The Relationship between Power and Position in Irrigation Networks in Egypt's Fayoum Oasis*

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Abstract

In 10 irrigation networks in Egypt's Fayoum Oasis, farmers rated the power of every farmer in the network to instigate others to engage in canal maintenance. Farmers' ratings were submitted to cultural consensus analysis to obtain an aggregate estimate of each farmer's power. Across all ten networks, there is a consistently negative relationship between power and irrigation network rank position, such that upstream farmers are perceived to be more powerful than downstream farmers. This relationship is strong in irrigation networks that do not rely on pump water lifting technology but weak in irrigation networks that rely on pumps to deliver water to farmers' fields. These results highlight the impact of technology on social structure.

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Knowledge of the distribution of power and decision-making authority in agricultural systems is required for a full understanding of economic and social inequality, the evolution of agrarian societies, and development. This paper addresses this important issue. Using data from structured interviews with several hundred irrigators in Egypt's Fayoum Oasis, we examine the relationship between irrigators' power to instigate crucial canal maintenance work and their positions in an irrigation network. Furthermore, we analyze the differences in this relationship between irrigation networks with different water delivery technologies to explore the impact of technology on social structure.

SETTING

The Fayoum Oasis is a natural depression located on the far eastern edge of the Sahara Desert in Egypt's Western Desert, 70 kilometers southwest of Cairo. The Fayoum is sometimes called a "semi oasis" because it receives water both from naturally occurring springs and from the Bahr Yusef Canal, which is directly linked to the Nile River. The Fayoum Depression is over 12,000 km^2 in area. Nile waters enter the Fayoum in the east at an elevation of 30 meters above sea level and eventually flow through canals and drainage ditches until they empty into Birka [Lake] Qarun at an elevation of 45 meters below sea level.

The Fayoum's proximity to the Nile and the longstanding hydraulic commerce with its water has created an ecological setting distinct from other depressions in Egypt's Western Desert. The declivity of the Fayoum from east to west allows for the possibility of gravity-fed irrigation. The history of the Fayoum demonstrates that during the last two thousand years a variety of administrations have coordinated depression-wide irrigation efforts with success rates which seem to hinge upon the centralized control of irrigation (Price 1993).

In the Fayoum, as in other gravity-fed irrigation systems (see Price 1995), there is a detectable trans-depression pattern in which up-canal villages fare better than down-canal villages during times of water scarcities or neglect of canal maintenance. There are four distinct methods of delivering irrigation water to the fields of the Fayoum: direct gravity flow, undershot saqqiya waterwheels, saqqiya waterwheels powered by water buffalo or donkey, and portable gasoline-powered pumps (Mehanna, Hunnington, and Anronius 1984). Gravity-fed irrigation simply means that water is delivered to farmers' fields without the use of any lifting device. Undershot waterwheels (saqqiya) range in diameter from two to four meters and are flow-driven waterwheels which lift water up from main supply canals and deliver it to secondary feeder-canals. The animal-driven saqqiya (or norea) is most commonly an approximately two meter in diameter waterwheel that is driven by a waterbuffalo and lifts the irrigation water up from secondary canals to nearby fields. The most common pumps are small, portable internal combustion pumps which irrigators move to primary canal area as needed. The distribution of water delivery methods in the Fayoum is as follows: 30% gravity alone, 20% undershot waterwheels, 35% animal-driven saqqiya, and 15% internal combustion pumps (Price 1993).

THE FLOW OF POWER

The rules governing the delineation of responsibility for water and water use in the Fayoum are clear and change as water flows through the Fayoum. The responsibility for water flowing in the main irrigation canals lies with the Egyptian Ministry of Irrigation. Once irrigation water enters the localized smaller canals its distribution becomes the responsibility of local water-share networks, or groups, known as munawaba.

