Changes in Water Resources Systems: Methodologies to Maintain Water Security and Ensure Integrated Management (Proceedings of Symposium HS3006 at IUGG2007, Perugia, July 2007). IAHS Publ. 315, 2007.

Historical analysis of irrigation and environment in two arid regions in South America

MAURITS ERTSEN & JOANNE VAN DER SPEK
Water Resources, Delft University of Technology, PO Box 5048, 2600GA Delft, The Netherlands
m.w.ertsen@tudelft.nl

Abstract This paper discusses how irrigators in two arid areas in South America have responded to irregular river flow patterns to match water availability with actual water requirements. The Pampa de Chaparrí (Peruvian north coast, 900–1500 AD) shows that irrigators may have adjusted irrigated surface and planting times. The Proyecto Río Dulce (PRD) irrigation area in Argentina (1850–present) shows how irrigators continuously increased control over water flows through physical infrastructure. The paper elaborates upon how irrigation systems can be understood as human responses to environmental constraints.

Key words Argentina; arid environment; hydrology; irrigation; Peru; strategies

INTRODUCTION

An important issue in water management is the nature of unstable water availability during seasons and over the years. Many rivers have an irregular flow pattern, with large fluctuations in and over seasons, and very low flows in the dry season. In such a setting it is difficult to match water availability with actual water requirements. Rational water use requires (to a certain extent) knowledge of river flow predictability. This paper will discuss two basic human strategies to optimize irrigation within the context of uncertain water availability. Both case areas are located in arid regions in South America (Fig. 1).

The first case study, on the Pampa de Chaparrí on the arid Peruvian north coast (900–1532 AD), discusses how irrigators may have dealt with fluctuations in water availability over the years by adapting their irrigated area. This case analyses how irrigation is adapted to the natural environment.

The second case, on the Proyecto Río Dulce (PRD) irrigation area in Argentina, shows how irrigators steadily increased their control over fluctuating river flows. This has increased incoming flows into the PRD per surface unit. This case analyses how the natural environment is adapted to irrigation.

Our cases are analysed from a historical perspective, as this gives interesting opportunities for some of the theoretical and practical concerns within the irrigation engineering domain. At present, irrigation is still one of the key resources for many groups in the world. The irrigation systems encountered today, the practices of actors involved, and the different institutions surrounding them are the product of history. An historical perspective not only provides the data for optimization of models, but also helps to increase our understanding of the nature of the relations between water availability and human intervention within natural environments.

