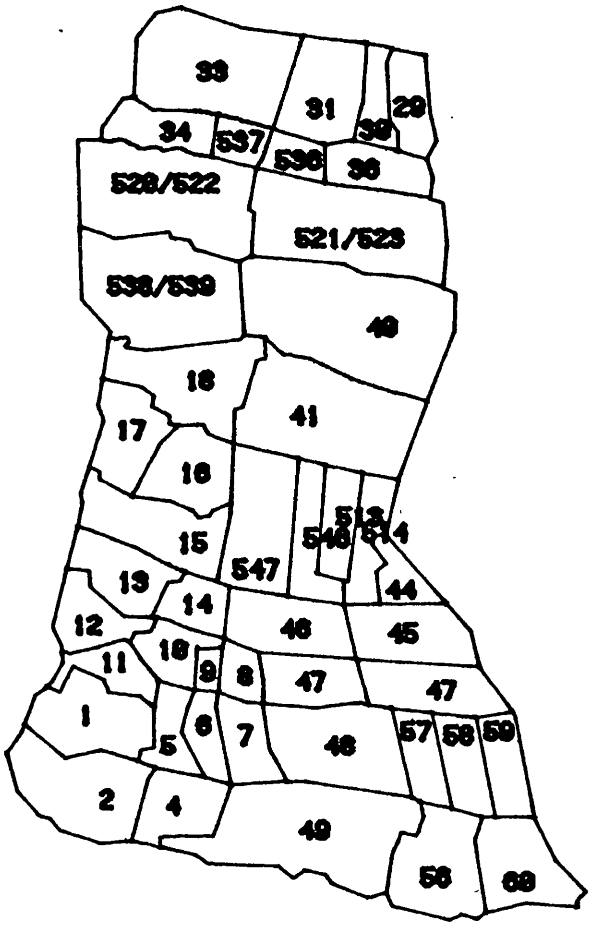
This map shows the village of Argali and its environs. Argali is a village in Palpa District and is inhabited mostly by Brahmins. The original map was taken from a tracing of an air photo of the area. This map was taken from a reproduction of that tracing. The map shows the general orientation of Argali, including the Kali Gandaki on the north and the several irrigation systems, and several areas identified as bari, nominally fields that are not cultivated for rice, although they may be irrigated for maize or wheat. Not visible on the map is the presence of steep mountains immediately to the south of Argali. They rise up almost immediately from the southern boundary of the irrigation systems to elevations of over 6,000 feet. The irrigation systems are Raj, Maili, Saili, and Kanchi Kulos. Each irrigation system is governed by a separate organization, although farmers in Argali may have fields in more than one system. A farmer with khet (rice fields) in several irrigation systems would participate in the governance of each system. We will examine closely one of these irrigation systems, Kanchi Kulo.

Kanchi Kulo: Base Map



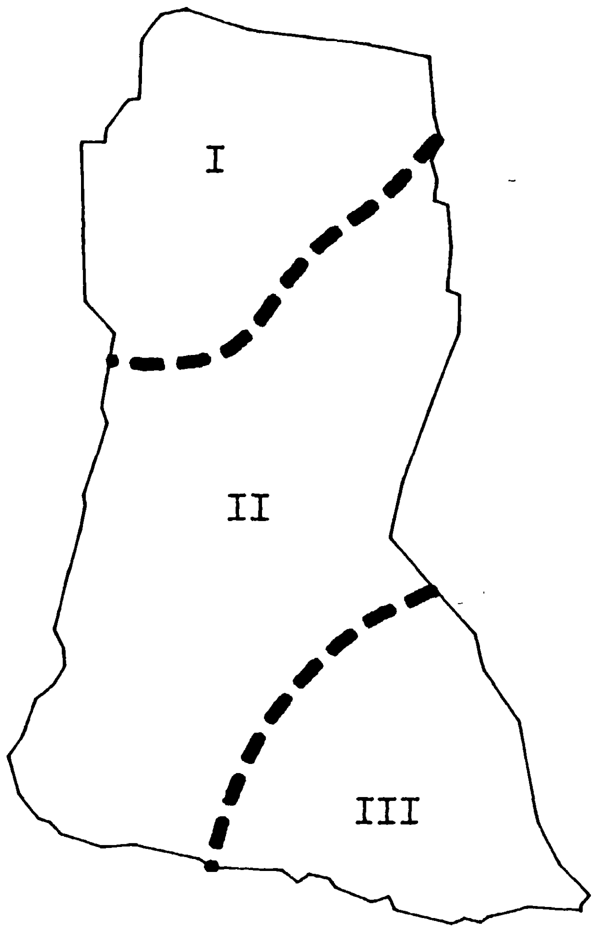
This is the base map, a boundary that is common among all map themes of this geographic location. The boundary was created via a "digital" process, the most important element of which is the establishment of a coordinate system. All other coverages are based on this map's boundary and coordinate system. Initially, a coordinate system is developed to meet the needs of map projection and to define measurement. A small unit of measurement is appropriate at this large scale. We select known geographic points for easily identifiable coordinates. Based on those known points, measurement is defined for all spatial features. A coordinate can be latitude and longitude or, if those are not available, then some other system can be developed. Based on the same coordinate system, map layers can be overlain. Each map layer is a different theme, but it is a theme with the same geographic location, i.e., based on the same coordinate system. A theme can be soils, rice fields, water allocation to rice fields, production, and so on. These themes can be represented on separate "coverages" (map layer). Depending on research needs, these coverages can be overlain to form a composite. A composite shows new patterns (polygons) and spatial relationships (topology) that are not easily perceived when each coverage is viewed separately. With computer-based Geographic Information Systems (GIS), production of overlays or composites is more precise, more flexible, and more efficient than a system of manual overlays. Additionally, it is accessible to a vast amount of data whereas manual systems are limited.