Among the non-pump-reliant networks (i.e., those using gravity, undershot waterwheels, and saqqiya) the munawaba oversees the allocation of specific irrigation timeshares which are inalienably tied to land ownership. Pump irrigators are not usually tied to schedules, and the timing of irrigation in pump-reliant networks is often determined by the availability of a pump and individual irrigators' perceptions of their irrigation needs.

Fayoumi irrigators have institutionalized a practice known as magrur, which attempts to compensate distant irrigators for the amount of water which is lost as water flows from the primary canals to the field destinations. Magrur refers to an extra time allotment which is added to an irrigator's time-share. This extra time is estimated by floating a piece of straw from the canal source to the destination. The time needed for this straw to reach the destination is then added on to an irrigator's allotment of irrigation time.

The institution of magrur recognizes the power of--and attempts to compensate for--conveyance loss, the basic infrastructural design feature of gravity-fed irrigation systems that favors up-canal irrigators. Despite attempts to compensate distant irrigators, some significant degree of water loss still occurs (Price 1993).

In this paper we examine whether position in an irrigation network and power to instigate canal maintenance are associated, even with the institution of magrur. We also investigate whether this relationship varies for irrigation networks with different water delivery technologies.

METHOD

All the farmers in 10 different irrigation networks participated in the study. The number of farmers in each network ranged from 13 to 26 (see Table 1).

The first author conducted systematic oral interviews in Arabic with every farmer in each irrigation network. During the interview, farmers were asked to rate on a 5 point scale the ability of each of the individual irrigators within their irrigation network (including themselves) to get other irrigators to engage in canal maintenance work. We refer to this perceived ability throughout the rest of the paper as farmers' "power." The labels for the 5 point scale were "no power," "a little power," "some power," "moderate power," and "much power." The list of names of irrigators was randomized for each network. Our measurement of power parallels that of Freeman, Azadi, and Lowdermilk (1982) who asked farmers to rate how much power specific irrigators had in "matters of mobilizing other farmers to clear and maintain the commonly held water channels" (p. 71).

RESULTS

Farmers' ratings were submitted to cultural consensus analysis for each irrigation network separately in order to determine farmers' level of agreement about individual farmers' power and obtain an aggregate estimate of each farmer's power (Batchelder and Romney 1988, Romney, Batchelder, and Weller 1987, Romney, Weller, and Batchelder 1986). Cultural consensus analysis involves first constructing an interinformant agreement correlation matrix (in this case, the correlations between farmers' ratings for each irrigation network) and then factoring it with minimum residual factor analysis. If this procedure yields a single factor solution (i.e., the first factor's eigenvalue is several (approximately 3) times larger than the second factor's eigenvalue), then the agreement data fit the consensus model. Informants' loadings on the first factor represent their cultural competences, or amounts of agreement with others for their responses to the systematic interview questions. For the data to fit the cultural consensus model, all informants' competences should also be positive except for sampling variation. Thus, if informants' responses fit the cultural consensus model, then informants share knowledge about the "culturally correct" answers to the systematic interview questions.

The "culturally correct" answers to the systematic interview questions are estimated by weighting each informant's responses by his competence and then averaging these weighted responses. In this study, these estimated answer keys indicate the consensus evaluation of individual farmers' power in each irrigation network. We report here the results from the ordinal/interval scale <u>data</u> model for consensus analysis (Romney, Batchelder, and Weller 1987) as implemented in ANTHROPAC (Borgatti 1992). Seven of the ten rating data sets show better fits to the ordinal/interval scale data model than to the formal process model for multiple choice data (Romney, Weller, and Batchelder 1986). To control for individual differences in the use of the rating scale, we standardized each farmer's ratings before analysis (cf. Weller and Romney 1988, p. 42).

The consensus analysis results appear in Table 1. Farmers' responses in four irrigation networks (Keman Faris 1, Qasr Al-Basl 2, Shakshouk, and Sanhour 1) demonstrate good fits to the cultural consensus model, while farmers' power ratings in the six other irrigation networks display marginal fits to the consensus model. None of the negative competences observed are extremely negative (most were greater than -.15). Overall, farmers in an irrigation network agree moderately with each other about the power of the irrigators in their network.