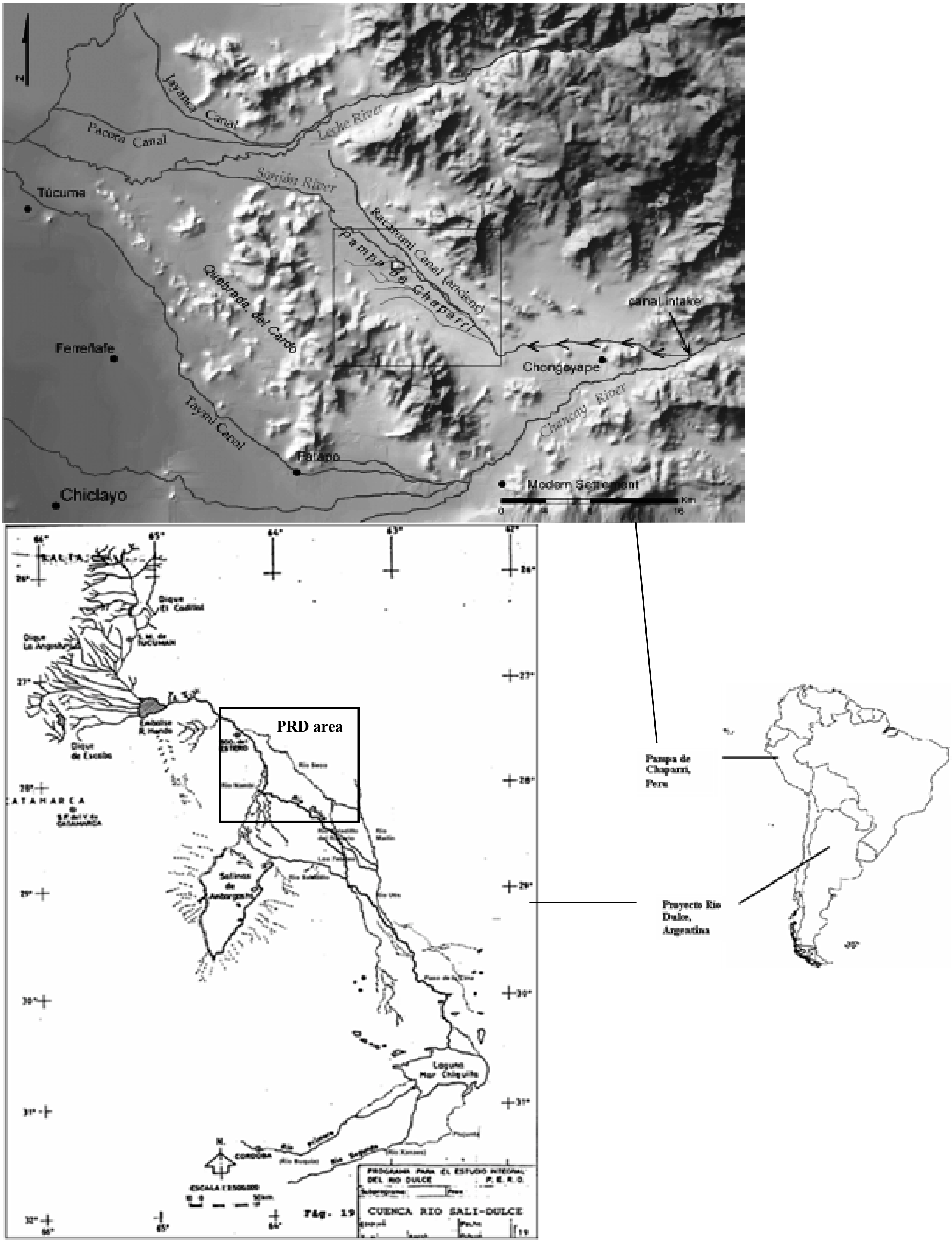

Fig. 1 Case studies discussed in this paper.

ADAPTING IRRIGATION TO THE NATURAL ENVIRONMENT

Our first case study discusses irrigated agriculture in the Pampa de Chaparrí on the arid Peruvian north coast (Fig. 1). Despite its harsh and arid environment, pre-Colombian civilizations have prospered, at least partly because the rivers provide the fertile coastal plains with irrigation water from the Andean mountains. The irrigation system of the Pampa de Chaparrí has been dated as being used between 900 AD and 1532 AD. It has been used by the Sicán, Chimú and Inca civilizations (Nordt *et al.*, 2004). In the 16th century the system was abandoned. Several publications about the Pampa are available on different issues. Téllez & Hayashida (2004) conclude that canals and walled fields on the Pampa were constructed with organized labour replacing taxes. Nordt *et al.* (2004) discuss soil fertility and show that infiltration capacities of the coastal soils and low salinity levels in the irrigation water would have given no problems related to salinization. What has been less intensely studied is how the irrigation systems have functioned in terms of both hydraulic behaviour (in relation to canal operation and management) and hydrology (water demand in relation to availability). What is clear is that irrigated agriculture must have depended heavily on the strongly varying discharge of the Río Chancay, caused by rainfall in the Andean mountains.

Crops cultivated on the Pampa de Chaparrí will have included cotton, beans, maize and potatoes. The growing season of cotton is about two months longer than of the other crops. Three areas had to be irrigated from the Rio Chancay, including the Pampa de Chaparrí. A fourth irrigated area derived water from the Rio La Leche north of the Chancay. Water from the Chancay River was diverted to the Rio La Leche when it was not used in the Pampa de Chaparrí. Assuming proportionality between water use and surface area between the three areas taking water directly from the Chancay River the Pampa de Chaparrí would have derived maximally about 1/3 of the discharge. We have taken 30% as target value. What amount of land was planted is an uncertain factor: the more cropped area, the higher the risk of insufficient water availability to irrigate all crops later in the season. When crops were planted is not easily determined either, although the main cropping season would have fallen within the Peruvian summer (January–April) when river discharges are generally highest. Obviously, measurements and observations of pre-Colombian river discharges are unavailable. In modern times, after 1960, several tunnels have been constructed which linked several rivers in the Andes. Therefore river discharge figures after 1959 are not usable for our purpose. However, it is not unreasonable to assume that the discharges before 1960 are representative for our period of interest. We used available discharge data for the period 1914–1959 (Fig. 2).

