

UNDERGROUND PIPELINES FOR LOCAL WATER DISTRIBUTION IN CANAL IRRIGATION IN PUNJAB AND GUJARAT, INDIA

CANALISATIONS ENTERRÉES POUR LA DISTRIBUTION LOCALE DE L'EAU DANS LES SYSTÈMES D'IRRIGATION PAR CANAUX AU PENDINGJAB ET AU GUJARAT, EN INDE

Vidya Mandave^{a1}, Peter P. Mollinga^b, Sachin Oza^c, and Pranjal Deekshit^d

ABSTRACT

This paper compares underground pipeline networks (UGPLs) in the Indian States of Punjab and Gujarat, with a focus on the Sardar Sarovar Project (SSP) in the latter. Drawing on existing documentation and own fieldwork the paper aims to understand why the reception and performance of the systems are so contrasting in these two States. In Punjab, farmers generally welcome and actively use the systems, while it brings surface water to tail ends of *chaks* where such water might not have arrived for many years; Gujarat exhibits an almost opposite experience. The paper shows that the institutional context in which the UGPLs emerge and are deployed holds the key to the answering the question more than their technical features and agroecological and hydro(geo)logical conditions.

Keywords: Underground pipelines; Agroecological conditions; Surface water; Institutional context; Performance of the systems.

RÉSUMÉ

Cet article compare les réseaux de canalisations enterrées (UGPL) dans les États indiens du Pendjab et du Gujarat, en mettant l'accent, pour ce dernier, sur le projet Sardar Sarovar (SSP). S'appuyant sur la documentation existante et sur les travaux de terrain des auteurs, il vise à comprendre pourquoi l'accueil et les performances de ces systèmes sont si contrastés dans les deux États. Au Pendjab, les agriculteurs les accueillent généralement favorablement et les utilisent activement, car ils acheminent l'eau de surface jusqu'aux extrémités aval des *chaks*, où elle n'était parfois plus arrivée depuis de nombreuses années ; le Gujarat présente une expérience presque opposée. L'article montre que le contexte institutionnel dans lequel les UGPL apparaissent et sont déployés explique davantage cette différence que leurs caractéristiques techniques ou les conditions agroécologiques et hydro (géo) logiques.

Mots clés : Canalisations enterrées; Conditions agroécologiques; Eau de surface; Contexte institutionnel; Performances de ces systèmes.

1. INTRODUCTION

Underground pipeline networks (UGPLs) are a technical innovation in Indian surface canal irrigation systems that replace surface, mostly earthen, channels and canals with underground pipes, either concrete or plastic, to deliver water to farmer-irrigators' fields. Water becomes available to farmers at 'wells', which are round or square structures of a certain depth, into which the underground pipes release water, and which regularly also are bifurcation points (see Figures 1 and 2). Valves to open and close particular lines may also be part of the infrastructure. The pipeline systems draws water

¹ ^{a)} IWMI, Delhi India, v.mandave@cgiar.org; ^{b)} ZEF, Bonn, Germany/SOAS University of London, UK; ^{c)} DSC Foundation, Ahmedabad, India; ^{d)} TISS, Mumbai India. For a 10K words version of this paper contact the authors.

from the higher scale canal infrastructure (branch, distributary or minor canals, as the case may be), through existing or newly constructed outlet structures.

This paper compares UGPLs in the Indian States of Punjab and Gujarat, with a focus on the Sardar Sarovar Project (SSP) in the latter. The paper draws on existing documentation on these pipeline systems for 'last mile delivery' of irrigation water to groups of farmers as well as own fieldwork to understand why the reception and performance of the systems is so contrasting in the two States. The central question of this paper is: why does the implementation of similar technical innovation produce such very different outcomes in these two States? Punjab and Gujarat were selected for comparison as both have State-wide implementation of a large number of UGPLs, while they exhibit very contrasting uptake and performance of the UGPL networks. With some simplification: in Punjab farmers generally welcome and actively use the systems, while it brings surface water to tail ends of *chaks* where such water might not have arrived for many years; Gujarat exhibits an almost opposite experience.