To examine our main research question, we computed the Pearson correlation between farmers' consensus power ratings and their rank positions in the irrigation network (based on the distances in the secondary feeder canal between each irrigator's plot and the main supply canal) for each network (see Table 1). In every network, the relationship is negative (upstream irrigators are perceived to be more powerful than downstream irrigators), but range in magnitude from -.09 to -.90. We inspected the scatterplots between irrigation rank position and power for each data set and all show linear relationships. Across the ten irrigation networks, the mean Pearson correlation obtained from Fisher's $\underline{z}$-transformations and weighting by the degrees of freedom ($\underline{N}$ of farmers in each network - 3) is -.64. The cumulative $\underline{Z}$ score that assesses the statistical significance of the ten correlations as a set, computed by Stouffer's method of aggregation (Mosteller and Bush 1954), is -8.67. The consensus power ratings and simple mean power ratings for irrigators in each irrigation network are very similar (the $\underline{r}$'s range between .88 and .99 across the ten networks).

We performed further calculations (see Rosenthal, 1991) to test for the statistical significance of the <u>variation</u> among the ten irrigation rank position x power correlations and for differences in these associations between different types of irrigation networks. There is significant variation among the ten irrigation rank position x power correlations, $\underline{X}^2$ (9) = 25.22, $\underline{p} < .005$. After the difference between the pump and non-pump irrigation networks is accounted for, however, there no longer is significant variation in the irrigation rank position - power association, $\underline{X}^2$ (8) = 7.94, $\underline{p} > .30$. The weighted mean $\underline{r}$ for the three pump irrigation networks is -.26, $\underline{Z}$ = -1.74 (ns), whereas the weighted mean $\underline{r}$ for the seven non-pump irrigation networks is -.74, $\underline{Z}$ = -9.22. The association between irrigation rank position and power is substantially and significantly stronger in non-pump irrigation networks than in pump irrigation networks, point biserial $\underline{r}$ = .73 and $\underline{Z}$ = 4.16. Furthermore, the weighted mean $\underline{r}$'s for the undershot and saqiya irrigation networks are virtually identical (undershot mean $\underline{r}$ = -.77, $\underline{Z}$ = -8.36; saqiya mean $\underline{r}$ = -.78, $\underline{Z}$ = -4.69).

DISCUSSION

In the ten irrigation networks we studied in Egypt's Fayoum oasis, farmers in each network generally displayed moderate agreement about the relative power of farmers in the network to influence other farmers to engage in canal maintenance work. In every network, aggregate estimates of individual farmers' power derived from cultural consensus analysis are negatively correlated with their irrigation rank position, such that upstream farmers are considered more powerful than downstream farmers. However, the strength of this relationship is much greater in irrigation networks with non-pump gravity-fed water lifting technology than in networks with pump water lifting technology. Indeed, the power - irrigation rank position relationship is strong in the non-pump networks (mean $\underline{r} = -.74$) but mild in the pump networks (mean $\underline{r} = -.26$).

With our cross-sectional data, it is difficult to make inferences about the causal ordering between irrigation network rank position and power. It seems probable, however, that upstream positions confer greater power than downstream positions and that the distribution of power is not to due to farmers who are "powerful" prior to inhabiting the lands irrigated by a canal settling in upstream positions. If the latter scenario were true, the power - irrigation rank position relationship would not be weak (as it is in the pump networks) in any of the networks.

Our results suggest that pump water delivery technology dramatically weakens the relationship between power and irrigation rank position. Pumps seem to dislodge irrigation rank position as the basis for the distribution of power. However, our findings do not indicate the factors that might underlie the distribution of power in pump irrigation networks. Although irrigators' ratings in one pump network display a poor fit to the consensus model (Qasr Al-Basl 1), possibly indicating an equitable or undifferentiated distribution of power, the other pump networks are not marked by low agreement. In addition, farmers' responses in a few of the non-pump irrigation networks also display quite marginal fits to the consensus model.

