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IRRIGATION'S IMPACT ON SOCIETY

editors | THEODORE E. DOWNING and McGUIRE GIBSON

collaborating authors |

Robert McC. Adams
Theodore E. Downing
Ian Farrington
Chris Field
Martin M. Fogel
McGuire Gibson
Eva Hunt
Robert C. Hunt
Wayne Kappel
Susan H. Lees
M. Edward Moseley
James A. Neely
Robert McC. Netting
J. E. Spencer
Brian Spooner
R. Gwinn Vivian

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CHAPTER 10

IRRIGATION AND MOISTURE-SENSITIVE PERIODS
A Zapotec Case

Theodore E. Downing
Bureau of Ethnic Research and Department of Anthropology, University of Arizona

Cultigen growth depends upon appropriate amounts of heat, sunlight, carbon dioxide, soil nutrients, space, time, and moisture. Of these, modification of moisture content has been one of man's more common tools for increasing cultigen yields. Given other adequate inputs, cultigen productivity is optimized when critical amounts of water are applied at the correct time. Herein, I discuss the importance of the amount, source, and timing of water application upon an irrigation system in southern Mexico.[1]

THE OAXACA VALLEY

The Oaxaca Valley lies at 5000 feet, 250 miles southeast of Mexico City. The Río Atoyac traverses the northwestern and southern arms of the Y-shaped valley. The Río Salado, bisecting the southeastern arm, joins the Atoyac near Oaxaca City at the Y's center. Extremely rugged mountains surround the valley, whose northern rim forms the continental divide.

Lying in the rain shadow of the divide, this watershed is a pawn of the Caribbean trade winds. In the dry season, roughly from October to April, stream beds are filled with sand, rocks, and boulders – but no water. Spring trade winds push rain-laden clouds onto the divide; these early clouds break away, bringing sporadic cloudbursts to a few fields in the valley. High on the escarpment slopes, heavy downpours rejuvenate dormant stream beds. Torrents of brown, foaming waters wash rich vegetable matter into the valley.

In July, daily rains punctuate the afternoons. A short period of decreased precipitation in August is followed by heavy rains in September. In early October, the final drizzles dampen the high slopes, and another dry season begins (Figure 10.1).

Rainy seasons are predictable; their magnitudes and starting and ending times are not. The wide range of annual rainfall, varying from 435 to 825 millimeters, makes the average annual rainfall (673 mm.) a meaningless statistic (Schmeider 1930:7). Valley farmers recognize this variability and contrast "wet" with "dry" years, occasionally comparing these with a mythical "average" year that rarely occurs.

Precipitation's random spatial distribution adds more uncertainty to farming. Most rains occur as cloud bursts or severe local thunderstorms which drench a small area – often no larger than a few square kilometers – while adjacent lands remain dry.

Rainfall's varying annual magnitude and uneven spatial distribution combine to make dry farming a risky enterprise. Moreover, these meterological conditions keep stream flows intermittent and of varying volumes, making irrigation from a temporally stable, permanent surface water source physically impossible.

VALLEY IRRIGATION

Flannery, Kirkby, Kirkby, and Williams (1967) outline the valley's long history of irrigation, discerning evidence of irrigation in one form or another since the Early Formative (1200 to 900 B.C.). Further, they distinguish three types of small-scale irrigation: *pot, canal,* and *floodwater. Pot irrigation* involves hand mining of groundwater tapped by means of small, shallow wells. Primitive well digging technology limits this technique to those parts of the valley with relatively high water tables (1.5 to 3.0 meters). *Canal irrigation* is gravity-flow diversion of perennial streams or springs, while the diversion of occasional flash floods during the rainy season is called *floodwater irrigation.*

It is important to realize that contemporary Oaxacan irrigation systems may not show historical continuity with pre-Columbian systems. Many of the canal and floodwater irrigation systems located on the high piedmont were abandoned following the Conquest. This abandonment was the result of a

