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Sayl and *Ghayl:* The Ecology of Water Allocation in Yemen

Daniel Martin Varisco[1]

*In this article, comparison is made between the two major types of water allocation systems in Yemen: seasonal flood (*sayl*) and highland spring flow (*ghayl*). Constraints in the nature of water as a flowing resource are defined for each system. The major distinctions between the two types of systems are variability in water flow (which influences the determination of access rights), techniques of water control, measurement of water turns, the need for supervision of irrigation activities, and the potential for economic expansion of the production system. It is argued that tribal political organization is an adaptive response to highland spring flow allocation in Yemen, but undergoes stress in coastal flood systems where competition for the same water source extends across tribal boundaries in upstream-downstream conflict.*

KEY WORDS: resource allocation; irrigation; water scarcity; tribal political organization.

INTRODUCTION

Two major types of irrigation systems have contributed to the greening of Arabia Felix, that part of the Arabian peninsula now covered by the Yemen Arab Republic and the Peoples Democratic Republic of Yemen. The seasonal flood (*sayl*) is exploited predominantly in the coastal area and foothills, whereas spring flow (*ghayl*) is significant in the highlands. In the coastal areas wells are used to supplement seasonal floods, but in the highlands wells are used mainly for irrigation of small garden plots near urban centers. Unlike Oman, which lies to the east of the Arabian

[1]Department of Anthropology, University of Pennsylvania, Philadelphia, Pennsylvania. Mailing address: 43 Mist Lane, Westbury, New York 11590.

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peninsula, very few underground infiltration galleries or *qanats* are found in Yemen. Although irrigation is the most productive form of agriculture, at least 84% of the 1.5 million hectares (ha) cultivated in the Yemen Arab Republic are based on dry farming.

In this article, a comparison is made between *sayl* and *ghayl* allocation systems in Yemen in order to illustrate the extent to which constraints in the nature of water as a flowing resource influence allocation decisions. Data on the seasonal flood systems have been gathered from the available literature and unpublished development reports, but data on highland spring flow were collected during an ethnographic study in the central highland valley of al-Ahjur.[2] It is argued that for the Yemeni allocation systems variability in water flow is of major significance in determining access rights, techniques of water control, measurement of water turns, the need for supervision of irrigation activities, and the potential for economic expansion of the production system. Further, the seasonal flood systems, which have the potential for upstream-downstream conflict due to periodic water scarcity, place a stress on traditional tribal political processes. By contrast, highland spring flow allocation systems seem well suited to tribal organization in Yemen.

The article begins with a definition of the concept of water allocation. Brief descriptions are given of the seasonal flood and highland spring flow in Yemen. The ecological constraints of water allocation in each type of system are identified. The impact of water scarcity on allocative roles is assessed and each type of allocation system is examined in relation to Yemeni tribalism.

CONCEPT OF WATER ALLOCATION

The concept of water allocation has received little attention as an anthropological problem, despite a significant number of ethnographic studies on irrigation societies.[3] Bennett (1967: 444) defined the broader concept of resource allocation as encompassing both rules for governing access to resources and mechanisms for controlling the distribution of resources. Lees (1973: 23) extended this definition to include the administrative organization generated in the process. Some anthropologists

[2]This was the site of my ethnographic field work in the Yemen Arab Republic during 1978 and 1979. For a full treatment of the spring flow allocation system, see Varisco (1982). Arabic terms cited in this article are not transliterated according to a critical system. Proper transliteration will be found in the glossaries of Varisco (1982).

[3]A review of the literature on water allocation and suggestions for approaching the study of water allocation systems can be found in Varisco (1982). See also Hunt and Hunt (1976).

(e.g., Conklin, 1980; Downing, 1974) have borrowed a legal distinction from European and United States law, specifically the doctrines of riparian rights and prior appropriative rights. However, the value of this legal model, which is a Western concept, has yet to be demonstrated for cross-cultural comparison of water allocation systems. Uncritical use of such a distinction may only serve to obscure the full range of allocation options in a community.

In the literature there is often confusion among water allocation, water distribution, and water control. Water allocation is generally reserved for rights or laws regardless of the physical mode of appropriation or distribution. Water distribution or control refers primarily to technological responses, but these may have political ramifications. The most common distinction in the irrigation literature comprises three methods of water distribution or control (Vandermeer, 1971: 158; Widtsoe, 1914: 358): continuous flow, intermittent flow, and emergency or applied-for flow. Continuous irrigation is that in which water flow in a major channel is diverted simultaneously into offtake channels for application to plots. Under the intermittent option each plot or set of plots receives water according to a rotation cycle of water turns. A third option is that in which access to water is determined by an external decision maker, whether an individual with power or one representing a communal association. The three options described here represent both the physical mode of flow and access rights. Thus, this is a *de facto* model of water allocation.