Kanchi Kulo: Map #1



Map #1 shows the irrigated area of Kanchi Kulo, including the borders of individual khets and numbers assigned to them by Martin and Yoder (Martin 1986; Yoder 1986). Kanchi Kulo is located in Argali Village in Palpa District in western Nepal. Just to the north of Kanchi Kulo is the Kali Gandaki, a major river coming out of the Himalayas that flows eventually into the Ganga in India. The area of the Kanchi Kulo irrigation system is 11.3 ha.

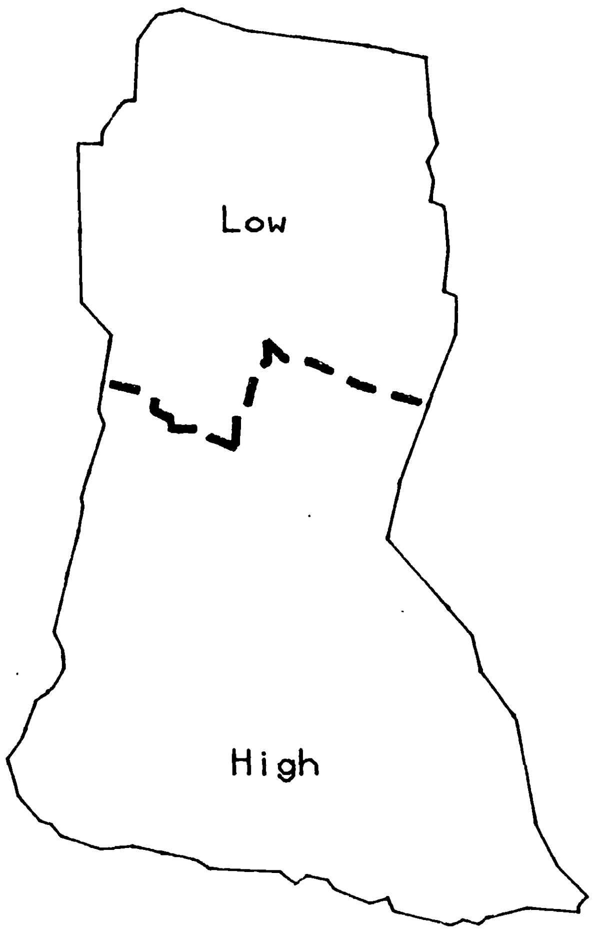
Kanchi Kulo: Map #2



Soil Types

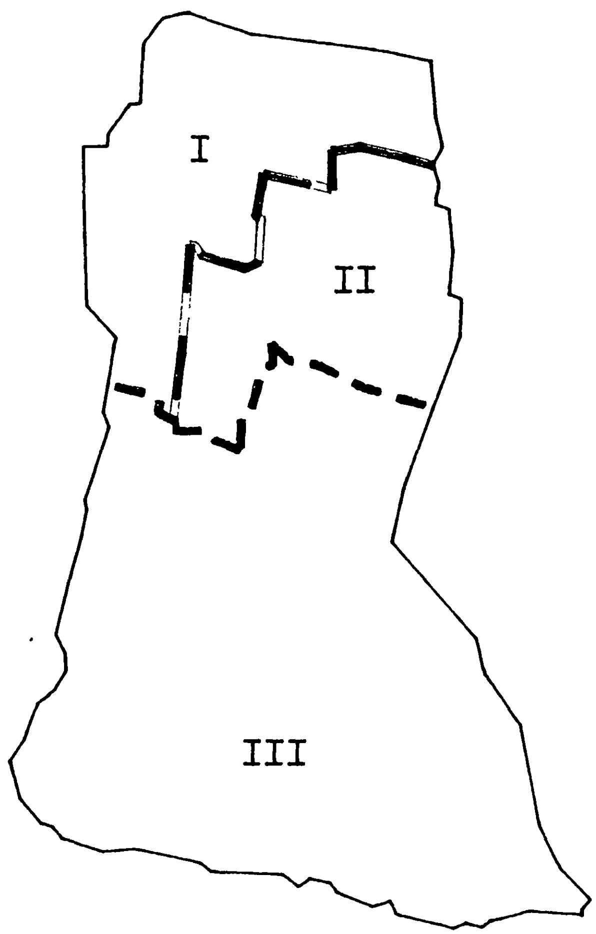
ID	MATO
I	Udic Rhodustalf or Udic Haplustalf A. Surface Texture: Silty Clay B. Subsurface: Silty Clay, Clay
II	Fine Clayey Thermic Udic Rhodustalfs A. Surface Texture: Clay Loam, Silty Clay Loam B. Subsurface: Clay
III	Fine Clayey Thermic Udic Rhodustalfs A. Surface Texture: Coarse Loam, Fine Loam, Clay B. Subsurface: Coarse Loam, Fine Loam, Clay

Map #2 shows the boundary of Kanchi Kulo with a coverage of the soils of the area. Three areas marked on the map with roman numerals I through III representing different soil areas. They are identified in the legend.