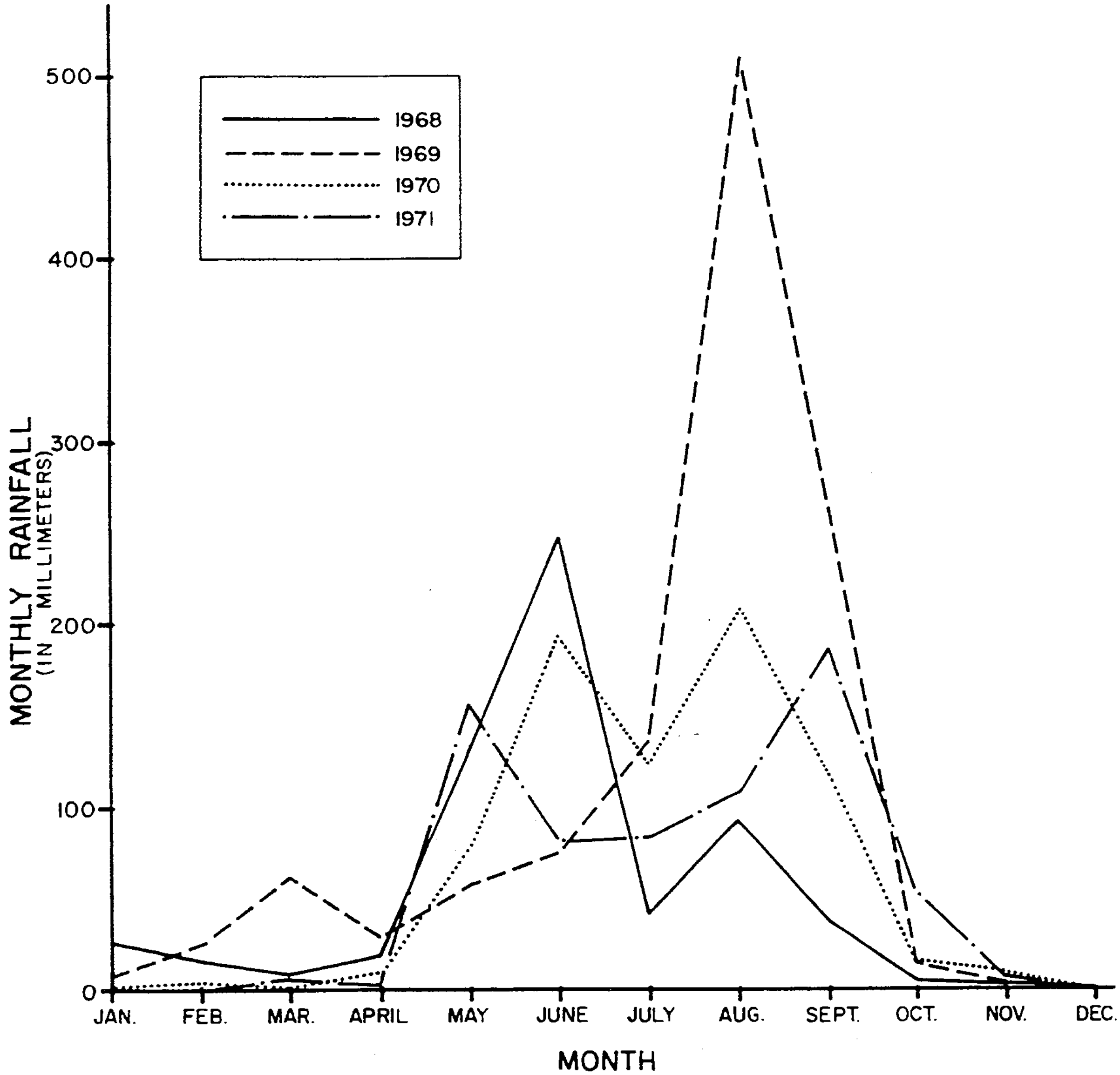

Fig. 10.1 Rainfall in the Tlacolula Valley, 1968-71. Source: gauging station of Cecil Welte, Oficina de Estudios de Humanidad del Valle de Oaxaca, Oaxaca, Mexico.

combination of secondary effects of depopulation, decreased demand for food, and consequent disruption of local level, socio-political organization. The late seventeenth-century population expansion brought resettlement of the high piedmont and re-establishment of some of the irrigation techniques. Presumably, these irrigation systems are similar to preconquest systems, although this assumption demands more careful historical reconstruction than has been previously attempted.