2. UGPL POLICY IN PUNJAB AND GUJARAT

In Punjab, UGPLs are constructed by two government departments: the Soil and Water Conservation Department (SWC) and the Punjab Water Resources Management and Development Corporation (PWRMDC). The latter has constructed UGPL networks since 2015, in a project based mode of 150-200 outlets in a contiguous area. Since 2015 39,776 ha has been covered. The former, SWC, has been constructing UGPLs for a longer period, since 1989-90. As an independent initiative, UGPL started in 2006; it is a flagship initiative of the Punjab Government under the Rashtriya Krishi Yojana, a Centrally Sponsored Scheme of the Government of India, allowing it to receive budgetary grants. The SWC programme is an open-ended scheme on first come, first serve basis, in which groups of farmers have to apply for the construction of an UGPL network. Currently there is 100% subsidy for the construction (where it used to be 90%/10% earlier).

UGPL networks are constructed across the state of Punjab, but the regional distribution is uneven. The bulk of the UGPLs is located in the southern and western part of the State (see Figure 3) where groundwater quality is poor (see Kumar et al. (2013)). The districts of Faridkot, Bathinda, Sangrur, Mukatsar, Ferozepur and Patiala for example together have 275,000 ha of coverage, which is about 57% of the total.

The SSP in Gujarat (see Figure 4) was designed as a conventional (protective) surface irrigation system, with all canals being earthen surface canals, with a high degree of canal lining (that is, to the level of the watercourse). Immediately in the first years of functioning of the canal system (from *Rabi* 2002-03) it became clear that the sub-minors, watercourses and field channels at the local level were

prone to get damaged and leak, while some also exhibited problems with alignment and slope. The major challenge was, however, the acquisition of land for the sub-minor construction, which farmers resisted. This was a key factor in slowing down command area development (Shah et al., 2010). The time gap between the construction of the main canal for water conveyance and the local system for distribution has undoubtedly induced farmers to start pumping water directly from the supply canals.



Figure 3. District wise UGPLs Punjab (Source: Rai (2024))

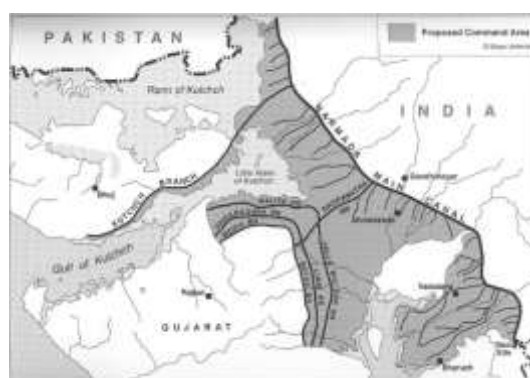


Figure 4. Location SSP in Gujarat (Source: <http://www.narmada.org/sardarsarovar.html>)

In 2009, International Water Management Institute (IWMI) researchers proposed that UGPLs should be undertaken with farmer investment and management, as in Maharashtra's Upper Krishna Basin. The 2010 *Report of the Expert Group* (SSNNL, 2010) that looked at ways to accelerate the development of the SSP command area was of a different view. Its recommendation about UGPL networks was negative. (Shah et al., 2010) A few years later the opinion of the UGPL networks changed, though only partly (see section 6). Due to severe land acquisition hurdles and fragmentation of small farmers' lands, the Government of Gujarat in 2014 formulated a UGPL policy for sub-minors instead of conventional open gravity channels. Within a year, remarkable progress was made in the construction of UGPL networks, which became a massive construction programme across the SSP command area.

3. FUNCTIONING OF UGPLS IN PUNJAB AND GUJARAT

Rai (2024) summarises a 2022 study of the Centre for Water Technology of the Department of Agronomy, Punjab Agricultural University. This study reports that, in Punjab, UGPL systems were instrumental in increasing rice equivalent yields by 6% percent, that is, 3.9 quintals/ha, compared to open channels, a 17.9 percent water saving and a per hectare cost saving of Rs. 1,192.5, (labour cost for channel maintenance and weeding savings). The study also reports that farmers are willing to contribute 20% of the construction cost, above the then current 10%.