Irrigation systems like the Pampa de Chaparrí have supported the great Peruvian coastal civilizations. This indicates that irrigators at the Pampa must have been successful in terms of production of surplus foods and fibre. How to define "successful" is a question in itself; for the purpose of this study we focused on the number of years of water shortage within the 45 year data range we used. We defined water shortage as the situation when more than 30% of the available discharge would have to be derived from the Río Chancay (we discussed above that the Pampa de Chaparrí would have the right to use about 30%). Cultivation of 70% of the area gave 8 years showing (less severe) water shortages. In the case where about 80% of the

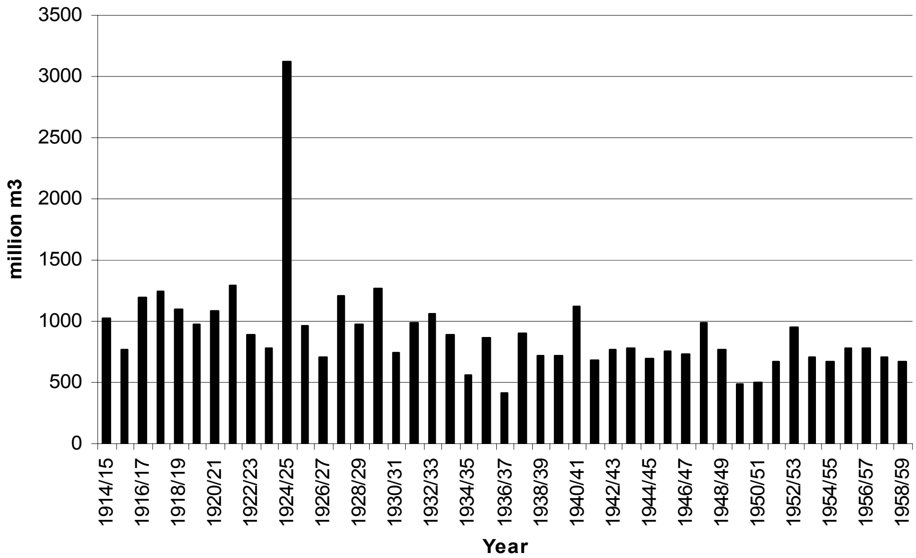

Fig. 2 Discharges of the Río Chancay between 1914 and 1959.

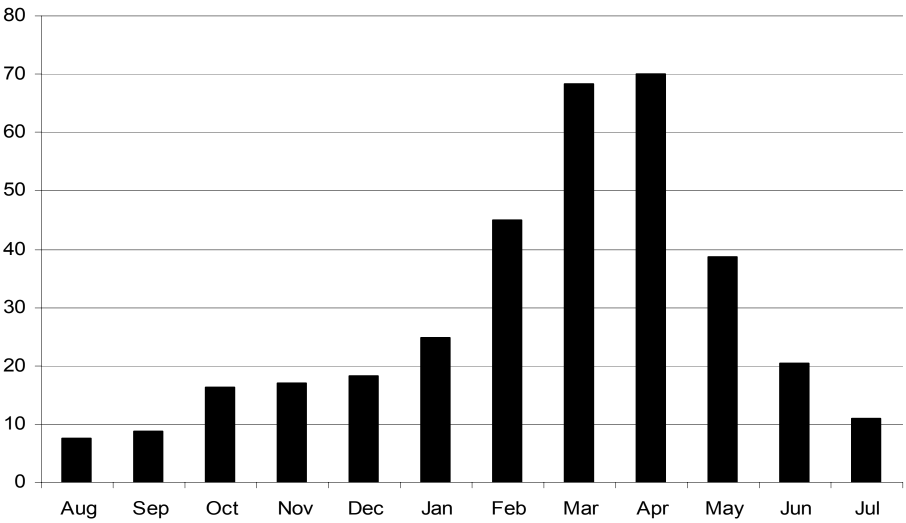

Fig. 3 Average discharge of the Río Chancay between 1914–1959.

surface would have been cultivated, 10 years out of 45 years would have shown such water shortages (from 1 to 3 months). With 100% of the area irrigated this would increase to 21 years, with larger amounts and longer periods of shortages. Assuming that water stress could be allowed every fifth year, a cropping intensity of 70–80% on the Pampa de Chaparrí appears to be a reasonable value.