Today, small-scale irrigation systems dot the Oaxaca Valley floor. *Small-scale* implies that the lowest level in the Mexican political hierarchy, the municipality, designs, builds, maintains, and administers the technique. These systems show considerable variation in allocation, administration, and physical size (cf. Lees 1973).

DÍAZ ORDAZ

The town of Díaz Ordaz, also known as Santo Domingo del Valle, operates one of these small-scale irrigation systems. Located in the Tlacolula wing, this nucleated community of 4,000 Zapotec-Spanish-speaking peasants borders the village of Mitla (Parsons 1936).

Resettled during the sixteenth century, Díaz Ordaz's economy was derived from wage labor on a nearby hacienda and herding, supplemented by dry farming and blanket weaving. This economy was altered by the political and economic disruptions in the early twentieth century. The Revolution forced the community to fend for itself through acceptance and a progressive expansion of a combined canal-floodwater irrigation system. Today, Díaz Ordaz ranks as one of the few corn-exporting villages in the Tlacolula arm's high piedmont. Irrigated agriculture is supplemented by wage labor and, to a lesser extent, sheep and goat herding, blanket weaving, and other small crafts.

The village cultivates less than 10 percent of its estimated 50 square kilometers of land. Most village lands are mountainous and barren, suitable for firewood, maguey, or beans. Farming proves most profitable in the small corner of village land on the valley floor. Of this land, approximately 500 hectares are dry farmed, yielding at best one maize crop per year. Other dry farmed crops include maguey, various kinds of beans, squash, and some castor beans.

Only a fraction of Díaz Ordaz's lands are regularly irrigated (±150 hectares). This land might be called the community's "breadbasket." Not only does it offer two crops of maize per year, but also it permits bountiful yields of alfalfa, winter wheat, chick peas, beans, squash, and castor beans.

WATER SOURCES

Farmers divert irrigation water primarily from an intermittent stream called the *Heu Ro'o* ("Large Stream"). Its watershed extends to the crest of the continental divide, encompassing lands of the upstream settlement, San Miguel del Valle.

San Miguel's agricultural practice, the swiddening of beans and potatoes, plays a critical supportive role for crops in Díaz Ordaz. Floodwater used by Díaz Ordaz farmers derives its rich nutrient content from vegetable material cleared by San Miguel farmers from their fields and subsequently carried downstream by erosion. Furthermore, San Miguel's peak work season is different from that of Díaz Ordaz, thereby providing the latter with a cheap source of labor for their more intensive agriculture.

Díaz Ordaz's Zapotecs segregate two kinds of river water (*nis heu*). The first, flash floods (*nis bae'n*), are infrequent and limited to one to six annual flows which last from two to six hours. In the daytime, Zapotecs attempt to predict these flows by observing rainfall patterns in the river's watershed. This prediction often provides irrigators with a two-hour advance warning. At night, only a distinctive rumble of flowing, turbulent water forewarns floodwater's arrival.

Day or night, when floodwater arrives, all social activities are secondary to channeling this highly valued water onto fields. For instance, I witnessed the local elementary school director lose his audience during graduation exercises. Floodwater arrived during his lengthy, prepared speech. Impatient fathers rolled up their pant legs, and at the first pause in the address, excused themselves and ran to get shovels. Manning their sluice gates had precedence over this otherwise important occasion.

The second category, clear water (*nis nia*), includes all river flow that is not floodwater. Clear water occurs intermittently throughout the rainy season – originating as either precipitation runoff or groundwater seepage in the river bed.[2]

Zapotecs distinguish four parts of a canal[3] (Figure 10.2). The first of these, *ru'u tom* (literally, "drinking mouth"), might best be glossed "diversion dam." Six diversion dams take water from the Large Stream. These dams stand 2 meters in height and 20+ meters in width; they are constructed of logs spaced every meter, interlaced with saplings, rock, and earth fill. Half the dams rest upon concrete footings, which were recently built to retard the persistent undercutting problem.