In a discussion of the forms of water allocation in India, Chambers (1980: 35-36) also combined physical methods with rules of access. One of the options he cited is to divide the flow in a channel by sluice so that water flows simultaneously to different irrigators according to a proportional measure. Another option is allocation by restricted acreage, which links access to water with land ownership. Allocation by anarchy is an option that does not specify a physical mode of appropriation or distribution.

The linkage between rights of access and physical methods of appropriation and distribution is evident. The important issue is the relationship between rights of access to water and the actualization of those rights. It is proposed here that a general concept of water allocation be defined as consisting of two related aspects: the rights and rules of access to water and the physical modes of appropriating and distributing water according to defined rights. These two aspects are linked in the behavior generated in the allocation of the resource.

A typology of water allocation options does not explain why people in a given community allocate water the way they do. This question cannot be adequately answered without first considering the ecological context of allocation, specifically the constraints of water as a flowing resource.

Irrigators must respond to constraints of variability in water flow with appropriate technology and a viable resource allocation strategy. This behavior cannot be reduced to a simple mechanical process, but some responses will be more adaptive than others. The comparison of seasonal flood and highland spring flow allocation systems in the same cultural context of Yemen illustrates how similar socio-political processes are adapted to varying ecological contexts in water resource allocation.

SEASONAL FLOOD (*SAYL*)[4]

The term *Sayl* is used in Yemeni Arabic for the seasonal flood or spate. There are no permanent rivers in Yemen, so great importance is attached to the floods that descend the major *wadis*[5] after the spring and late summer rains. Flood flow is diverted by means of low earthen barrages that divert part of the flow into offtake channels. Overall, one-half of the estimated 238,000 ha of irrigated land in the Yemen Arab Republic is watered by seasonal floods. Although most of this is in the coastal region and nearby foothills, flood systems are also found in parts of the eastern plateau in Yemen. An example of the latter is the famous Marib dam of pre-Islamic Yemen, which is mentioned in the Muslim Quran.

Flood irrigation in Yemen is supplemented by two other sources of water supply. The well provides water for crops during seasons when there is little or no water in the *wadis,* and is the dominant source of domestic water supply. Agriculture based on seasonal floods is also supplemented by dry farming, although with the limited rainfall in the coastal region this is a more marginal undertaking than flood farming.

The barrages constructed in the *wadis* are made of earth and brush as temporary structures. The construction and maintenance of barrages are communal concerns. There has been little state-directed construction of barrages in Yemen historically, with the exception of limited Rasulid control of *wadi* irrigation in the 13th and 14th centuries. Many of the barrages are destroyed by violent floods or must be breached in order to allow water to flow downstream to other irrigators with rights.

A seasonal flood system requires the rapid mobilization of communal labor during the flood season for physical distribution of the flow. Water is

[4]For a detailed description of seasonal flood irrigation in coastal Yemen, see Serjeant (1967) and Maktari (1971). Much valuable data can also be found in development surveys of the major coastal *wadis* (Halcrow, 1978; Makin, 1977; Mitchell *et al.,* 1978, Tesco *et al.,* 1971-1973).

[5]The term *wadi* in Arabic refers to a watercourse in which water may not be present for part of the year.

diverted by a major barrage or several small barrages into offtake channels. The water is applied sequentially to fields along the channels, with fields closer generally receiving water first. Each irrigator must be present to appropriate water as it arrives to his plots. Since land holdings are fragmented, an irrigator will often have to rely on family members or hired help to aid in irrigation of all his plots (Bujra, 1971: 59). If there is damage to the barrage or a major offtake channel, a work party must be mobilized immediately to repair the damage (Maktari, 1971: 63).

The allocation of flood flow among communities along a *wadi* is based on a traditional arrangement of upstream–downstream rights. A system of priority is established, in principle, to protect the downstream communities from unfair actions of upstream irrigators. Priority is determined by historical precedent, as articulated in customary law, and by changing political power. It is clear from historical records that significant changes in regional allocation have occurred along the major *wadis* in coastal Yemen (e.g., Tesco *et al.,* 1971-1973: 9:5), which may limit the number and size of barrages that a community can build, limit the time period of water appropriation (Making, 1977: 1: 73), or limit the number of times upstream users may water their fields before the flow must be allowed to pass on (Halcrow, 1978: 7: J-6).

Within a community, the allocation of floods in Yemen is based for the most part on a basic Islamic legal principle of watering the higher fields before the lower fields.[6] The prophet Muhammad made this ruling in resolving a dispute over the use of flood flow to irrigate date palms (al-Mawardi, 1960: 180). This need not be interpreted in a literal sense; rather, the field closer to the point of inflow should be watered before that farther away (Maktari, 1971: 4). This is a practical principle applied in customary law throughout the Middle East. Given the nature of flood flow, which flows continuously for a short period of time, the most efficient distribution is according to the natural sequence by gravity. It is easier for the irrigator to control and minimizes water loss in transport.