Kanchi Kulo: Map #3

Map #3 indicates what Yoder and Martin call the high and low water allocation areas. These areas represent relative abundance (or scarcity) of water in the two areas. This does not "imply the head versus tail problems of water delivery often talked about in the irrigation literature" (Yoder 1986). Rather, it refers to an expansion of the system that occurred in the past. "About 70 years ago the khet area was expanded from 8.5 ha to the present 11.3 ha. Individuals who owned khet in the system and bari adjacent to the farthest end (geographic tail) of the system, received permission to convert bari into khet" (159). The high water allocation area, or head, refers therefore to the approximately two-thirds of the system nearest the intake which was khet before the system expanded and from which water was not taken in expansion. The low water allocation area, or tail, refers to the area of khet that was involved in the expansion.



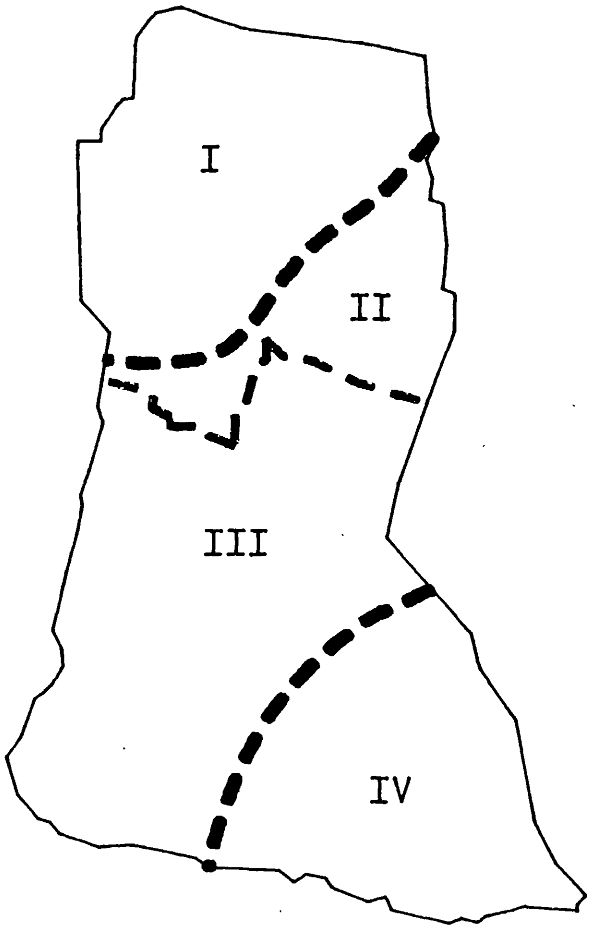
Kanchi Kulo: Map #4

Water Allocation Area

ID	Allocation Area
I	New Low Water
II	Old Low Water
III	Old High Water

Map #4 shows three areas, labeled I, II, and III. The area that represents the expanded irrigation area is labeled "I" while the area labeled "II" is the area from which water was taken to irrigate the expanded area. Areas I and II combine to form the low water allocation area. Area III corresponds to the high water allocation area.

Kanchi Kulo: Map #5

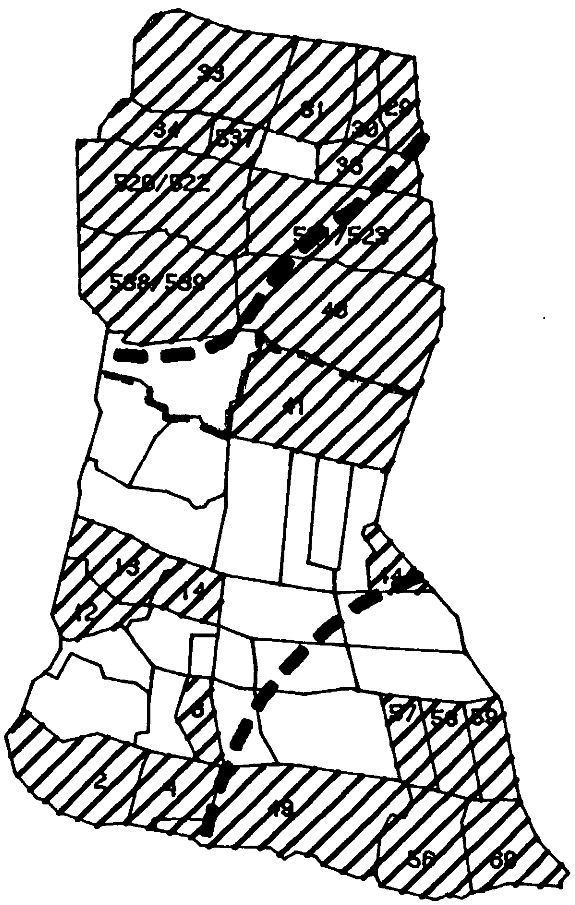


WAA & Soils Classification

ID	I
WAA	Low Water Allocation Area
MATO	Udic Rhodustalf or Udic Haplustalf
ID	II
WAA	Low Water Allocation Area
MATO	Fine Clayey Thermic Udic Rhodustalfs
ID	III
WAA	High Water Allocation Area
MATO	Fine Clayey Thermic Udic Rhodustalfs
ID	IV
WAA	High Water Allocation Area
MATO	Fine Clayey Thermic Udic Rhodustalfs

Map #5 shows an overlay of the soils coverage and the water allocation areas. The red lines represent boundaries for the soils coverage, while the blue line represents the boundary between the high and low water allocation areas. The overlay of these two maps results in the formation of four areas, or polygons in the terminology of GIS.