Pumps also have the potential to undermine rapidly the sustainability of Fayoum irrigation systems in two ways (Price 1993). First, maintenance neglect may drastically increase with the adoption of pumps. The amount of water irrigators take in pump networks essentially is not influenced by the canal's condition except when canal maintenance has been extremely neglected for some time. It is also possible that the weak relationship between power and irrigation rank position in pump networks reflects the decreased prominence of canal maintenance in these networks. Second, many farmers in pump groups seem to be over-watering their lands and are thus dangerously increasing the salinity of their soils.

In effect, pumps remove the functional constraint that prevents farmers both from over-watering and neglecting the maintenance of their irrigation systems. This balance weighing issues of stratification, sustainability, and intensification is key to any evolutionary consideration of technology's impact on society. Cross-culturally, in many instances of technological innovation the most common effect is intensified stratification and decreased sustainability (cf. Harris 1977; Johnson and Earle 1987). The Fayoum case is interesting in that it provides us with a instance where--at least in the short term--the adoption of a new technology seems to lead towards a different (possibly equitable) distribution of power, at least in terms of ability to instigate canal maintenance. Unfortunately, the trend of pump groups tending to over-irrigate crops seems to indicate that this new technology could well be decreasing the long-term sustainability of this system.

Future research should examine the power - irrigation rank position with quasi-experimental studies in which irrigation networks that remain dependent on non-pump technology are compared with networks that switch from non-pump to pump technology. If the type of water delivery technology has a direct influence on the power - irrigation rank position relationship, then the results from such a study should show that: 1) the power - irrigation rank position association weakens after the introduction of pump technology in those networks that adopt it, and 2) the association remains essentially the same over time in "control" networks which retain non-pump technologies. Further research should also examine whether the relationship between power and irrigation network position observed in the Fayoum is present among irrigators in other societies.

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TABLE 1. CONSENSUS ANALYSIS AND CORRELATIONAL RESULTS FOR THE TEN IRRIGATION NETWORKS

Irrigation Network	Keman Faris 1	Keman Faris 2
Irrigation technology	Undershot	Undershot
N of farmers	19	17
Eigenvalue ratio	4.21	1.93
Number of negative competences	0	1
Mean (s.d.) competence	.62 (.17)	.50 (.25)
r irrig. rank position x power	-.62	-.71

Irrigation Network	Naqalifa 1	Naqalifa 2
Irrigation technology	Undershot	Undershot
N of farmers	17	26
Eigenvalue ratio	2.38	2.47
Number of negative competences	2	2
Mean (s.d.) competence	.43 (.34)	.44 (.23)
r irrig. rank position x power	-.90	-.78

Irrigation Network	Qasr Al-Basl 1	Qasr Al-Basl 2
Irrigation technology	Pump	Pump
N of farmers	20	14
Eigenvalue ratio	1.48	4.36
Number of negative competences	3	0
Mean (s.d.) competence	.33 (.33)	.70 (.13)
r irrig. rank position x power	-.09	-.20

Irrigation Network	Qasr Al-Basl 3	Shakshouk
Irrigation technology	Pump	Saqiya
N of farmers	14	13
Eigenvalue ratio	2.47	5.30
Number of negative competences	1	0
Mean (s.d.) competence	.50 (.28)	.66 (.16)
r irrig. rank position x power	-.53	-.87

Irrigation Network	Sanhour 1	Sanhour 2
Irrigation technology	Saqiya	Gravity
N of farmers	13	13
Eigenvalue ratio	4.29	2.73
Number of negative competences	0	2
Mean (s.d.) competence	.64 (.20)	.48 (.38)
r irrig. rank position x power	-.65	-.32