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CT 4410 Irrigation & Drainage Exam

Understanding water delivery performance in a large-scale irrigation system in Peru

The article and questions were discussed with

We decided that everyone would write his own report based on the discussion.

1. Why would "most large-scale irrigation systems in the world" be considered to have "low degrees of management performance"?

An important reason why most large scale irrigation systems in the world are considered to have low degrees of management performance follows from the image people might have about layered management and the efficiency of this management layers. Large scale irrigation systems do have different layers. As in the Peruvian system often primary, secondary and tertiary canals and units are present. When all these "irrigation layers" have different management this might cause long management gatherings (in Dutch: "poldering") resulting in no or late decisions resulting in low management performance.

An illustration on the statement that was made in the introduction of Vos' article is the paradox between growing demand for adequate hydraulic control when irrigation systems grow versus the decrease of centralized planning with increasing management size and layering. When water is delivered on demand, in Peru per *riego*, good management is needed to deliver water on time without affecting the hydraulic stability of the system and the parts of the system where fluctuations are mostly propagated to. When irrigation systems grow, the need for good management will increase while communication between an increased number of management authorities becomes slower and harder. This might cause problems with the on demand delivery of water, delay times in hydraulic control and other negative influences to system performance.

2. What is volumetric distribution?

Volumetric distribution is a water distribution method in irrigation systems in where the users (usually farmers) can request a certain volume of water for which they pay for. In the Peruvian irrigation system farmers can buy water, which they request at the office of the *Comisiones de Regantes:* the managers of the secondary canals. One unit of water delivery is called a *riego*. This equals one hour of water delivery with a flow of 160l/s to the field.

Volumetric allocation, charging and delivery of water is a solution that is widely promoted to increase the performance of a large-scale irrigation systems (Grimble, 1999). Volumetric charging is supposed to increase water use efficiency since it gives farmers an incentive to save water (Vos, 2005, p. 68). The increased water use efficiency in volumetric distribution is offset against area-based distribution where farmers get water delivery proportionally to the area of the farm.

3. Explain why hydraulic flexibility is not a static property. Use example calculations

First: a static property is a property for which the situation does not change in time.
The hydraulic flexibility can be used to *predict* the propagation of fluctuations in an open canal system with upstream control (Vos, 2005, p. 69). It is determined by the following formula:

$$F = \frac{S_{offtaking\ canal}}{S_{ongoing\ canal}} \quad \text{in which } S = \frac{\Delta Q}{Q_{initial}}$$

The hydraulic flexibility can't be a static property because of various reasons. At first the discharge to off taking canals do depend on upstream water levels according to the discharge relationships for weirs (for example $Q = 1{,}7bH^{3/2}$). The hydraulic flexibility therefore depends on the upstream water level above the off taking structure. Since water level fluctuations in a canal occur due to for example dry and a wet years (affecting total supply), filling times, delay times or illegal water turn (Vos, 2005) the hydraulic flexibility at a bifurcation point can never be static.
This is illustrated with an example worked out in table 1. The formulas above were used.

	Q_{in} [m³/s]	$Q_{offtake}$ [m³/s]	$\Delta Q_{offtake}$ [m³/s]	$S_{offtake}$ -	$Q_{ongoing}$ [m³/s]	$\Delta Q_{ongoing}$ [m³/s]	$S_{ongoing}$ -	F -
Initial	10	2	-		8			
Change 1	20	10	8	400%	10	2	25	16
Change 2	6	0	-2	-100%	6	-2	-25%	4

Table 1: example calculations for an off take (weir)

The initial discharges in the canal are presented in the third row. When the discharge in the incoming canal, Q_{in}, rises to 20m³/s. The total $Q_{offtake}$ increases to let's say 10m³/s resulting in F=16>1 so fluctuations in the head end. When in a second situation (Q_{in}=6m³/s) the water level drops to below the crest level of the weir, the total $Q_{offtake}$ may drop to 0m³/s resulting in 6m³/s in the ongoing canal. This results in F=4. So this illustrates that the hydraulic flexibility is not a static property. Besides this technological proof, sabotage to the off takes by the farmers can totally change the hydraulic property of a bifurcation point!