Kanchi Kulo: Map #6



KHET-ID	YIELD (KG/HA)	WAU/HA
33	3530	8.73
31	3170	11.21
40	3390	13.11
41	2980	25.67
2	3600	31.95
49	2610	38.91
56	2810	29.64

Map #6 represents another overlay. This time, we have combined the coverage showing different khets with the soils coverage and the water allocation areas coverage. Yoder's work has production figures from 22 khets in Kanchi and from these, we selected a number of khets that fall wholly or nearly completely within each of the four polygons. We have constructed a table that shows khets from each area and their production per hectare. With this means, areas in an irrigation system can be easily compared for production and performance.

We will conclude this paper with a comparison of two irrigation systems, one of which we've already seen, Kanchi Kulo. The other one is called Thulo Kulo and both were studied by Robert Yoder during his dissertation research. Key in this comparison is the different sets of rules that control for differential behavior and performance of the two systems.

Thulo Kulo

Thulo Kulo is located in Chherlung, like Kanchi Kulo, in western Palpa District. Like Kanchi Kulo again, it sits on a tar or terrace on the south side of the Kali Gandaki river. Thulo Kulo has an irrigated area of 34.8 hectares and supports three crops per year, wheat, maize, and rice. The average yield for all three crops on Thulo Kulo land exceeds 8 metric tons per hectare per year.

Thulo Kulo is a relatively new FMIS in Nepal. In the 1920's, the two founders of the system, small landowners, sold jewelry and some of their land to raise money. Twenty-five others also contributed small amounts of cash and shared in the construction activities. When water finally flowed in the canal, those who had invested in the construction determined the conditions under which other members of the community would be allowed to share the system (Yoder 1986:94).

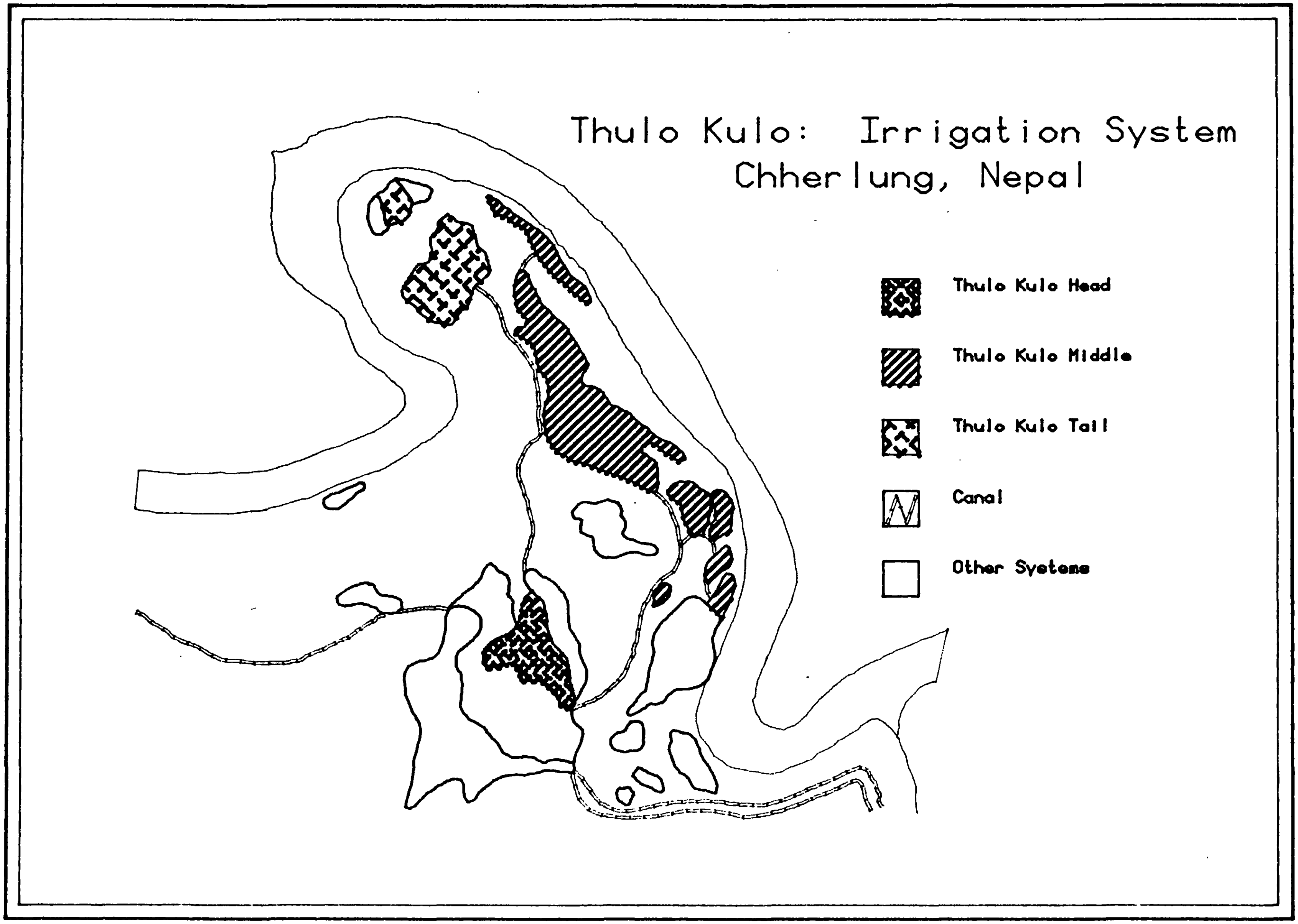
To build Thulo Kulo, a contract was given to four men from Gulmi, including an agri (miner) who cut tunnels and laid out the alignment of the canal. These four men hired and supervised 25 to 30 other laborers. The amount of the contract in 1928 was Rs 5,000 plus a gift of 0.12 hectares of potential khet land (Yoder 1986:99).