Rai (2024) lists the benefits that farmers report under four headings “1) *Enhanced Water Distribution*: The installation of UGPLs has significantly improved water distribution, particularly for tail-end farmers. 2) *Increased Agricultural Productivity*: The reliable and equitable distribution of water through UGPL systems has led to better crop yields. 3) *Ease of Operation and Maintenance*: Farmers have reported that UGPL systems are easier to operate and maintain compared to open channels. 4) *Reduction in Water Losses*: UGPL systems have reduced water losses that were common in open-channel systems due to seepage and evaporation. The improved efficiency of water use has not only conserved water resources but also ensured that more water reaches the fields, particularly in areas with scarce water availability.”

Panwar et al. (2025), using a Randomised Control Trial (RCT) approach find, for Patiala and Sangrur districts, “significant improvements in crop yield and economic efficiency” (p.174) for UGPL as compared to non-UGPL situations. Yield increases ranged from 1.97% to 25.6%; the benefit-cost ratio of UGPLs lies between 1.26 and 1.38 (implying a payback period of 4-10 years).

Several studies on the SSP in Gujarat by IWMI and others, and field visits by the present authors at regular intervals since 2015, indicate the disappointing performance of UGPLs constructed by the Sardar Sarovar Narmada Nigam Limited (SSNNL). Talati and Shah (2002) is based on joint field visits of IWMI-Tata researchers and field staff and engineers of the SSP to develop a firsthand assessment of the preparedness of the irrigation communities to receive and utilize Narmada water for irrigation. Some 40 villages in different parts of the command area were covered. All the villages visited had taken some action to form WUAs under prompting from SSP field staff. However, almost everywhere, what was found were only Management Committees (MCs) with a president-designate. A few MCs had already had a general body meeting, but none had actually begun enrolling irrigators as formal members of WUAs.

A subsequent IWMI-Tata study (Talati and Liebrand, 2003) of 543 irrigators in 12 villages of the SSP command during rabi 2002-03, the first irrigation season in SSP, showed that of the 1,150 ha irrigated with Narmada water in the 12 villages surveyed, 727 ha were irrigated by lifting water, and the remainder by gravity flow or using siphons. It also showed that for every rupee farmers paid to the SSNNL for water charges, irrigators spent Rs 2.25 on lifting from minors. Pump irrigation markets were booming with farmers lifting and transporting water up to 2,500 feet (760 meters).

Farmers in 10 of the 12 villages surveyed invested in 40 diesel pump sets with 5 to 8 hp capacity and 14,024 meters length of delivery pipes of various makes and materials, such as rubber, HDPE (High-density polyethylene), fertilizer bags and PVC (polyvinylchloride), to operate on the newly catalyzed water markets. A pump dealer whose business was on the upbeat and interviewed by Talati and Liebrand said he had already sold 30 pump sets in *Rabi* 2002-03 itself and expected to sell 350 the following year.

Ghosh and Rai (2019:3), almost 20 years after the Talati and Liebrand study, report similar findings: Sufficient water is available is a limited number of outlets in their sample; they observe (stark) differences between head-end and tail-end villages along minor; large areas outside the official command area are irrigated with Narmada canal water.

Palrecha and Kalakuri (2024) summarize the reasons for inequitable distribution of irrigation water as 1) a diversified cropping pattern that complicates irrigation water requirements calculation; 2) farmers do not pay water charges or submit demand notes to estimate irrigation water requirements; SSNNL releases water irrespective of receiving demands, since, as Ghosh and Rai (2019:5) suggest, “since the ultimate objective of SSP is to provide irrigation and support farmers The SSNNL authorities are unable to enforce the regulation of not providing water unless 51% of command area farmers submit their demand forms as it will hurt the agricultural economy.”; 3) WUAs are absent ; 4) pilferage and blocking of UGPL networks; 5) unregulated lifting of water from supply canals with pumps by those who have the means and land in a suitable location; 6) poor maintenance and implementation of rotation schedules; 7) diverting of water to undesignated areas through electoral/political influence.