According to Muhammad, the amount of flood flow that should be applied to a field of palm trees is the depth of two ankles or an amount sufficient to reach the tree trunk. As the 11th-century Islamic jurist al-Mawardi (1960: 181) noted, this measurement was not meant to apply to all crops and to all varieties of land. The underlying principles are that the amount applied be sufficient to water the crop and that it be easy to measure. What is specifically condemned is wasting of water in a geographical area where water is a scarce resource. "The man who holds

[6]For a concise introduction to principles of Islamic water law, see Maktari (1971) or Wilkinson (1978). The study by Caponera (1973) contains many inaccuracies and should be used with caution.

back water from another," said Muhammad (in al-Mawardi, 1960: 183), "will have God's mercy held back from him."

Flood systems in Yemen invariably have well-defined roles for irrigation officials who supervise the distribution of water. During the Rasulid period in the 13th, 14th, and 15th centuries an official was appointed by the state to look after the maintenance of *wadi* irrigation systems in some areas under state control (Serjeant, 1967: 35-36). The Rasulids attempted to centralize control of water allocation along several major *wadis,* a move unparalleled in the Yemeni highlands, in order to extract as much revenue as possible from the populace.

Descriptions of contemporary irrigation officials in seasonal flood systems indicate a wide variety of duties.[7] Maktari (1971:66) described irrigation officials at Lahj in southern Yemen who were appointed by the regional *Sultan.* These officials had authority to decide specific allotments of water turns in a given flood based on their understanding of the available water in the flood and the condition of the plots at the time of the flood. In Wadi Zabid today an irrigation official has responsibilities for mobilizing labor to repair damages, determining the precise times for opening and closing offtake channels, and collecting fees and charges (Tesco *et al.,* 1971-1973: 9: 14). Along Wadi Mawr the irrigation official (*wakil*)[8] supervises the distribution of water, day and night, at the time of the flood. He also assesses the labor duties of the irrigators for maintenance of the barrages and channels. In some cases the *wakil* in Wadi Mawr acts as an agent for a powerful landlord; in other cases he is himself from a powerful family (B. Mitchell *et al.,* 1978: 53).

Disputes over water allocation within communities are generally resolved locally by village *shaykhs* or other important individuals in the community. Water disputes between communities resulting from upstream–downstream tensions have usually been settled by irrigation officials or in Islamic law courts. Islamic judges draw on principles of resource allocation in Islamic law, but there is no clearly defined code of water law. Consequently, most decisions validate traditional customary practice in a region (Halcrow, 1978: 7: J-15; Maktari, 1971: 30; Serjeant, 1967: 34-35, 55-57). As Wilkinson (1978: 91) has observed, Islamic jurists have approached water disputes with the idea that "if the system works leave well alone, so long as it fulfills the basic principles of justice."

Despite the presence of appointed officials and Islamic judges, allocation rights can be alienated from individuals. The political elite did on

[7]Unfortunately, no systematic study of allocative roles has been undertaken for a seasonal flood system in Yemen.

[8]This is a general term in Arabic for an authorized representative and is applied in a variety of contexts.

occasion usurp land and water and justify their actions through bribing judges (Halcrow, 1978: 7: J-3; Makin, 1977: II:75). In Lahj of southern Yemen a 20th-century *Sultan* in the region usurped the water rights of many irrigators (Maktari, 1971: 66). The seasonal flood system is thus one in which an individdual's rights can be alienated due to external factors, specifically communal conflict between upstream and downstream irrigators along the *wadis*.

SPRING FLOW *(GHAYL)*[9]

The term *ghayl* is used in Yemeni Arabic for water flowing from a spring, rather than the spring *per se*. Springs are the dominant sources of irrigation in the Yemeni highlands, accounting for one-third of the total irrigated land area in the Yemen Arab Republic. Use of spring flow for irrigation is documented for pre-Islamic Arabia and no doubt extends back several thousand years. There is little historical evidence however, for state initiation of major spring flow irrigation systems as there is for the exploitation of seasonal floods along the major coastal *wadis* in Yemen.

One of the most impressive spring flow terrace systems is found in the highland valley of al-Ahjur, where about 20 major springs irrigate a valley roughly 5 km wide and 10 km long. Most of the terraces lie in the northern arc of the valley just below the most important line of springs. From an aerial view, these terraces take on the shape of a giant Roman amphitheater. Springs also provide water for domestic supply. Consequently, there are no wells in the valley. Areas in the valley where spring flow does not reach are dry farmed by directed slope runoff into fields.