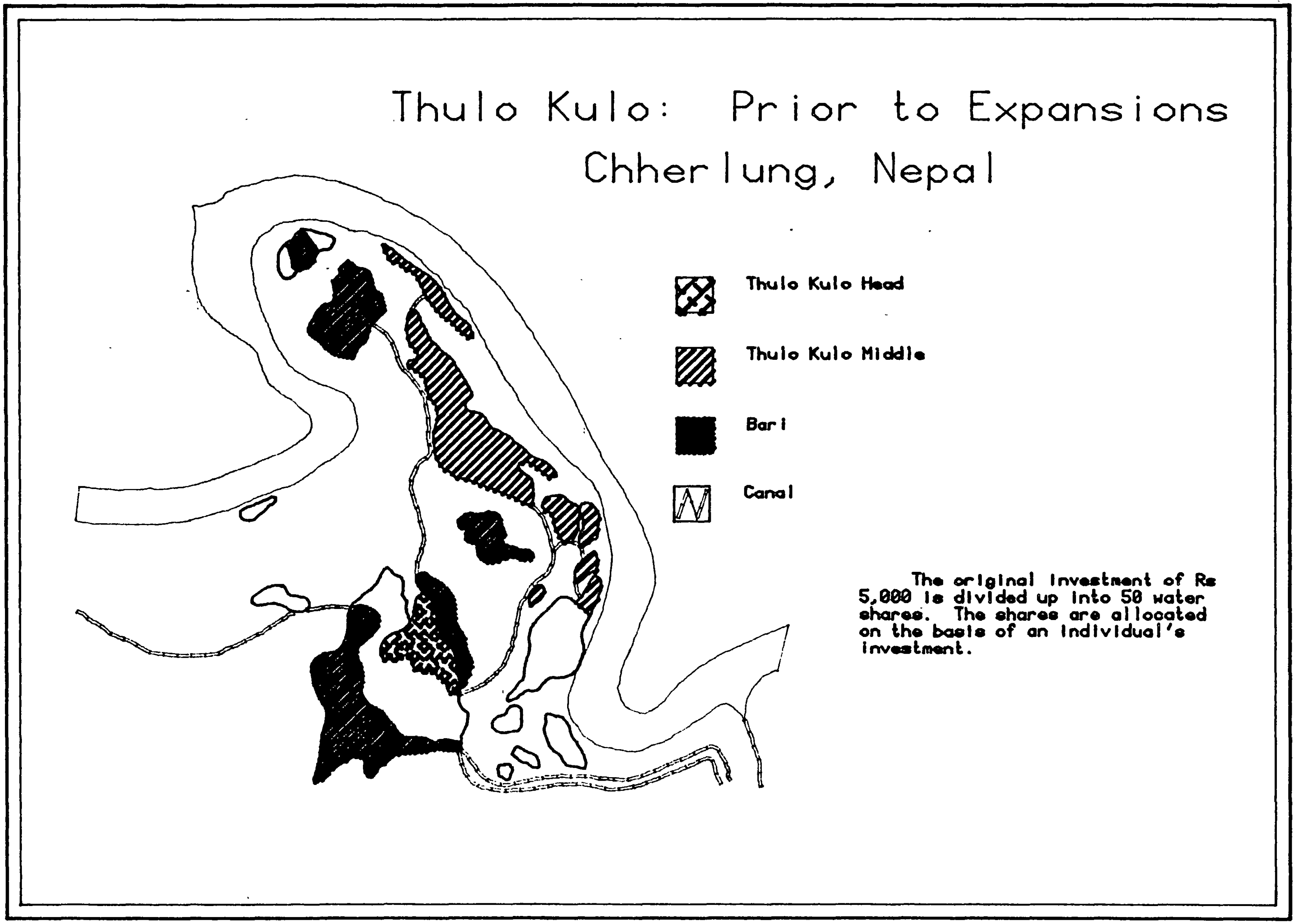
Construction work began in 1928 and continued for ten months each year until 1932, when water was brought through the length of the canal for the first time. The initial excavation of the canal was small and only brought enough water for a few fields, but it demonstrated to all in the community that water could be brought 6.5 kilometers through rugged jungles and through channels cut into vertical cliffs. The canal has since been improved on an annual basis (Yoder 1986:100).

Rights to water in Thulo Kulo evolved out of a set of condition peculiar to the financing and construction of the system. When Thulo Kulo was built, the boundaries of the irrigated area had not yet been established; there was little relationship between the investor's landholding size and the size of the contribution for construction. Furthermore, the two farmers who had invested most of the resources were interested in recovering some of their costs. There was still work to be done on the system that would require an additional investment. And, since there were four family lines represented in Chherlung, there was no common respected patriarch who could dictate and enforce rules for allocating the rights to use water from the canal. These considerations led farmers to choose a method that based the right to use the new irrigation property on the individual's investment in its construction rather than on the landholding of each household (Yoder 1986:215-216). Allocation of rights to water was based on the ratio of the contributions to the Rs 5,000 contract. Members divided the Rs 5,000 into 50 shares and each household received shares in proportion to its contribution. Since the size of the contribution varied, some shareholders had more water than they needed to irrigate their fields, while others did not have enough. Others, who had not contributed initially, now wanted access to water (Yoder 1986:216).