During floodwater peaks, these dams channel water down their main canals. Each irrigator along a canal regulates the amount of water entering his fields by means of a breach in the bank plugged by a large rock. As irrigators close their sluice gates, back pressure builds up and combines with the massive force of flooding and undercutting. The diversion structure collapses. Floodwater rushes downstream and is again diverted by the next dam. This process continues until either the flood is exhausted or all fields are irrigated.

In addition to diverting floodwater, the diversion dams impound "clear water" during periods of minimal flow. In this case, the main canal sluice gate is closed until the small reservoir behind the dam reaches its capacity. Then, the gate is opened and one "tank" or *reigo* released.

The *ja'a tom* is that stretch at the canal's head located between the main sluice gate and the first irrigated parcel. Like the diversion dam, it is subject to heavy silting and requires periodic maintenance.

The remaining length of the canal is subdivided into segments called *bias* plus a proper name. These segments have no operational significance in the

They assign obligatory work loads to all irrigators within the section, collect a small tax, and distribute water allocated to their section. For these duties the officials receive no compensation and little praise.

Work loads (*tareas*) and taxes (*impuestos*) are distributed among water users proportionate to the amount of maize which potentially could be seeded on their parcels at one planting.[5] Each section along a canal contributes equal shares either in labor, materials, or more rarely, cash, for the upkeep of the canal head (*ja'a tom*), and the diversion dam. Major repairs to aqueducts or to breaks in the main canal are borne by those downstream from the damage. In contrast, work within the section is not done cooperatively. Section officials mark off lengths of the canal to be cleaned and assign them to different irrigators. These irrigators or their hired labor must clean their assigned portions by a certain date, but do not necessarily work together.

There is considerable variation in water allocation among sections. Within some sections the total allotment of water is divided equally by the users. Others apportion water according to the surface area of land held by each irrigator. Sections receive allocations of water from the next level in the irrigation hierarchy, the *síndico.*

SÍNDICO

The síndico is a local authority who is in charge of water distribution to the 70+ irrigation sections (*tramos*). Water allocation is not the síndico's primary duty. As the second highest official in the municipality's local level political system (known to Meso-American scholars as the civil-religious hierarchy), the síndico is the jural representative of the state government at the local level. He shares responsibility with the local judges in the adjudication of all intra-village disputes, and holds sole responsibility for referring all cases of capital offenses and "civil disobedience" to the district courts. The vague definition of this latter offense provides the síndico with his power. Extreme disagreement of an irrigator with others may be interpreted by the síndico as endangering community harmony. Civil disobedience, which may be interpreted as extreme counter revolutionary activity may lead to heavy legal expenses and possible lengthy incarceration. Villagers are aware of this sanction although the síndico seldom exercises it. This power would lead to a potentially dictatorial situation if it were not for the obligatory and limited term of office. Like other municipal officials, the síndico is chosen by consensus and serves an economically and psychologically punishing three-year term. Like the tramo officials, he receives neither compensation nor praise.

Criteria for selection of síndico does not include water administration abilities or irrigation experience. The past two síndicos in Díaz Ordaz have considered water administration a nuisance and readily admitted they poorly understood the irrigation system beyond their own duties. These duties are to 1) inspect the diversion dams and head sections and decide when they are in need of repair, 2) mediate disputes not resolved by section (tramo) officials, and 3) allocate water among sections. Understanding how water is allocated requires considering temporal changes in the availability of water.

TIME, WATER AND RIGHTS

Western European law distinguishes three principal doctrines for the distribution of surface water rights. Under riparian doctrine, owners of land located adjacent to a water source have rights to it whenever they wish. This doctrine is modified under the condition called "correlative rights" wherein these prime users should exercise some consideration of others; e.g., downstream users' rights should not be completely usurped by upstream users. Finally, under the prior appropriation doctrine, priorities to water are determined by historical precedence or administrative fiat rather than by proximity of an owner's land to the source. Kazmann (1965:122) and others note that the riparian doctrine corresponds with areas of excess water, like the eastern United States, and the prior appropriation doctrine corresponds with water-deficient regions, like the southwestern United States.