Spring flow in al-Ahjur is not applied directly to the fields, but is collected in cisterns or dammed-up basins for later distribution. Water is allocated according to a rotation cycle of turns throughout the year. Access to water is linked with land ownership, a practice followed in almost all Islamic legal systems with the major exception of some contexts in the Maliki law of North Africa.[10] The water share is validated by ownership of the land to be watered. This is generally recorded on the land deed, which is essential in clarifying rights in water or land disputes. A man may rent out his turn of water on a temporary basis, but water and land rights cannot be alienated by sale or through inheritance. A water turn in the rotation cycle is

[9]The only previous study of spring flow systems in Yemen is a short survey by Rossi (1953).

[10]In Islamic law water as a resource is considered shared by all Muslims; thus, in theory, water cannot be owened privately. Geertz (1972) argued that private ownership of irrigation water was a theme in Moroccan society, but this is misleading. In many areas of Morocco water rights are attached to the land and individuals cannot dispose of the water right as they will (Bruno, 1913; Roche, 1965; Rosen, 1979). Wilkinson (1977: 105) has suggested that water rights may be separated from land rights when there is disruptive water scarcity.

measured at the cistern according to either a defined time unit or a measure of volume.

The Sanaba spring in al-Ahjur provides an example of the way in which spring flow is distributed. Residents of three villages share flow from the Sanaba, and water is sometimes sold to residents of two other nearby villages. During the day, spring flow is collected in the Sanaba cistern, located just below the spring. At night the flow is transported through a major channel to the cistern of ʻAlit, more than 1 km away. Each cistern is located on land associated with two distinct villages. However, all irrigators in the Sanaba system know each other on a face-to-face basis and there are many cross-cutting kinship links.

The Sanaba cistern has a rotation cycle of 17 days. The smallest unit in the cycle here is the *rubʻ*, a time measurement of 3 hours or one-fourth (*rubʻ*) of a 12-hour day. In practice landowners may receive a half or whole day of flow, depending on how much land they own. In the past each *rubʻ* was measured according to a local shadow scheme, but now a wrist watch is generally used. An individual shareholder may have turns on several days in a given rotation cycle. Thus, access to water is not necessarily at 17-day intervals. Theoretically, the water is for a given plot of land, but the irrigator may apply it to any plot of his land that he wishes. This allows flexibility in choice of crops and in playing with the water market.

The ʻAlit cistern is also based on a rotation cycle of turns, but each turn is measured according to volume. A stick is submerged in the cistern and the number of hand widths (*kufuf*) of the wet portion are counted. A turn is equal to a defined number of hand widths, according to the amount of land owned. Although the irrigator is receiving a fraction of the total volume of the cistern, this can be converted easily into a specific time unit. At both cisterns the irrigators themselves measure the turn; no official is present to oversee the process.

The appropriation, distribution, and application of *ghayl* flow can be illustrated by looking at a turn of 4 *rubʻ* units or 12 hours in the Sanaba cistern. The rate of flow of the Sanaba spring is less than 10 liters per second. The cistern of about 110 m^3 capacity fills in about 4 hours. Local farmers claim that a full cistern is sufficient for watering 25 *lubna* (2700 m^2) of terraced plots. After the cistern has filled, the mud and stone blocking the exit hole are removed by the irrigator. He follows the water through the channel network in order to remove obstacles in channels and direct the flow to the proper plot, which may be as much as 1 km away. When the flow reaches the plot to be irrigated, a mud dam is mounded up in the channel to divert all of the flow into the plot. All plots are bunded, but some consist of internal basins and others of furrows. The type of plot is directly related to the crop being cultivated. Sorghum is grown along furrows; wheat, barley, alfalfa, and mature tree crops are grown in basins. The irrigator is generally watering several plots during a turn and his methods are designed to minimize water loss and spillage. The cistern empties in about 3 hours, at which time it is blocked to fill again. The distribution process is repeated on new plots in the afternoon. By the time of the sunset call to prayer, the Sanaba cistern has emptied and spring flow is directed into another channel to the 'Alit cistern, where it collects at night.

The distinctive characteristic of spring flow distribution in al-Ahjur is that everything is in the hands of the irrigator himself who is responsible for appropriating the water at the cistern. He is not dependent on simultaneous activities by any other individual, nor is he directed by an irrigation official. For each spring system there is a superficial allocative role of an elected official known as the *wakil*. The *wakil* plays a role in coordinating communal cleaning of the cistern, but he has no authority to alter the allocation schedule, makes no decisions over production, and is always one of the irrigators receiving water in the system. For his role in the system he does receive extra water. In practice, he has little to do on a day-to-day basis.