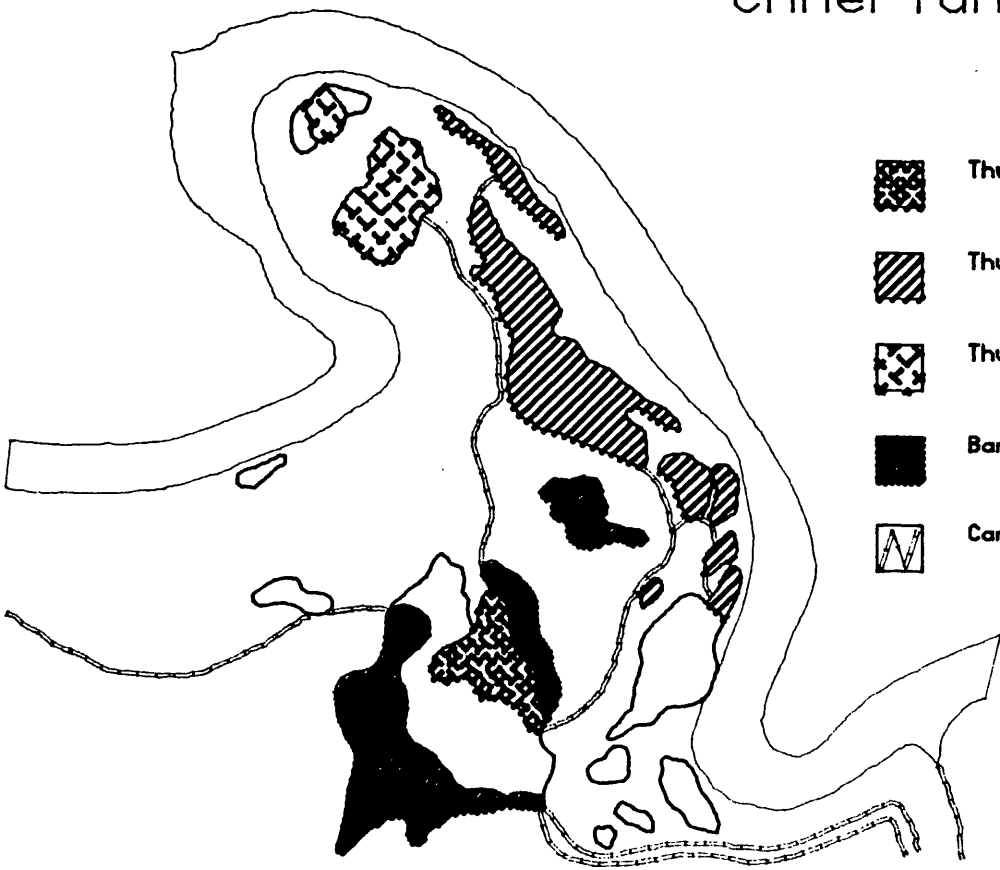
Consequently, households who needed water approached those who had a surplus of water, and so the principle of buying and selling water shares was established. Shares of water can be purchased in either of two ways. If an individual wishes to purchase water, he can do so from any shareholder prepared to sell. When no individual is willing to sell a share (or a fraction of a share) of water, the buyer, or a group of individuals interested in the purchase of water can approach the canal committee to buy from the system rather than from an individual. When shares are sold from the system, the total number of shares is increased and the discharge of water per share is proportionally decreased. In 1977, ten shares of water were sold to 28 persons for Rs 2,800 per share. This money was then used to make canal improvements so that water could be delivered more reliably (Yoder 1986:218).

With water allocation according to purchased shares there is a mechanism for adding new members and expanding the system.


Thulo Kulo: Irrigation System
Chherlung, Nepal
Thulo Kulo Head
Thulo Kulo Middle
Thulo Kulo Tail
Canal
Other Systems


Thulo Kulo: Prior to Expansions
Chherlung, Nepal
Thulo Kulo Head
Thulo Kulo Middle
Bari
Canal
The original investment of Rs 5,000 is divided up into 50 water shares. The shares are allocated on the basis of an individual's investment.

Thulo Kulo: Expansion
Chherlung, Nepal



The principle of buying and selling water shares is established. Farmers who did not invest in the system originally can purchase shares from the organization or from shareholders. The system has expanded to include what is now the tail and is expanding into an additional 8 hectares of bari.

Kanchi Kulo

Oral history suggests that the Kanchi Kulo was built sometime between 150 and 250 years ago. The total khet area is 11.3 hectare, but an additional 4 hectare of bari also receives irrigation water for wheat and maize. Since this bari can potentially be turned into khet for growing monsoon rice, the system is not land constrained for rice, the most important crop (Yoder 1986:155).

At present, there are 28 households that own khet irrigated by the kanchi Kulo. Only these 28 are considered members of the Kanchi Kulo system, even though several other households receive water to irrigate bari. All of the land is owner-operated and most "field neighbors" are also "house neighbors." All but one of the members are Brahman, and most are related to each other. Although now the non-member irrigators of bari wheat and maize contribute labor for non-monsoon maintenance of the system, control and responsibility for its operation rests solely with the members. The members of the system are considered the owners of the irrigation system both by themselves and the community (Yoder 1986:159).