The Mexican state follows the doctrine of prior appropriation. Díaz Ordaz Zapotecs selectively ignore the doctrine and alternate between riparian and prior appropriation rights within the same year.

Ostensibly, shifting from riparian to prior appropriation rights is accomplished by a stroke of the síndico's pen; he declares the municipality water under rule (*en regla*). This action brings all irrigators under his authority by activating the previously described hierarchy (Figure 10.3). While water is under rule, the síndico maintains a water distribution list. Sections (tramos) are apportioned water on a "first come – first served" basis. Each receives a fixed number of hours or impoundments, varying with the type of appropriative methods the síndico feels most equitable. After each irrigation, a section may put its name on the list for an additional turn.

This period of prior appropriation ends when either (1) the river goes dry or, less commonly, (2) the first floodwater crashes down the escarpment – whichever occurs first. Thereafter, the riparian doctrine prevails until the síndico again declares water "under rule."

Timing of these shifts from one doctrine to the other would appear to confirm the excess-scarcity hypothesis used to explain the geographical distribution of the doctrines in the United States. However, the correlation between a physical fact (water quantity) and a cultural fact (the allocation system) demands the interlinking of variables explicable at the level of observable social behavior.

How does the switch from riparian to appropriative rights occur? Closer examination reveals that the síndico's activation of the prior appropriation doctrine rests, in part, upon a social-psychological mechanism: an individual's tolerance to stress. During the riparian period while rainfall and stream flow are high, conflicts over water rights are low. As precipitation and stream flow decrease, the frequency and ardor of conflicts over water rise. These conflicts are taken directly to the síndico, because the administrative water hierarchy is inoperative. He resolves these disputes in his capacity as an authority in the local level political system, not as an irrigation system administrator. Finally, the síndico grows weary and overtaxed with water disputes. Without warning, he declares the system under rule. This means that no one, including the síndico, can anticipate when prior appropriation begins.

Once prior appropriation is established, conflicts between irrigators subside. This decrease may be attributed to structural change in the adjudicative processes. A single individual, the síndico, mediates disputes under riparian rules. Under appropriation, a three-level hierarchy of mediators buffers disputes before they reach the síndico. If those conflicts unresolved by the lower level in the hierarchy reach the síndico, they are considered much more serious by the officials and community than disputes occurring under riparian periods. The former conflicts are those that could not be resolved by peers in the fields or by the tramo officials. The síndico now has public support to exercise his most coercive power – shifting the dispute to district court under the guise of a "civil disorder." Thus, the ultimate power for water regulation lies outside the local level. This power is based upon the síndico's dual role as local-level water administrator and civil official in the Mexican state.

Conflicts between sections (tramos) are rare because the criteria for membership prevents sections from becoming corporate groups. Partible inheritance scatters most households' fields, meaning that many households are members of several sections. Just as a kindred system creates cross-cutting links between individual kinsmen, making corporate kinship alliances logically impossible, so multiple section membership creates conflicts of interests between members. Informants provided this explanation when asked why no inter-section conflicts could be recalled.

This structure explains why conflicts subside under the prior appropriation doctrine, but fails to account for the flare-up of conflicts at the end of the rainy season. The excess-scarcity hypothesis also lacks correspondence with the data. If scarce precipitation and stream flow lead to frequent conflicts, then disputes should be high during the beginning of the rainy season when these same hydrologic conditions