During the authors’ field research in 2025, farmers stated that 10% farmers are taking water from UGPL, while 90% from lifting water from open canals. From 2002 to 2025 not much has changed in the management of canals in the SSP command area. While open channels have been replaced by UGPL networks, the system continues to be plagued by tail-end deprivation, poor O & M of pipelines, low recovery of irrigation charges and widespread water theft. UGPLs are an extremely unreliable provider of irrigation service.” (Ghosh and Rai, 2019:5)

4. DIFFERENT OUTCOMES: DOES TECHNICAL DESIGN MATTER?

The UGPL networks in Punjab and Gujarat have the same technical design principles when put in very general terms. They replace sub-minors, water courses and field channels. In the later phases of construction in the SSP the minor canal was also included, enlarging the UGPL networks by taking off directly from a branch or sub-branch canal. This leaves the overall idea of underground piped networks with exit points for farmer-irrigators to deliver irrigation water at or close to the field unchanged.

Differences in design include 1) the network layout. 2) the pipe material and its robustness, and 3) the nature of the outlet to the *chaks*/(sub-)minors. The major difference in network layout is that in Punjab the underground pipelines neatly follow the original alignments of watercourses and field channels within the *chak*. In SSP/Gujarat this is not the case. The pipes follow the shortest distance between exit points. This suggests that a major difference between the UGPL networks in the two States is that in Punjab the innovation ‘fits’ (maps onto) an existing (even if dilapidated) infrastructure, while in Gujarat there is no such ‘fit’. While technically this is not of great consequence, institutionally it is (see below).

A second difference is the material of the pipes. In Punjab the pipes are concrete pipes; in Gujarat, all is plastic (of different types, depending on pipe diameter). Overall the Punjab networks make a more robust impression, with fewer leakages/breakages. For explaining the different outcomes in the two States the construction material is not a significant difference. In principle all systems can function when properly constructed and maintained.

The third difference, the nature of the outlet to the *chaks*/(sub-)minors, may carry more significance for explaining the different outcomes. In Punjab, the supply into UGPLs is proportional to the main system discharge through the APM (Adjustable Proportional Module) outlet. Most outlets observed in 2025 fieldwork are in practice fixed rather than adjustable, but still they seemed to be in a state that they would more or less deliver proportionally. In Gujarat, semi-modular outlets in the form of open throated flumes were part of the original design of the surface distribution This was also adopted, at least in 2015, for the outlet structure that fed the UGPL network. In 2025 the design was different – the outlets had become gated structures to be adjusted by canal staff, as observed during the construction of UGPL networks in Kutch (with the network now also being at minor level – scale enlargement).

With heavy canal-level understaffing and the ease of tampering with the gate settings, the chances of a reliable and predictable, let alone a proportional, discharge into the UGPL networks seem remote.

Nevertheless, this design difference cannot explain the preference for individual pumping from canals and using UGPL wells as pumping points (see Figure 1) or leaving UGPLs largely aside.

These design differences are interesting and potentially relevant, but the bigger point to make is that very few of the networks in Gujarat are used as planned. Already in 2015, the authors observed that the wells were used to pump from more than the envisaged surface distribution from the well (see Figure 5). In the north part of SSP in 2025 we found that large parts of the newly constructed networks were not functioning, at best, the main line, and that individual farmers had made adaptations to remodel the UGPL infrastructure for their own needs.



Figure 5. Exit point well as spot for individual pumping, west part SSP, 2015
Source: Photo by Peter Mollinga

5. DIFFERENT OUTCOMES: DOES THE SURFACE – GROUNDWATER SITUATION MATTER?

In both Punjab and SSP/Gujarat there is a strong interest of farmer-irrigators in getting (improved) access to surface water. The reasons for that vary, however. In Punjab, groundwater-based agriculture operating a rice-wheat system (with summer paddy added when feasible) is under threat due to declining groundwater tables and particularly deteriorating groundwater quality. As already observed above, the district-wise prevalence of UGPL networks for (additional) surface water provision maps well onto a groundwater quality map (see Kumar et al. 2013: Figure 4).

In Gujarat, the situation is geographically more diverse. In semi-arid areas like Saurashtra, Kutch and Banaskantha, the Narmada canal water was eagerly awaited. So much so that during fieldwork in Kutch in 2019 the authors observed farmers already having installed diesel pumpsets and flexible pipes to lift water from the section of the branch into which water was not yet released but was going to be released shortly. In Central Gujarat where borewells now go to 700 feet depth the Narmada canal water is a welcome supplement and source of groundwater recharge, a recharge phenomenon that is reported by farmers across the SSP command area. There are also regions where surface irrigation water is less desired because of farmers' hesitation to irrigate so called black-cotton soils, that is, very heavy clay vertisols (in Bharuch and Patan/Banaskantha). Nevertheless, for the larger part of the SSP command area, additional (Narmada) surface water is a highly desired resource.