Several persons have become members by purchasing khet in the system. There has also been some purchase exchange of land, and therefore water property, among members. But most members have inherited their land and water property; fragmentation of holds continues as it is divided among sons. About 70 years ago the khet area was expanded from about 8.5 hectares to the present

11.3 hectares. Individuals who owned khet in the system and bari adjacent to the farthest end of the system, received permission to convert bari into khet (Yoder 1986:159).

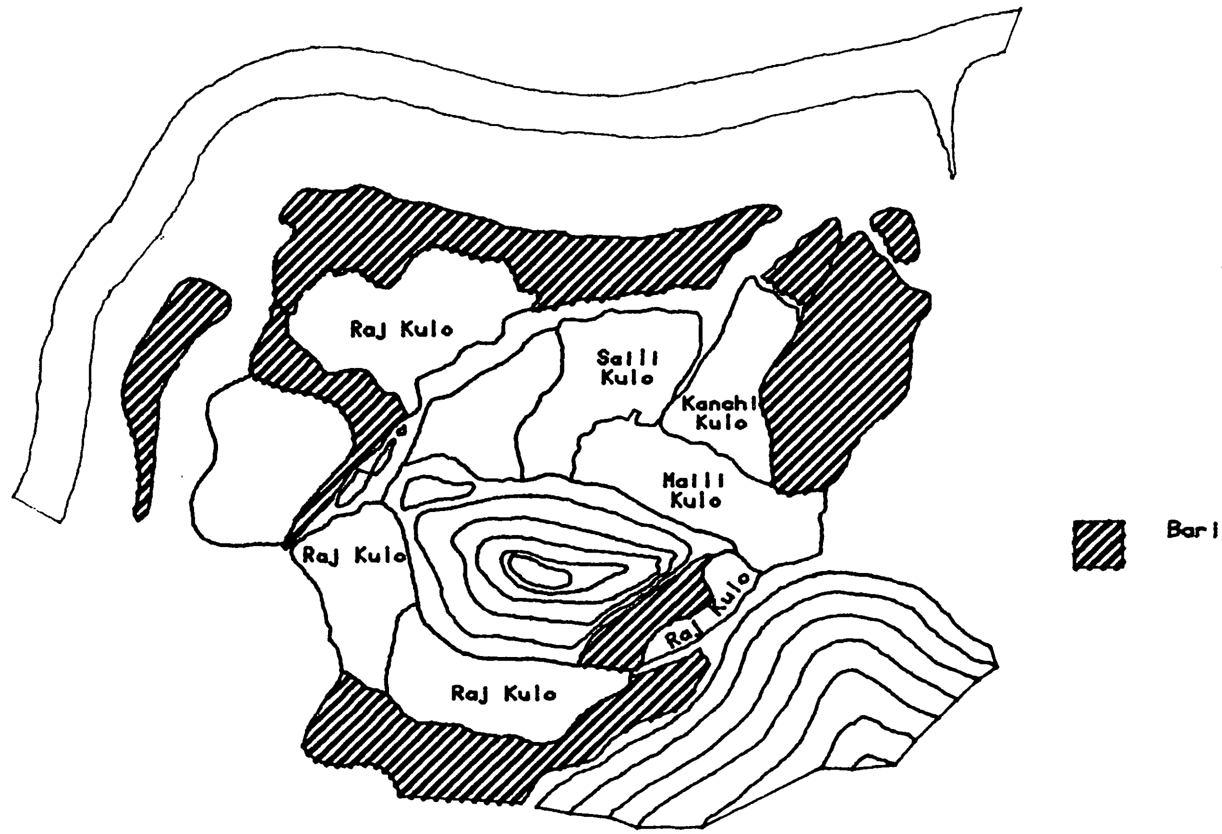
The portion or share of water that each member's khet is entitled to receive, has been fixed and is recorded in the system's written records. This is public information and most members could identify the water allocation of each plot in the system. People in Kanchi Kulo said that the water was originally allocated by proportioning the discharge in the canal equally per unit of land area (Yoder 1986:163-164).

Water available in the irrigation system was originally set equal to the area of land that was to be irrigation. The terms for both the area of the land and the units of water available to irrigate it were the same: maato muri. There are now 249.5 maato muri of water available for irrigation in Kanchi Kulo. The water allocation is no longer equal to the land area since land was apparently not measured accurately originally and as farmers shifted water from one of their plots to another to account for differences in percolation rates (Yoder 1986:165-166).