River discharges were generally increasing in January and stayed high enough in most years to provide sufficient irrigation water for the crops (Fig. 3). Furthermore, discharge fluctuations in the period between November and February were much higher than later in the season. Thus, predicting river flows in November/December would have been somewhat more difficult compared to January/February. Planting cotton in January sets the end of the growing season in June/July, when river flows were already low. Crops planted in January would put a relatively high demand on these low flows. Crops planted in January would have suffered more water shortages in the 45 year period we simulated, but these shortages would always occur at the end of the growing season, when crop damage is less severe. Planting in December would mean that the crops could profit from the more abundant water availability in April, resulting in less water shortages in the growing season than for planting in January. However, water shortages in the December cropping scheme would have been more severe and more often in the middle of the growing season when crops are generally more vulnerable to water shortages. Water shortages could not just have been caused by dry years as such. Years with average flows could still cause water shortages in some months, because the distribution of flows within the (normal) season was irregular. Another possibility was that the rains in the mountains stopped early and river discharges dropped earlier than normal.

ADAPTING THE NATURAL ENVIRONMENT TO IRRIGATION

The results presented above are the first from the Pampa de Chaparrí area, which is one of the case areas within a larger research project focusing on the development of larger irrigation systems in semiarid regions of South America. In modern historical times, the changes in this Peruvian region have been enormous, including construction of tunnels, reservoirs and lined canals; these need to be studied further. In the next case study, similar changes towards (what has become known as) modernization will be discussed. This case shifts attention to the semiarid northwest region of Argentina, where the Dulce River basin covers about 100 000 km^2. Within the basin, the area known as the Proyecto Río Dulce (PRD, irrigable area 122 000 ha in a command area of around 350 000 ha) is one of the largest irrigation schemes of the country and the most important irrigated area in the province of Santiago del Estero. This second case study discusses a common reaction of societies to water availability fluctuation described above: increasing control over water flows.

In 1577, Spanish settlers built their first irrigation ditch (acequia) in Santiago del Estero. In 1583, this reached a length of 5 km. In 1680, an irrigator's register was established. In 1873, 73 acequias existed. These canals were not the small ditches one would perhaps expect: most were longer than 10 km, some extending even up to 50 km with a width of 6 m (Michaud, 1942). Officially about 8000 ha were irrigated by the canals, but in practice this figure would have been higher. In 1878 canal La Cuarteada was built. In 1886 an intake structure was constructed for La Cuarteada, which was renewed in 1898. In 1905 the existing irrigation infrastructure was further extended. From then on, the intake diverted water to a main canal, at the end of which (La Darsena) Canal Norte, Canal Sud and Canal La Cuarteada branched off. This was the first public irrigation system in Santiago del Estero, irrigating about 38 500 ha (with 14 500 ha being irrigated from private acequias). In 1913, a communal canal on the right bank was constructed: Canal San Martín, with a length of 64 km. In 1947 the federal organization for water affairs, Agua y Energía Eléctrica (AyEE), began building a permanent diversion weir in the river, the Dique Los Quiroga. San Martín continued to derive water directly from the river, as did the remaining private acequias. However, these canals downstream of Los Quiroga had difficulties getting water, in particular during periods of low flow,

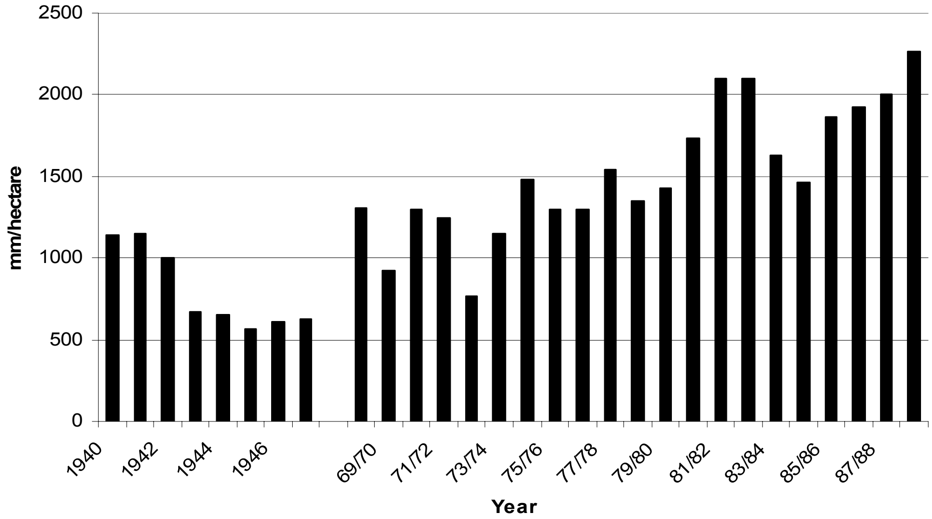

Fig. 4 Water use in the PRD area in different years (Prieto, 2006).