What differs between the two States is thus not the desirability of augmenting and improving surface water supply, but the way in which farmer-irrigators appropriate that surface water (and how government facilitates that appropriation). While in Punjab this happens through the existing canal water *warabandi* distribution system, into which UGPL networks have been fit (by design or by default), farmer-irrigators in Gujarat have massively opted for individual pumping from canals with, mostly diesel, pumpsets. This has created what could be called without too much exaggeration a

water grabbing scenario, in which those relatively close to the canals and with sufficient financial resources appropriate canal water through individual pumping at volumes exceeding the one-season supplementary irrigation that is the basis of the SSP design. Regarding this paper's question what explains the different outcomes of the UGPL innovation in Punjab and Gujarat, we conclude that the (different) groundwater challenges that the two States face explain farmer-irrigator interest in gaining access to (additional) surface canal water, but not the different fates of the implementation of the UGPL networks.

6. DIFFERENT OUTCOMES: DO THE INSTITUTIONAL FEATURES OF FARMER-IRRIGATOR GROUPS/COMMUNITIES MATTER?

This paper argues that the deciding factor in explaining the different outcomes of the UGPL network innovation in Punjab and SSP/Gujarat lies in the type of local institutional arrangements (or their absence) for distributing (appropriating) the surface canal water available at the outlets to the UGPL networks. These arrangements exist in a particular context and have a history. Simply put, in Punjab working, historically established, *chak* level institutional arrangements in most cases were effectively mobilised from a dormant stage into a new active application. Again simply put, in SSP/Gujarat a highly individualised mode of water appropriation has prevailed, in the form of lifting water from canals with mostly diesel pumpsets by individual farmers. Palrecha and Kalakuri (2024) observe, for SSP/Gujarat, that “[f]armers owning individual pipe and pump systems sell surplus water to other cultivators in a manner similar to groundwater markets. Though water selling is widespread even with privately procured water, collective installation of pumps and pipes is not evidenced.” This is also because technically lifting water is considered illegal by SSNNL.

For Punjab the context and history of the *warabandi* system of irrigation is well-documented in the literature (Narain, 2008). The only surprise perhaps is that the dominance of groundwater irrigation through tubewells has not fully eroded and made disappear the local institutional arrangements for surface water distribution that are part of the *warabandi* system. Quite the contrary, it seems they were laying in waiting.

When the Gujarat government decided to go for UGPL networks in 2014, the institutional structure of open canal sub-minors was maintained in the implementation of UGPL networks at sub-minor level. Forming WUAs at the minor level with farmers' committees at the VSA (Village Service Area) level was an integral part of the UGPL-based distribution network. Only the technology was changed, from surface canal to underground pipeline, but the institutional setup with WUAs remained as envisaged.

This decision contrasted with the IWMI proposal. IWMI suggested distributing water through an entrepreneurial model, where a group of farmers or individuals would invest in laying the infrastructure for UGPL sub-minors and recover costs by selling water to the farmers (Shah et al., 2010). Contrary to this model, the SSNNL thus continued to make WUAs responsible for minors and sub-minors, while the operation and management of the SSP canal system, from the main canal head regulator to the minor canal head, remained with SSNNL. For sub-minors, a VSA coordination committee was to be formed to collect demands from farmers from each *chak* and consolidate them at the sub-minor level. This committee was to coordinate with WUAs for their operation and maintenance (O&M) needs. The designs of the sub-minors were finalized by a contracted agency, which had to enter into a tripartite agreement between the beneficiary farmers, the SSNNL, and the implementing agency at the *chak* level.

More than 3000 WUAs were formed, however, due to a lack of adequate social mobilising processes and unreliable water supply, the WUAs remained dysfunctional. Finally, in 2023, SSNNL gave up the idea of supporting WUA. With no institutional mechanism at the VSA level, the farmers had to fend for themselves to obtain water.