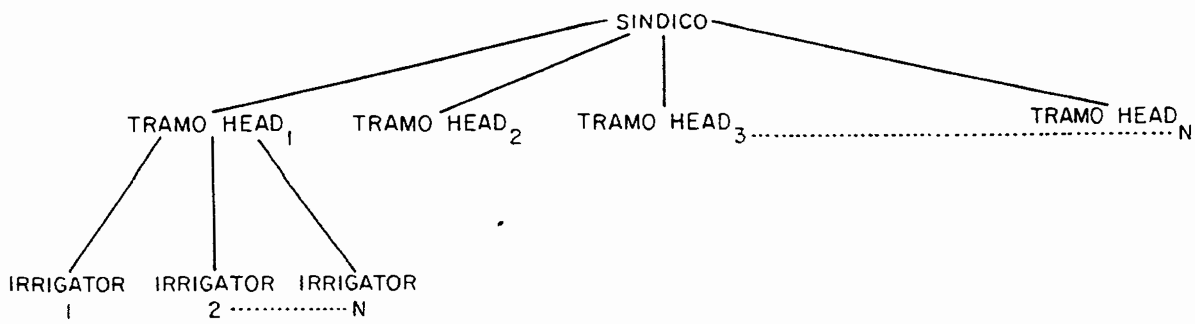

Fig. 10.3 Present social organization of water allocation (1970).

hold. That is, the "low precipitation = scarce water = more conflicts = more social control" explanation breaks down, because the system is under riparian rights at the beginning of rains, and under appropriation rights at their end, while precipitation is equally sparse at both extremes. The key to this puzzle lies in defining water scarcity in terms of the moisture needs of cultigens rather than in terms of absolute water quantity.

MOISTURE-SENSITIVE PERIODS

In 1899, Brounov introduced the concept of a plant's critical period, meaning that part of a plant's developmental cycle most sensitive to meteorological events. Salter and Goode (1967) refined Brounov's work by introducing the concept of a plant's moisture-sensitive period (MSP), referring to that point or points in a plant's developmental cycle at which it is most sensitive to either excess or scarce moisture conditions. They review the literature for several hundred cultigens and demonstrate that these MSP's are crop specific.

Agronomists' research on the moisture-sensitive period of maize is of direct interest in this ethnographic case. The MSP of maize has been defined using observations of its differential yields under conditions of a) irrigation application experiments, b) soil drought response, and c) statistical studies of its response under different precipitation patterns. Using irrigation application experiments, Cordner (1942) discovered that irrigation before silking increases the plant's size, but not its yield; irrigation after this point brings about increasing yields. Howe and Rhoades (1955:98) found that "the yield of plants irrigated just before tasseling and during silking (144 bu./acre) was almost as high as, and not significantly different from, plants irrigated throughout the season (153 bu./acre)." Their control, unirrigated maize, yielded only 69 bu./acre, while a single irrigation in late tasseling yielded 101 bu./acre.

Robins and Domingo (1953) and Denmead and Shaw (1960) used an alternate strategy for determining maize's response to soil moisture. They allowed plants to deplete the moisture to a permanent wilting percentage at various stages of its development. They found that such deficient moisture conditions maintained for two to three days during tasseling and silking reduced yields 22 percent, while six to eight days of moisture deficiency reduced them 50 percent. Depletion of water during other phases of the plant's development failed to show such dramatic effects. Statistical studies of rainfall's effect upon maize production corroborated these experimental findings.

Salter and Goode (1967:32) summarize over twenty-five such controlled experiments:

> The results of both experimental and statistical studies thus suggest that soil mositure conditions during the period of flowering and early grain formation are particularly critical in determining grain yield in maize. They are reflected in many recommendations made over a number of years to irrigate the crop during this period.

IRRIGATION'S MULTIPLE FUNCTIONS

This information on the moisture-sensitive period of maize permits further specification of water's place in Díaz Ordaz agriculture (Figure 10.4). Floodwater irrigation lengthens the annual growing season by placing a small, yet crucial, amount of water on the fields four to eight weeks ahead of the onset of rainfall adequate for dry farming. Given a four-month growing season for maize, the MSP for the first irrigated crop falls during the peak of the rainy season. This crop's irrigation needs are minimal, and rainfall is sufficient. However, limited irrigation does occur during this period. The variation in rainfall distribution leaves some fields drier than farmers feel necessary, and they may irrigate (under riparian rights). However, such irrigation involves risks. If a heavy downpour succeeds the irrigation, excessive saturation of the fields can cause erosion and crop damage. Due to these uncertainties, most informants choose not to irrigate.