There are relatively few disputes over water rights in al-Ahjur. Irrigators say that the system is fair and that everyone knows exactly what is coming to him. When there is an occasional case of water theft, it is often due to a continuing conflict between individuals or households rather than to a real need for water. Local disputes can be handled effectively by village *shaykhs* and other local mediators according to tribal customary law. Although the same spring may be shared by two or more communities, these are linked by strong kinship and economic ties. There is no upstream-downstream problem in the spring flow systems of al-Ahjur. When a dispute over land takes on regional significance, the case may be submitted to a formal court of Islamic law in the nearby regional center, a rare and expensive occurence. The spring flow system in al-Ahjur is thus one in which the individual's rights to water are clearly defined and protected and where there is no external interference.

ECOLOGICAL CONSTRAINTS OF WATER ALLOCATION

A viable resource allocation strategy must respond to constraints inherent in the resource and involve the application of a technology and the generating of sociopolitical mechanisms for determining access and coordinating water control. Because water is a flowing resource, the most important constraint inherent in any water allocation system is variability in water flow. This is a major concern to irrigators because the ultimate issue is one of water scarcity and its effect on the production system.

Seasonal flood flow in coastal Yemen is intermittent and often unpredictable. In the southern Yemeni town of Hureidah, for example, there were no floods for 3 years before a massive flood in 1963 that inflicted more erosion damage on the field system than the estimated value of the crops (Bujra, 1971: 58). The irrigator in a seasonal flood system must deal with the unpredictable nature of his water supply as a way of life.

Seasonal flood flow contrasts sharply with the spring flow of the highlands. In al-Ahjur flow from springs is continuous and without discernible annual variation. Informants indicated that they were not aware of any springs that had dried up in recent history. Some of the water turns were validated in land deeds of more than a century in age, indicating a stable flow over the years. From year to year the irrigator knows how much water is available at each point in the agricultural cycle. Unlike the flood systems, there is no danger of erosion from spring flow. Water scarcity can only arise due to increased demand rather than declining supply.

The nature of water flow has a direct impact on the options in water control. Because flood flow is seasonal there is a greater demand for labor just before and at the time of the flood season, which may only be 2 or 3 weeks of the year. A communal effort is needed to construct and maintain barrages in a major *wadi* and to remove the silt that accumulates at the barrage and in the channels.[11] The flood flow must be distributed as it arrives, necessitating a flurry of simultaneous activities by numerous irrigators. If the flood is large and violent, it may destroy the barrage or be impossible to control. The technology of the temporary diversion barrage in coastal Yemen is the adaptive response to the nature of seasonal flood flow.

In a spring flow system however, the response to a continuous, unchanging spring flow is to collect it in a cistern so that individual irrigators can handle the entire distribution process on their own. Some springs have an insufficient flow for direct distribution to the plots in the terraces. Collection in a cistern allows the irrigator to control the velocity and amount of flow in a water turn. By collecting night flow in a cistern the problem of irrigating at night is avoided.[12] Irrigation at night on the steep terraced slopes of al-Ahjur would be far more difficult and dangerous than on the relatively flat and broad fields in a flood system. The technology of the cistern is thus an adaptive response to constraints in the nature of highland spring flow.

[11]The accumulation of silt may also raise the level of the fields (Bowen and Albright, 1958:69). In some cases the silt can be dug up in blocks and sold to potters as raw material (Katakura, 1977: 35).

[12]Collection of night flow from a spring into a cistern is common in Yemen (Ingrams, 1936: 57; Rossi, 1953: 352; van der Meulen, 1941: 91); North Africa (Champault, 1969: 102; Hilton-Simpson, 1924:428). Iran (Flower, 1968: 602), and even Peru (Mitchell, 1976: 32).

The nature of water flow also influences options in measuring water turns. The need to "measure" water is primarily a function of water scarcity (Vandermeer, 1971: 157; Wilkinson, 1977: 109). In many Islamic water allocation systems, for example, turns are only established during a dry season when there is not enough water to go around (Lambton, 1937-1939: 664; Roche, 1965: 82).

A distinction is often made in the literature between measurement of turns by time and by a unit of volume. This distinction is important when there is the potential for seasonal variation in a water source, but it is not very relevant for understanding allocation from a uniform source of flow, where time and volume are easily equated. A fixed time unit may be applied to communities in a flood system, but it is rarely applied to the irrigation of individual plots. One reason for this is the difficulty of verifying time measurements during the rush of activities at the time of the flood.