4. On page 71 it is mentioned that farmers do not pay for the hours to fill the canals. Explain which canals need to be filled in this particular case, give an estimation of filling times and explain when payment for filling canals happen.

There are three canal types present in the system. The main canal, the secondary canals and the tertiary canals. It is said in the article that the main canal "Taymi" functions like a reservoir (p. 72) and that the intake is adjusted in such a way that the water level in the tail end is more or less constant (p.76). These are indications that farmers do not pay for the hours to fill the main canal. Whether or not the farmers pay for the filling time of the secondary or tertiary canal is not explicitly stated in the article but I make some hydraulic calculations in order to see what the possible filling times and volumes are.

The length of secondary canal San Jose is approximately 40km. With Strickler it can be calculated that for a flow of 3m³/s (see figure 4 of the article) b=5m, y=0,64m and m=1 for K_s=40m$^{1/3}$/s and a slope of $1*10^{-3}$. When this canal starts empty the total volume is:

V=A*L=(b+my)y*40000=(5+0,64)*0,64*40000=144384m^3. With a discharge of 3m^3/s the filling time of a secondary canal is 13,3 hours. This is equal to 250 *riegos*. This is the upper boundary of the filling time of this specific secondary canal. From the article it follows that secondary canal San Jose has an average flow of 2 m^3/s (figure 4) and that a tertiary unit has an average flow of 0,5m^3/s. Therefore this secondary canals is divided in approximately 4 tertiary canals. Each tertiary canal has 0,5m^3/s=3riegos of continuous flow. In this way one tertiary canal delivers 24*3=72 *riegos* per day. Since one farmer takes an average of 16 *riegos* per season one tertiary canal delivers to 72*riegos/d**365d/16*riegos/farmer/year*=1640 farms/tertiary canal and one secondary canal delivers to 1640*4=6560 farms/secondary canal. I think that the filling costs of the secondary canal are not paid for by the farmers because it is to hard to exactly determine who of the 6560 farmers is responsible for the filling of the canal and the filling amount is to large to assign to a few farmers that irrigate at a time after the canal is just filled. The filling of the secondary canals are probable registered by the *sectoristas* as a turn to fill a canal (p.76).

The filling time of a tertiary canal with Q_{max}=0,8m^3/s (figure 6), b=2, y=0,50, K_s=40 $m^{1/3}$/s, slope=1*10^{-3} and m=1 and an estimated length of 10km (figure 1) gives V=A*L=(b+my)y*10000=(2+0,5)*0,5*10000=12500m^3 (21 *riegos*). With a discharge of 0,8m^3/s this takes a tertiary canal 4,3 hours to fill (from an empty to a full capacity water level).

The hours to fill the canal are not paid for according to Vos. The filling hours can be considered as a system cost (natural resource), but is sometimes paid for by the farmers themselves when they take an illegal water turn that is registered by the *sectoristas* as a turn to fill one of the canals.

5. On page 71 allowed water deliveries are given, together with water actually distributed to rice. Discuss these figures in relation to the rice water requirements for this system.

In table 1 of Vos' article the relative water supply at field level (RWS) is calculated by using the RWS formula from page 68 of the article: $RWS = \frac{Volume\ of\ water\ requested\ by\ a\ farmer}{Crop\ water\ requirements}$.

The terms used in the table are:

- Crop water requirement (mm/season)=water requirement of a crop for optimal yield
- Official maximum allocation at field level (mm/season)=maximum water allocation by the AT
- Average requested by farmers in 1998-99 irrigation season (mm/season)=the actual requested and delivered water(requested water=delivered water is a assumption that was made at page 68 of the article).
- Relative water supply at field level (RWS)=volume of water requested/CWR

Discussion point 1: It can be seen from this table that the CWR (1004mm)<official maximum allocation (1400mm) at field level. It surprises me that the farmers might use more water than CWR. This means that the management itself (AT) doesn't give incentives to use water more efficient. The farmers themselves try to weigh costs and benefits of taking the extra water or not. It illustrates that volumetric allocation gives incentives to the farmers to use water in an efficient way.