The government's preference for WUAs and IWMI's proposal for an entrepreneurial approach drew on existing institutional models elsewhere. The government's preference for a WUA model was a

continuation of the Command Area Development programme approach that had started in the 1980s. The IWMI approach referred to groups of farmers owning tubewell in Gujarat and entrepreneurial models in Maharashtra and other countries. Palrecha and Kalakuri (2024) compare the widespread existence of group ownership of tubewells for groundwater irrigation in Gujarat with the absence of such arrangements on canals. “One primary reason is that lifting water from canals is considered illegitimate, and thus policies for such practices are not considered.”

Also, lifting and transporting water from canals is affordable for a certain class of farmers, while giving them full control over water supply (when there is water in the canal at least). Palrecha and Kalakuri (2024) observe for SSP/Gujarat that “affordability of investments in pipes and pumps [for lifting water from the canals and guiding it to one’s farm, MMOD] is due to growing opportunities in off-farm livelihoods and the availability of agricultural loans for improving irrigation and agriculture.”

This suggests that historically emerged institutional arrangements were highly important in Punjab, and could be mobilised for the successful implementation of the UGPLs. Whether that ‘fit’ was by design or by default is not fully clear and needs further research. In SSP/Gujarat institutional arrangements were equally central to the outcome. This was a situation where new institutional arrangements needed to be crafted. There were different proposals on the table, one familiar to the engineers of the irrigation bureaucracy was chosen, but was not implemented effectively, and eventually abandoned.

7. CONCLUSION

The UGPLs in Punjab generally, but not universally, as observed in 2025 field research, work well in the sense that a *warabandi* schedule of water distribution is reinstated, apparently without too much of a problem in most cases and that canal water reaches the tail end (often after many years of dependence on groundwater pumping only). This is remarkable given that the dominant idea in the literature and policy discourse is that with paddy cultivation having become dominant in Punjab, the *warabandi* system has gone defunct. This may not be untrue, but the 2025 fieldwork suggests that the time-share-based distribution has been reinstated effectively and still seems to have a strong fit with the local conditions and institutions. The UGPLs have been constructed following the existing/older alignments of watercourses and field channels, and are basically just putting these underground. The networks do not make any changes in the delivery from the main canal system: the APM outlet structure stays in place, the UGPL network starts downstream of that. Our explanation for the ‘success’ of UGPL networks in Punjab is that it is a sociotechnical model that fits what already existed, even when what existed may have been dormant (*warabandi* rotation rules) or (partly) dysfunctional or even disappeared (watercourses and field channels). Our field research shows that *warabandi* is a strongly established (or maybe one should say embedded) institution that is mobilised and followed in practice when the opportunity and need arises. This success is also expressed in the high number of requests for the construction of UGPL networks by groups of farmer-irrigators (and the lack of sufficient funding to cater to all these requests, Rai, 2024). To what extent the ‘fit’ of the chosen approach is by design or by default is something that cannot be decided based on presently available research. It would require more detailed work on the evolution of the UGPL approach over time, that is, the innovation *process*, where this paper mainly looks at the innovation as a *thing*. The major enabling factor for the interest in UGPL networks by farmer-irrigators is clearly the declining quality of groundwater (see section 5). This is expressed in the frequent occurrence of UGPL networks in the southern part of the State, where groundwater quality is poorest. Even when surface water (of good quality) only fulfils a limited part of the water needs of (paddy) farmers, it is still highly welcome as a supplement to (poor quality) groundwater.

The ‘embeddedness’ and ‘fit’ observed in Punjab is exactly what is absent in Gujarat. Based on the authors’ 2025 fieldwork it is observed that at the very best UGPL networks in the SSP were used to some extent, and then mostly the main line (and not the bifurcations of it), in which the wells are convenient points for pumping water. There are a number of factors contributing to this. One is that farmers prefer individual pumping from the canal (group pumping was not found) and these pumping

arrangements were already in place before the UGPL networks were constructed (time lag between construction of different levels of canals). Another factor is that the irrigation bureaucracy is now supporting this, like in Mandvi, Kutch. There it allows pumping to non-command areas also and issues receipts for farmer payments of that (with the non-command area rate being higher than the command area rate). However, the effect is that the canal water only reaches up to a limited distance from the canal from which it is pumped. Two kilometres is a distance mentioned frequently. This means that large parts of the envisaged command area do not get any canal water. This type of inequality (basically a form of water grabbing) is accepted by default by the irrigation bureaucracy (and by implication by political leaders). How the thus deprived have responded to this is not clear and needs to be researched. It was shown above that this inequality has been observed by all who have looked at the field situation of water distribution since 2002.