A more important distinction is between flow measured at a defined point of appropriation into a channel and at the point of application to plots. In a flood system it is often difficult to predict how much water will be available for distribution. By measuring water as it arrives at the plots, each irrigator served is assured sufficient water for crop production. In a spring flow system, however, it is more equitable to all the shareholders if water is measured at the cistern, especially since plots to be irrigated by a spring are not necessarily adjacent to each other. Measuring at the cistern is also necessary for the water rental market. Under Islamic law in Yemen, water can only be rented or sold if it is a known amount that does not vary from renter to renter. If water is rented to a man with his fields a kilometer from the cistern, this man will receive far more of the shareholders' water supply than one who has plots close to a cistern. This is due to inevitable loss in water transport. The only valid arrangement to protect the rights of the shareholders is to measure a defined amount at the point of appropriation from the cistern.

Methods of physically controlling water in a channel network appear at first to be similar in flood and spring flow systems. Little more than a simple shovel-scoop is needed to maneuver water in small channels and mound soil in plots. The overall pattern of the channel network, however, has an influence on the techniques of water control. The plots in a flood system are relatively flat and level, constructed in a linear alignment along the sides of the *wadi* or a major offtake channel. There are numerous channels from which water may be simultaneously diverted from the flood. The fields in a spring flow system, by contrast, are steeply terraced. Channels branch out from a stationary source in a dendritic pattern according to variation in the local terrain. Unlike a flood system, there may be several ways of directing water from the source to the plots and the individual irrigator acts alone in the process. Thus, the physical pattern of the distribution networks offers different problems in flood and spring flow systems.

The determination of rights of access to water is also influenced by the nature of water flow. In a system of flood flow there is no guarantee that the water will reach all the potential plots to be irrigated. This places a premium on land in upstream communities and on plots closer to the point of inflow in a channel network. Fields farther away from the inflow are marginal and are not cultivated every year. The differential value of land is reflected in the duties levied in a flood system for communal repairs. Those with prime land pay more than those with marginal land (Bujra, 1971: 57-58; Tesco *et al.,* 1971-1973: 9:15). In a spring flow system, by contrast, an equilibrium can be reached between water supply and cultivated land. All plots served by spring flow are relatively equal in value, regardless of distance from the source. In a spring flow system the precedent of owning land with an attached water right is the validating factor. In a seasonal flood system proximity to flood flow, rather than land ownership, provides the best opportunity to receive irrigation water.

Constraints in the nature of water flow influence mechanisms for economic expansion of an irrigation system. Water supply in a flood system can be increased by improving design and placement of barrages in a *wadi,* a fact that development surveys are quick to point out. However, technological development requires the disruption of traditional allocation schedules and increasing centralization of regional resource use. In the past a major option for expanding flood cultivation has been the use of wells to supplement irrigation (van Beek, 1974: 59). Unfortunately, the uncontrolled sinking of wells and use of hydraulic pumps in coastal Yemen has seriously altered the water table and threatens future agricultural expansion. In a spring flow system it is difficult to increase water supply. Cisterns are traditionally lined with a type of cement plaster. The water does not remain in a cistern long enough for major evaporation to occur. Admittedly, there is major loss in transport through the temporary channels. Yet it would be expensive and disruptive of the traditional system of land tenure to line channels and make them permanent. Spring flow irrigation can be supplemented by control of slope runoff, but such a practice offers marginal economic returns and has been increasingly abandoned in the valley.[13]

The nature of the two systems also influences the strategy of crop production. In the seasonal flood system most of the cultivated crops have to be drought resistant, such as sorghum and millet. Cash crops, such as

[13]An advantage of runoff farming in the past, when basic foodstuffs were not available from the international market, was that more irrigated land could be freed for cultivation of cash crops. Local markets served for the regional distribution of goods from both production systems.

cotton and tobacco, need to be supplemented with other sources of water. Until the introduction of hydraulic pump wells in the coastal region, it was difficult to produce cash crops using flood flow alone. A much greater variety of crops could be cultivated in spring flow systems, such as the major crops of coffee and qat [*Catha edulis*].[14] From the standpoint of the individual farmer, the steady water supply of the springs offered a better opportunity for meeting subsistence needs and producing cash crops than was the case in the coastal flood systems.

WATER SCARCITY AND ALLOCATIVE ROLES

This comparison of *sayl* and *ghayl* systems in Yemen demonstrates the significance of variability in water flow. Understanding the nature of water flow in an irrigation system is a necessary first step for interpreting the meaning of allocative roles in a community. In the coastal flood systems there is a need for supervisory roles in the allocation process to coordinate the distribution of water flow at the time of the flood. In some cases irrigation officials have authority to determine who will receive water from a given flood or supervise the measurement of turns. If the barrage or a major channel is damaged, someone must direct the communal mobilization of labor for repairs. Some of the officials have responsibilities for settling water disputes. Supervisory officials are needed because of the complexity of the allocation process when a large number of irrigators must act simultaneously in a limited period of time, which presents a situation of potential conflict.