Discussion point 2: The RWS for rice is 0.95 and is way higher than the RWS for sugarcane, maize and beans. This can be because farmers give more priority to rice in scarce water times or because rice yield responds quicker to water shortages than the other crops. This last reason was also illustrated in the irrigation management game of this course. The RWS of rice can also be relatively high when compared to the other crops because the CWR of rise was estimated to low (the land preparation and percolation losses might be higher than 200+200mm).

6. Many of the canals have full capacities below surface level, making theft relatively difficult. Explain why this canal property cannot guarantee that water will not be stolen.

First of all the article illustrates on p. 76 that illegal water turns are sold to the water users by the so called *sectoristas* (operators of the secondary canals). Two examples are given:

1. A *sectoristas* can sell water directly to a farmer, but registers the turn as a turn to fill a canal.
2. The *sectoristas* can try to deliver less than the planned 160l/s per *riego* to a farmer in order to save water to deliver an illegal water turn.

Besides these illegal water turns sold by the *sectoristas* water theft can be done at tertiary level. Farmers can adjust their gates, the measurement devices or can claim water from their neighbours because of internal power relationships.
At last I suppose that water is brought to the farms by gravity meaning that some sort of canal needs to lie above the fields with an off take from the secondary canal at a distance x upstream allowing gravity irrigation. This must give opportunities to steal water at tertiary levels.

So although the normal flow level in most canals is still below the level of the neighbouring fields, water theft cannot be guaranteed. Social control among the water users as a supplement to technical boundaries against water stealing can though minimize the possible theft of water.

7. On page 72 Vos states: "The main canal functions like a reservoir to increase stability of the delivered flows and to respond to sudden increases in delivery to the secondary canals at the tail end". Are these two functions supporting, overlapping or contradicting each other? Explain.

From my point of view these two functions are mainly overlapping. The first part of the phrase states that the main canal functions like a reservoir to increase stability of the delivered flows. This stability might decrease in a system without a reservoir because of the hydraulic flexibility at off takes resulting in the typical upstream-downstream problems. This is also the case in the Peruvian system since at page 72 Vos states that "fluctuations are mostly felt at the tail end of secondary canals". In a situation without reservoir sudden increases in delivery to the secondary canals at the tail end could not be managed because of the lack of water availability at the tail end of the main canal.
In a certain way these two functions are only supporting each other since a main canal that functions as a reservoir cannot guarantee good response to sudden increases in delivery to the secondary canal. On demand delivery to the tail end definitely also depends on the structures used (with corresponding hydraulic flexibilities) and skills and experience of operators in the system.

8. Vos concludes that "understanding this remarkable finding is only possible if institutional factors, technical factors, and their interaction are taken into consideration". In case someone would argue that this conclusion is inappropriate in the sense that the case from Vos can be explained by only taking into account the 'institutional' factors, would you agree? Explain.

Based on the article I would not agree with this "argument". First of all it is not that easy to respond to a quote that does not have any scientific basis such as is the case in this "argumentation". Based on Vos' article and my own point of view the success of an irrigation system is a mix of technical, institutional and their interactions and can't be explained by the institutional factors only. The first argument for this is that the choice for different off take structures influences the hydraulic flexibility and performance of the system. This is a clear technical solution, as is the design of for example width, slope, and other dimensions of the canals. Besides this, modernization of irrigation is understood as transforming irrigation management to enable it to serve the demands of the farmers

(Ertsen, 2009, p. 1). Such a service-oriented approach demands irrigation experts with high technical qualifications in hydraulics and hydrology (Ertsen, 2009, p.1). So based on my own intuition and the two scientific papers I conclude that the technical factors, institutional factors and their interaction are important in understanding system performance rather than only institutional factors.

<u>Literature list</u>

Ertsen, M.W. *From central control to service delivery? Reflections of irrigation management and expertise*. Irrigation and drainage #58. University of Delft, 2009.

Grimble, R.J. *Economic instruments for improving water use efficiency: theory and practise*. Agricultural Water Management #40: 77-82.