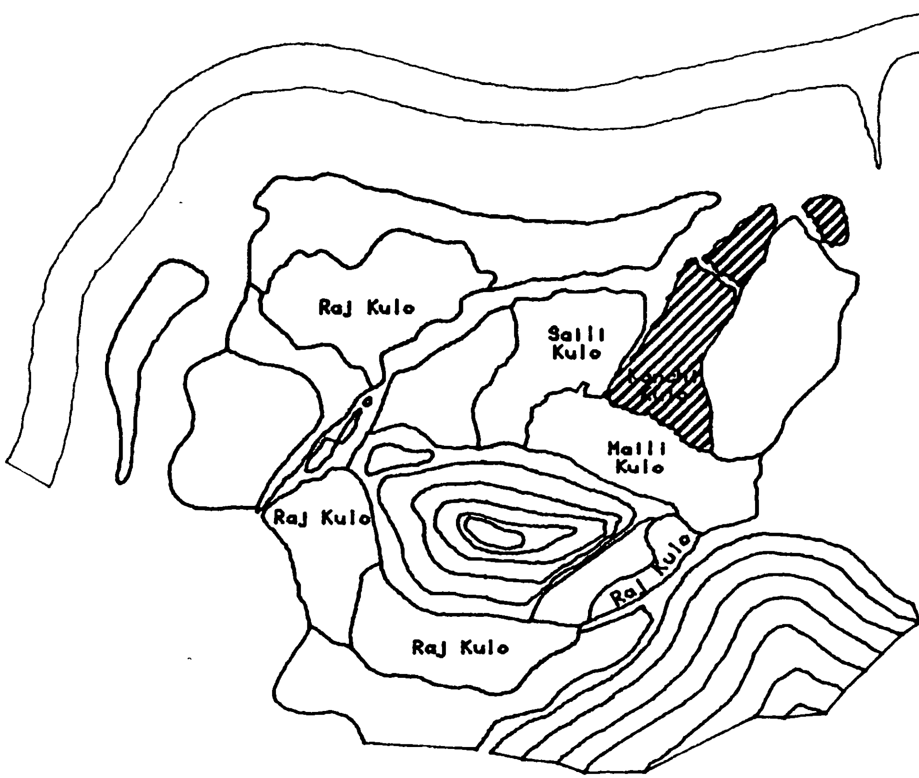
The method of water allocation described here for monsoon rice in the Kanchi Kulo is the most common method of water allocation found in the study of farmer-managed systems in the hills of Nepal. Discharge in the canal is distributed to each member according to the ration of each irrigator's land holding to the total area in the system. Although some shifting and redistribution of water takes place, it is primarily within one landowner's khet. The expansion of the system is limited to the border where khet owners also own bari (Yoder 1986:167-169).

Each member's water allocation for monsoon rice was fixed proportionally to the khet area the member owned in the system. The water rights were inseparable from the land to which they were originally allocated and were transferred along with the land whenever the ownership changed. This method of water allocation established a rigid boundary for the khet area and allowed expansion only along the borders where a member also owned or could purchase bari to convert to khet. Water from a member's original khet could then be shared with the new khet. This seriously limited the expansion of the Kanchi Kulo system. In the head of the system, the water allocation remained unchanged even though improvements in the system had increased the water supply. Irrigation in the head of the system was by continuous flow to all of the fields. To maintain continuous standing water in all the khet, an irrigation discharge of at least 5 liters per second per hectare was required. Farmers with fields in the tail of the Kanchi Kulo, where expansion of area had taken place, demonstrated that a water supply of 3 liters per second per hectare could achieve yields equal to those in fields in the head if rotational irrigation from one member's field to the next was practiced. By following the same management practices in the head as in the tail, the area irrigated by Kanchi Kulo could have almost doubled with the water supply available in 1982. Under the existing rigid allocation of water in the Kanchi Kulo system, there is no mechanism or incentive for transferring water to new members for expanding the khet area (Yoder 1986:315-316).

Farmer Managed Irrigation Systems
Argali Village, Palpa District, Nepal



Kanchi Kulo and Potential Expansions

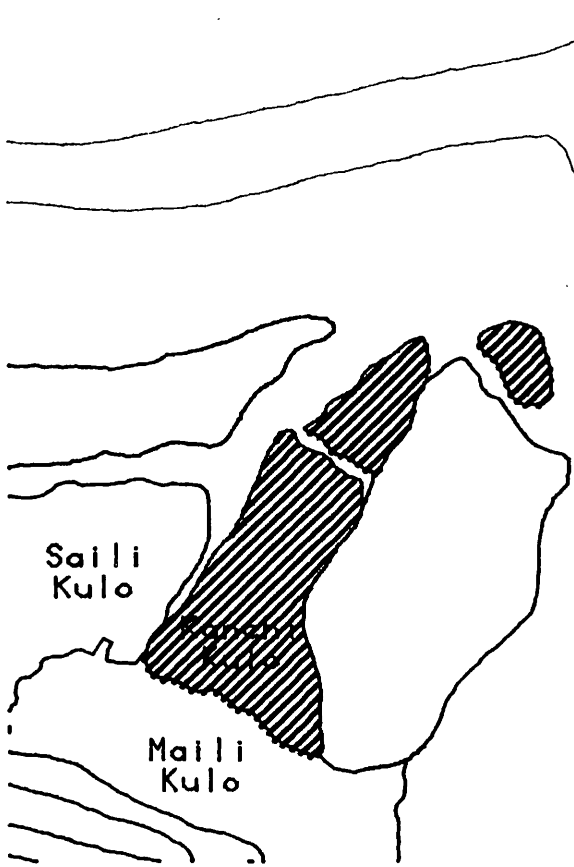


Potential Expansion Area

Kanchi Kulo

Water rights in Kanchi Kulo are tied to land. The system expanded at one time to a contiguous area when farmers took allocations of water from their fields and applied them to neighboring fields. This map shows potential expansion areas that neighbor the existing irrigated area for Kanchi Kulo. Since water rights are tied to land, however, it is difficult for the system to expand into this area.

Kanchi Kulo and Potential Expansion Areas



Potential Expansion Area

Kanchi Kulo

There are neighboring lands to Kanchi Kulo that could be irrigated but, due to the present rules, are not. If a system of water shares was developed similar to Thulo Kulo, surplus water in the head portion of Kanchi Kulo could be sold to farmers in the potential expansion area.

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