In a highland spring system, by contrast, there is little need for a supervisory role in the day-to-day activities of the irrigators because each irrigator is capable of handling the entire sequence from appropriation at the cistern to application in a field plot. Access to the source of flow is not in the hands of other irrigators; thus, there is no potential for upstream-downstream conflict. The only communal activity in allocation is the periodic cleaning of a cistern, but the timing of this is not crucial. The village *shaykh,* who has no formal role in irrigation, may call for a cistern cleaning.

In seasonal flood systems there are a number of formal allocative roles that often include major decisions in the production system. During some historical periods, officials have been appointed by the state for a more centralized control of regional water distribution. An irrigation

[14]Leaves of this tree are chewed as a stimulant in Yemen. It has rapidly become the most lucrative cash crop in many parts of the highlands.

official may be little more than an agent for important landlords. In some cases the economic incentives can be high, including both wages and the potential for bribes.

In spring flow systems the role of irrigation officials is superficial. In al-Ahjur each spring system has an elected official (*wakil*) who is always one of the shareholders in the spring system. He is never the agent of a landlord, nor does he have any decision-making responsibilities in the distribution process or the overall production system. The duties of a *wakil* are not clearly defined in al-Ahjur, but they include calling attention to the need for cleaning the cisterns and verification of water turns in the system. The *wakil* does not oversee the measurement of water turns, although this may be a duty in other systems of spring flow in the Yemeni highlands (Rossi, 1953). Although the *wakil* may take part in the mediation of disputes over water, this is not a formal function. The lack of an authoritative role or a position with major economic rewards for the *wakil* in al-Ahjur is a function of the viability of local tribal customary law for regulating access to water and land. Allocative roles for spring flow systems appear to have more meaning near urban centers, where the duties of irrigation officials merged with those of agents for landlords. There is little or no external threat in al-Ahjur to a community's exploitation of a spring.

Water scarcity may arise in a community for a number of reasons, but fundamentally it is the result of the balance between supply and demand. A classic problem with *wadi* and river systems in the Middle East and throughout the world is upstream-downstream conflict. (The upstream-downstream problem is discussed by Chambers, 1980: 36-37, Lees, 1973: 127-129, Millon, 1962, and Vandermeer, 1971.) This can occur within a local community or between communities. Local political mechanisms, especially the role of the village *shaykh* in Yemeni society, are generally sufficient for mediating local water disputes. But disputes between communities along a continuous water source require political mechanisms that extend beyond a local community. Studies by Wade (1979), Downing (1974:121), and Canfield (1973:30) point to the significance of water scarcity on political organization in a community or region.

ALLOCATION AND TRIBAL POLITICAL ORGANIZATION

This comparison of seasonal flood and highland spring flow systems in Yemen has focused on ecological constraints and their specific impact on the allocation process. A water allocation system, however, is part of a broader cultural framework. Social and political processes cannot be reduced to simple mechanisms appropriate for allocation of natural resources, but they can be more adaptive in one ecological context than in another. This is illustrated by an examination of the viability of tribal political organization for the allocation of flood flow and spring flow systems in Yemen.

In the highland valley of al-Ahjur, as in most of the central and northern highlands where spring flow irrigation is practiced, the irrigators are predominantly tribal. (An overview of the tribal concept in Yemen is provided by Adra, 1982 and Varisco and Adra, in press.) Tribesmen are the backbone of the agricultural labor force, often own their own land, and have relatively little contact with the central government. Traditionally, tribesmen have protected two other social categories in the rural central highlands: a religious elite called *Sada* and a client grouping of service groups called *Bani Khums*. Tribal customary law has been the basis for regulating local disputes between members of all social categories.

Tribal political organization spreads rather than concentrates political power over resources. The tribe, which in Yemen has more of a geographical than a genealogical meaning, is divided into several levels of segments with varying responsibilities. The primary production unit in the highlands is the extended family (*bayt*), which is patriarchal. The largest possible land-holding unit is a minimal lineage called a *dayma,* which consists of several closely related families sharing a house or living otherwise in close economic cooperation. The lineage grouping of the *lahm,* which extends back seven generations (consisting of six literal generations and a real or imagined ancestor as eponym), is the segment that defines the marriage pool for the preferred cross-cousin marriage. In practice, two or more *lahm* groupings make up a village, which has an elected leader or village *shaykh*. The village *shaykh* has administrative duties and serves as a mediator of local disputes. The village *shaykhs* elect a regional tribal *shaykh,* but regional *shaykhs* do not have authority over local resource allocation.