This research started with the idea that perhaps lessons could be learnt from the Punjab experience that would be relevant elsewhere, including Gujarat. Given the different histories and designs of canal irrigation in Punjab and Gujarat (even when both have been designed as protective systems), the Punjab experience does not hold many lessons for Gujarat. The drivers for installing UGPLs in Punjab are different from those in Gujarat. For example, presently an important driver in Punjab is to push as much canal water down the canals so that Punjab comes closer to full utilisation of its Water Tribunal quota. A structural feature in Punjab is the declining quality of groundwater. In Gujarat, a major driver seems to be simply the desire to create infrastructure for water distribution. Since 2023, efforts at local institutional development have been abandoned.

A summary answer to the paper's research question what explains the different outcomes of UGPL network installation in Punjab and Gujarat, is that Punjab has a history in which a working local-level *warabandi* rotational water distribution system got established. This is not the case in Gujarat. There, the Narmada irrigation water arrived in situations where irrigation was new or where there was established individual and group-owned tube well irrigation. In the latter, water distribution functioned as a quasi-market (selling of pumped water to individual farmers). The government's chosen option of creating WUAs for UGPL network management did not bear fruit. That no collective/group farmer-initiated institutions emerged for surface water distribution has to do with the policy context (lifting of water from canals is formally illegal; WUA establishment was half-heartedly pursued and finally abandoned), and probably as well as, we suggest for further research, with the context of changed and changing agrarian relations (notably tenancy).

References

- Ghosh, K. and G.P. Rai. 2019. *Piped distribution of irrigation in SSP [Sardar Sarovar Project]: Making sense of the chaos*. Paper presented at the 3rd World Irrigation Forum (WIF3) on Development for Water, Food and Nutrition Security in a Competitive Environment, Bali, Indonesia, 1-7 September 2019. 7p.
- Kumar, R., Singh, K., Singh, B. and Aulakh, S.S., 2014. Mapping groundwater quality for irrigation in Punjab, North-West India, using geographical information system. *Environmental earth sciences*, 71(1), pp.147-161.
- Narain, Vishal. 2008. Warabandi as a sociotechnical system for canal water allocation: opportunities and challenges for reform. *Water Policy* 10(4):409-422.
- Palrecha, A. and H. Kalakuri (2024) Assessing the Performance of Underground Pipelines in the Sardar Sarovar Project, Gujarat: Lessons Learned. Report. IWMI and People in Centre.
- Panwar, P., Pal, S., Dogra, P., Premi, O.P., Kumar, M. and Khola, O.P.S., 2025. Economic Viability of Underground Pipeline Irrigation System Projects in Punjab: Evidences from Randomized Control Trials. *Indian Journal of Soil Conservation*, 53(2), pp.170-178.
- Rai, G.P. 2024. Accelerating Pipelining of Last Mile Canal Irrigation in Punjab: Identifying Constraints and Exploring Policy Options. PowerPoint Presentation at the IWMI-ITP Partners Meet 2024. The Nature Conservancy. September.
- Shah, T., Krishnan, S., Hemant, P., Verma, S., Chandra, A. and Sudhir, C. 2010. A Case for Pipelining Water Distribution in the Narmada Irrigation System in Gujarat, India. IWMI Working Paper #141.
- SSNNL (2010) Report of the Expert Group for Strategy for the Accelerated Development of Sardar Sarovar Project Command Area. May.

- Talati, Jayesh and J Liebrand (2003) Evolving Institutions for Irrigation Management in Sardar Sarovar Project Command, IWMI-Tata Programme, Anand, (unpublished paper).
- Talati, Jayesh and Tushaar Shah (2002) Institutional Vacuum in Sardar Sarovar Project: Framing Rules of the Game. IWMI-TATA Water Policy Programme (unpublished paper). Published as: Talati, J. and Shah, T., 2004. Institutional Vacuum in Sardar Sarovar Project: Framing 'Rules-of-the-Game'. Economic and Political Weekly, pp.3504-3509.