Vos, J. *Understanding water delivery performance in a large-scale irrigation system in Peru*. Irrigation and drainage #54. Wageningen University 2005.

1 It is commonly seen that as systems become larger the control of the management diminishes. The performance of management entails: cost recovery, water use efficiency, water delivery performance.
As management control is easiest if there is direct control, the performances are thought to be the highest. When several levels of management are added between the decision making top of the management and the lowest branch of management who have to act control decreases. Another important facet is the lack of attention of the management to each part of the system. As a large number of managers has to control the gates, it cannot be constantly monitored and guarded. These are reasons for the low degrees of performance.
Cost recovery is noted as a problem in big systems as payments are lost among managers.
The volumetric water distribution chosen in this system is noted to be problematic in other large-scale systems, problems noted are: "problems with charging and delivery ... , because of high costs, and technical and social difficulties in water distribution."

2 A volumetric water distribution, means that a certain volume of water is given to someone who bought the water rights. In contrast to for example proportional water distribution where not a certain volume but a percentage of the total volume. The volumetric water distribution is chosen to create an incentive for the farmers to increase the water efficiency. As they pay for each volume, they will not receive more than what they paid for. The water is valuable so they will be more careful to use it, which may lead to higher efficiencies.
"Payments for the requested volumes can be enforced by only supplying the volume of water paid for."

3 Hydraulic flexibility is limited by the sizes of canals and divisors. In the system which is described gates are used. The hydraulic flexibility in this situation is calculated.

$h_{upstream}$	$dh_{upstream}$	A	$h_{1downstream}$	$h_{2downstream}$	q_1	q_2	dq_1	dq_2	S_1	S_2	$F=(S_2/S_1)$
0.2	0.05	0.5	0	0	0.99	0.99	0.12	0.12	0.12	0.12	1.00
0.2	0.05	0.5	0	0.05	0.99	0.86	0.12	0.13	0.12	0.15	1.31
0.2	0.05	0.5	0	0.1	0.99	0.70	0.12	0.16	0.12	0.22	1.90
0.2	0.05	0.5	0	0.15	0.99	0.50	0.12	0.21	0.12	0.41	3.51

As can be seen, the flexibility changes, therefore it is not static.

4 The filling of the canals which do not exclusively deliver to the person who bought the water rights. If a canal which only leads to and is being used by one person is being filled the filling time will not be charged. The filling of a secondary and tertiary canal have been calculated in the table below.

	L (m)	A (m^2)	Q (m^3/s)	T (s)
secondary canal	42500	3.5	2.5	59500
tertiary canal	1920	1.5	0.8	3600
		total T (s)		63100
		total T (hrs)		17.53

Illegal water deliveries which are registered by sectoristas as a filling turns, the farmer would pay but it is not an official payment. Those filling turns are not free.

5 The rice fields have a Crop Water Requirement of 1004 mm/season. Including preparations and deep percolations losses. The maximum allocation might be based on the maintenance of water table levels to correct levels. As is noted that “the rice crop does not have a standing water layer during the whole growing period”. The maximum may have included this water layer.
An alternative reason might be that the CWR is an average value, the actual value may differ because of different ground structure and different crops. This may be known by the water board and they may have corrected for this.

6 Water can still be pumped out of the canal. Water can also be stolen by tampering with the gate settings in cooperation with sectoristas. Creating additional outlets from the canal upstream to irrigate downstream. Blocking the canal to raise the water level to field level.

7 This statement is overlapping. As a reservoir has the function to buffer variations in the outflow, meaning an increase in the stability of the outflow. And an increase in outflow is buffered by a reservoir.

8 I agree that the reasons given for the success of the system are all linked to the ‘institutional’ factors. But I don’t agree with the statement that they are explainable without the technical factors. As the technical part of the system itself is the reason it can be operated the way it is now. For example, the fact that the system has manually operated sliding gates is crucial to it’s success. Would the system be designed to have static dividers, water management wouldn’t be so well set up. The technical part of the system enables the institutional part of the system to work as it does now.