Tribal political organization in Yemen is well suited to the allocation of spring flow because there is no need for decisions above the local community level. All shareholders know each other on a face-to-face basis and all accept the local mediation process and the role of the village *shaykhs.* The total output of the spring is controlled locally, so regional water disputes rarely arise.[15]

The statement that tribal political organization is well suited to the exploitation of highland spring flow does not explain the total distribution

[15]Where several springs combine to form a small watercourse, as in Wadi Dahr, upstream-downstream conflict may occur. In such cases many communities are sharing the same water source.

of tribal authority in Yemen. In the southern highlands, where spring flow systems are also found, the tribe seems never to have been politically powerful. The evolution of tribal organization in Yemen is far more complex than a simple association with a particular type of water resource. It is sufficient to observe, however, that there is nothing inherent in the constraints of spring flow in the Yemeni highlands that placed stress on the political mechanisms of the tribe.

In the coastal area of Yemen, where flood irrigation has been dominant, there are both tribal and nontribal communities along the major *wadis*. The seasonal flood system at Hureidah in southern Yemen was nontribal, with the bulk of the labor force consisting of low-status groups (Bujra, 1971). Access to land and water was controlled by the religious elite of *Sada,* who were influential at that time with the regional sultanate. The tribes had no direct role in the allocation of water for irrigation at Hureidah. Hartley (1961), on the other hand, studied a flood system involving tribal irrigators in southern Yemen. One of Hartley's conclusions, as reported by Millon (1962), was that the tribal political system was unable to cope with the problem of communal mobilization and settlement of upstream-downstream conflict. This suggests that flood systems may place a stress on tribal politics that spring flow systems do not.

In this study of tribal irrigators in canal systems of southern Iraq, Fernea (1970: 207) found that water scarcity seriously disrupted tribal political processes, even though the tribes could sustain a viable irrigation-based agriculture. A major problem in a river canal or seasonal flood system is that the water source invariably extends across tribal boundaries. To the extent that regional decisions over water allocation must be made, the local autonomy of the village *shaykh* and those he represents is threatened. A tribal leader at a higher level does not have the authority to enforce allocation among tribal segments when the problem crosses tribal boundaries. Since there is no mechanism for a unified and directed allocation of the resource, the potential for conflict among communities is great. In a similar argument, Wilkinson (1977: 228) has argued that tribal organization in Oman was fundamentally unsuited to the nature of the irrigation systems. The need for large capital investments in the Omani *qanat* systems and for coordinated exploitation in a regional context could not be met by an emphasis on small, independent-minded tribal landowners.

The nature of tribal political organization makes it difficult to coordinate allocation of a resource that is necessarily shared on a regional basis, because of the competing interests of tribal segments and communities. One solution to this problem is to look outside the tribal system for mediators. Along the major *wadis* in Yemen, regional disputes have often been submitted to Islamic judges who are not aligned with a particular tribe or tribal segment. This is an alternative to a centralized and directed allocation along the *wadis*—an alternative that may bend but not break the authority and independence of tribal segments.

CONCLUSION

This article has demonstrated that constraints of water as a flowing resource limit the options for appropriating, distributing, and applying water in a channel distribution network. Seasonal flood or *sayl* systems spread out along the major *wadis* in coastal Yemen have been compared with small, isolated highland spring or *ghayl* systems. A greater variety of allocative roles has been generated in the flood systems and these roles often have major decision making responsibilities. A major reason for this is the need for coordinating labor at a critical time in control of flood flow. In the spring flow systems, by contrast, each individual irrigator controls the process from appropriation to application without need of activities by other irrigators.

Tribal political organization in Yemen is well adapted to the allocation of spring flow in the highlands, but undergoes stress in the context of coastal flood systems. The important factor is the ability of a local community to control total access to the water resource. Where there is the potential for major upstream-downstream conflict, political decisions must be made outside the local tribal segments. The understanding of tribal dynamics in Yemen, where tribes consist mostly of sedentary agriculturalists, cannot be reduced to differences in water allocation systems. Yet the example of water allocation elucidates how certain tribal political processes may undergo stress and have to be modified or rejected.

One of the implications of this study is the importance of the water allocation system as a conceptual tool for understanding how ecological problems are related to broader cultural concerns. There is a need to define the variables involved in specific allocation systems, examining in detail the environmental context of water sources and the technological options for a community. Irrigation systems must be approached as part of the more general process of resource allocation. By focusing on the allocative roles generated in allocation systems it is possible to see how communities adapt to constraints in the vital resources they exploit.

It is far more important to understand what is involved in the process of water allocation than to subsume specific systems under arbitrary classificatory schemes. As John W. Bennett (1976: 27) has observed, "ultimately, cultural ecology must investigate the question of how power is related to Nature *via* human actions." In traditional Yemeni society water sources have represented one of the major bases for economic success in the agricultural production system. Yet it is clear that "power" has been exercised through different sociopolitical processes in the same general cultural context. It has been argued in this article that understanding differences in allocation systems must begin with recognition of the constraints inherent in the resources to be allocated. Nature does not dictate to those who would use or abuse it, but neither is it passive in the process.

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