since almost the full flow was diverted to the La Cuarteada system on the left bank. Again, assistance from the National Government was looked for. As a solution, the San Martín system was connected to La Matriz through a siphon around 1954. AyEE presented plans in 1957 for the construction of a reservoir in northwest Santiago, the Embalse *del Río Hondo*. This reservoir was completed in 1968. The reservoir has shaped the potential for irrigation all year round, although its capacity is insufficient to provide more than annual regulation. Data from the PRD show that inflows per hectare are significantly higher after 1968 compared to earlier days, especially before Los Quiroga was built (and probably also compared to when Los Quiroga was in use, for which we have no data yet) (Fig. 4). The outflow of the system is extremely low compared to the inflow. It is likely that non-irrigated areas within the command area should be considered as "subsurface irrigated areas" with perennial vegetation. In this case, a large amount of water, perhaps larger than from cropped areas, would leave the system through evaporation from natural vegetation (Ertsen *et al.*, 2004).

In actual practice, smaller farmers irrigate their cotton or alfalfa on average three to four times per year and use about two and a half times more water per turn than allowed (240 mm event^{-1}). Smaller farmers reproduce the former distribution schedule from the second period in the development process of the PRD area. Before the reservoir the irrigation infrastructure provided two or three irrigation turns for each farmer in late spring and summer, when water levels in the Río Dulce were sufficiently high. This irrigation strategy shares many characteristics with the irrigation pattern discussed for the Pampa de Chaparrí. What has changed for the irrigators in the PRD is that the increased control over inflows has secured the starting conditions of the growing season. One does not have to wait for rainfall anymore, as the first irrigation turn can be planned better in advance because of the water stored in the reservoir. Other farmers in the PRD, mainly the larger ones with more diversified cropping patterns, do take advantage of the new potential made possible by the reservoir. They combine the irrigation strategy of the smaller farmers (irrigating crops a few times), but take water during 6 to 8 turns because they irrigate only a fraction of the area available to them each turn. They sometimes irrigate a larger area than officially allowed (Prieto, 2006).

CONCLUSIONS

In this paper we discussed two typical human responses to uncertainties in water availability. A first response is to adapt irrigation to natural water availability, as in the Pampa de Chaparrí. A second response, usually associated with modern irrigation, is to increase control over the natural environment, as in the PRD. Both strategies still exist today. Even within the controlled environment of the PRD many farmers still use an irrigation strategy typical for the first type of response. Historical research can (partly) explain such strategies and make engineers more aware of their potential implications. Although success is not guaranteed, one would expect that engineering interventions will improve when the irrigation context in which these interventions need to take place is better understood. "*History does not repeat itself in detail, but drawing analogies between past and present allows us to see similarities. For this reason, generals study military history, diplomats the history of foreign affairs, and politicians recall past campaigns. As creatures in a human-built world, we should better understand its evolution.*" (Hughes, 2004).

REFERENCES

Ertsen, M. W., Prieto, D., Pradhan, T. M. S. & Angella, G. (2004) Historical analysis of water flows in the Río Dulce catchment. In: *Proc. 2nd Asian Regional Conf., Intern. Comm. on Irrig. and Drain.* (Echuca-Moama, Australia).

Hughes, T. P. (2004) *Human-Built World: How to Think About Technology and Culture*. University of Chicago Press, Chicago, USA.

Michaud, C. (1942) *Regadios en Santiago del Estero y en particular en la zona del Río Dulce*, Santiago del Estero, Argentina.

Nordt, L., Hayashida, F., Hallmark, T. & Crawford, C. (2004) Late prehistoric soil fertility, irrigation management, and agricultural production in northwest coastal Peru. *Geoarcheology* **1**(19)21–46.

Prieto, D. (2006) Modernization and the evolution of irrigation practices in the Río Dulce irrigation project. PhD Thesis Wageningen University, Wageningen, The Netherlands.

Téllez, S. & Hayashida, F. (2004) Campos de Cultivo Prehispánicos en la Pampa de Chaparrí. *Boletín de Arqueología PUCP* **8**, 373–390.