The extended growing season also makes possible a second crop; its planting *immediately* follows the first harvest. Adequate rainfall during the planting period assures the second crop's germination. Heavy rainfall during the pre-tasseling period produces substantial plant foliage. Indirectly, the correspondence of heavy rainfall with early plant growth stimulates positive feedback to agricultural production. The leafage provides draft oxen with fodder during the dry winter months. Therefore, the well-fed oxen are capable of constant harrowing during the period before spring planting. Some farmers consider the second crop a "moderate success" if it yields only fodder for the winter.

The second crop's moisture-sensitive period occurs during the time of decreasing rainfall (about late October), and creates problems distinct from those for the earlier crop. Irrigation during this MSP differentiates those farmers harvesting only fodder from those harvesting fodder with grain. Unlike the situation in other periods, water now becomes a factor limiting productivity. Provided that the earlier crop meets a farmer's subsistence needs, the second crop is converted into the few amenities enjoyed by subsistence farmers.

Given the uncertainties of receiving rainfall and irrigation water during this period, and potential dangers from the onset of frost, some farmers opt for less moisture-sensitive and frost-resistant crops like alfalfa, chick peas, and wheat. These command a lower market price, but are less risky if water proves scarce.

With these physical constraints, the increase in water disputes during the second crop's moisture-sensitive period seems understandable. Water equals grain and Zapotecs know it. In turn, the low frequency of water-related disputes during the beginning of the rainy season seems reasonable. Water would be scarce during the earlier MSP if fodder were needed (i.e., to increase the plant's foliage), but alternative sources of fodder reduce this necessity.

The high frequency of disputes seems explicable given this modification of the water-scarcity hypothesis to take into account the specific water needs of maize. But the cultural response (the specific manner of water allocation) cannot be so easily linked to hydrologic conditions.

Activation of the prior appropriation doctrine and the administrative hierarchy echoes a theme of equality common to other sectors of Zapotec culture (for example, in equal inheritance rights of all heirs and equal civil obligations of family heads). The overall effect of the water distribution system prevents an individual from gaining an advantage over his neighbors. Likewise, the administrative structure with its rotation of officials makes it impossible for any one individual to take advantage of his administrative authority for any length of time. Thus, the structure of the administrative system proves consistent with the method of allocation itself.[6]

IMPLICATIONS

This analysis has attempted to clarify the key characteristics of an irrigation system, but the painfully small sample impairs generalization. Nevertheless, most case studies implicitly hypothesize some model, and my discussion is no exception. I suggest that water scarcity must be defined in terms of the availability of water to plants during their moisture-sensitive periods. In drier climates, irrigation proves

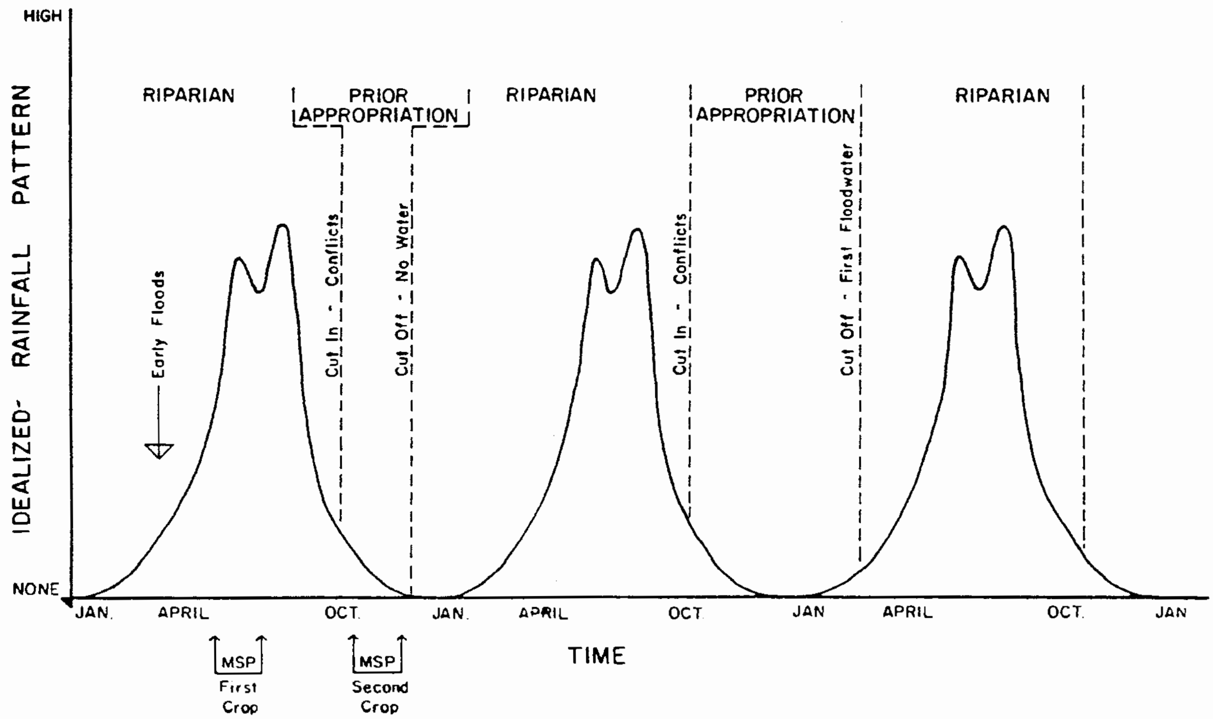

Fig. 10.4 Water shifting from riparian to prior appropriation distribution.

either an alternative or a supplement to rainfall. In determining the water scarcity of a system, the relative importance of these two sources must be considered. Hopefully, some day, rainfall and stream flow models from hydrology will be adapted to a discussion of this anthropological problem.

Assuming climatic conditions in which the entire planting of a society's main crop must take place at approximately the same time, I hypothesize the water scarcity during the moisture-sensitive period forces some kind of rigid social organization to allocate water. Whether the allocation favors equal or discriminatory distribution depends upon cultural factors, not water availability.

This conclusion reflects that of others in this volume. Irrigation is a phenomenon more complex than such crude nursery facts as that water evaporates and flows downhill. The failure of anthropological theory to link types of social organization with irrigation systems may be traced to its current inability to refine both sides of the irrigation-society equation. Although anthropologists arduously typologize and theorize about society, their work on irrigation lacks this maturity. Until irrigation systems are as adequately discriminated as social systems, theories relating them remain as trustworthy as a surgeon with poor eyesight.

NOTES

[1] I wish to acknowledge the invaluable assistance of Cecil Welte, Director of the Oficina de Estudios de Humanidad del Valle de Oaxaca, who provided the rainfall data for the Tlacolula wing used in Figure 10.1, and to McGuire Gibson, Wayne Kappel, Chester Kisiel, and Dianne Wightman for their comments and revisions of earlier versions of this paper.

[2] In addition to floodwater and clear water, Díaz Ordaz Zapotecs exploit groundwater, using a recent technological innovation which they call an "underground dam" (*presa submerida*). This device is an unusual variation of a *kanat*. For a description of a real kanat, see Neely's paper in this volume. Informants claim this device was introduced in 1932 by the well-known Mexican engineer, Jorge Tamayo.

[3] No Spanish word for "canal" is used in this village except by a few village farmers who worked as *braceros* in the United States.

[4] This paragraph refers to a canal's longitudinal extension. Canals are moved several meters latitudinally up or downhill on a "trial and error" basis until the appropriate topographic location is reached. This relocation was still occurring during my field work in 1970.

[5] This measure roughly approximates field size (Downing, 1973).

[6] Explication of this theme of equality falls outside the scope of this paper, but is critical to any explanation of Mesoamerican social structure.

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