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Irrigated Agriculture and Farmers Behaviour in Pakistan's Inland Basin – Analysis of Scale Fitness

***[1]Tahira Syed and [2]Enamul Choudhury**

[1]Water Diplomacy Program, Tufts University, Boston, Massachusetts, USA
[2]School of Public and International Affairs, Wright State University, Dayton, Ohio, USA
*Corresponding Author: tahira.syed@tufts.edu

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ABSTRACT

Policies for water governance are often designed to operate along administrative boundaries while intended policy outcomes are expected at larger, often basin scale, thus creating an inherent scale mismatch between policy design and implementation. The question of which scale of policy is important is often evaded given the potential for complexity brought on by political boundaries that either compete with resource boundaries or totally disregard them. This paper argues that the underlying structural problems between policy design and successful implementation are due to the lack of scale-based thinking of behaviours of a range of actors-from farmers as water users to irrigation managers at subnational to policy makers in the national capital. Such scale mismatch generates inefficiencies and inequities that must be recognized and resolved for meaningful policy impact. Using the Scale-Descale-Rescale (SDR) analysis, policies are unpacked across multiple governance and resource use scales to show how scale mismatch interplays using primary data from farmers. The study established that ignoring scale mismatch in critical assumptions of policy design and implementation arrangements is hindering full realization of policy outcomes. The study also identified specific areas of adjustment for an improved outcome of policy objectives.

INTRODUCTION

Issues of scale-fit have a long history in ecological science research. The lack of fit between scale of resource boundaries and governance boundaries is what scholars have called the archetypical problem of scale in environmental governance (Young, 2002; Cash *et al.*, 2006). In considering scale misfit, the issues of mismatch or misalignment as well as overlap between resource and governance boundaries are both relevant (Hajer and Wagenaar, 2003; Termeer *et al.*, 2010). Any attempt at recognizing scale misfit also requires an explicit recognition of the problems of blurred boundaries between politically defined jurisdictions, overlapping authorities with duplicate functions, and conflicting responsibilities for decision making within the institutional tiers at various scales. Scale often refers to various dimensions including spatial, temporal and systems (Gibson *et al.*, 2000; Cash *et al.*, 2006). This paper uses the spatial dimension of governance scales such as national, province, and district, to show how policy design and structures embody cross-scale interactions over multiple jurisdictional boundaries (Syed and Choudhury, 2018).

For water governance policies, policymaking is often confined to the national and sub-national governing units, with little, albeit, growing acknowledgment of their misalignment with resource boundaries that follow the course of watersheds and river basins. A key challenge in designing scale-appropriate policies is that the institutional structures are often organized along governing units, instead of ecological units where these problems occur. Most scholarship on appropriate governance arrangements for social–ecological systems, addresses either the very local level or the broad international or global level (Schoon and Cox, 2018). Matching resource boundaries with governance boundaries have evolved into a subset of concerns in contemporary policy design for common-pool resources

(Bernstien *et al.*, 2018). Within the water governance discourse, the past few decades have seen a clear shift towards holistic, integrated, and inter-sectoral approaches such as integrated water resources management (IWRM) as well as incorporating the basin-wide considerations into policy frameworks such as the European Water Framework Directive (Moss, 2012; Green *et al.*, 2013). Yet, there is little convergence in terms of systematically recognizing scale misfits (Padt *et al.*, 2014) and incorporating these into policy design and institutional structures (Grafton *et al.*, 2018).

Whether a broad spectrum of policy would work for all stakeholders, or a more differentiated, fit-to-scale policy approach is needed remains an open question. There is no systematic way to analyze and align governance and resource boundaries to arrive at the best-fit policy options. While the IWRM approach promotes scale-awareness, it does not provide meaningful way to operationalize scale fit into policy making. IWRM policy approach builds on the premise that river basins are appropriate units for management but there are no useful ways in which the governance units of municipalities, provinces, or even states or nations become aligned with resource management units of catchments, sub-basins, and basins (Cohen, 2012). However, the notion of river basins as natural boundaries for water governance is also contested based on heterogeneity and complexity of interactions among institutions and stakeholders exerting influence over decisions regarding managing natural resource systems across scales (Pahl-Wostl *et al.*, 2012; Padt *et al.*, 2014). Despite these insights into scale issues, there is little agreement on how to systematically study the effects of scale misfit in policy designs (Chone, 2012; Pahl-Wostl *et al.*, 2012). Scholars emphasize various aspects in considering scale issues such as the need for elaborating normative aspects of evaluating scale-sensitive governance (Padt *et al.*, 2014); the importance of understanding the behavior of non-state actors at different scales (Norman and Bakkar, 2015) as well as the need for redesigning governing structures through rescaling processes (Cohen and McCarthy, 2015). However, partial application remains problematic in understanding scale issues when only few areas, geography, or institutional structures are considered without the accounting of the heterogeneity of actors, institutional tiers and multiple locations in the policy chain.

To overcome the practical limitations in designing appropriate analytical tools that can be applied to multiple scales across different governance and resource boundaries, a reframing of scale fitness is needed. For consolidated analysis, both the governance scale of observation (e.g., sub-national, national, or global) as well as resource scale of observation (e.g., catchments, watershed, sub-basin, and basin) must be acknowledged. Most water governance problems result from the mismatch between the scale of human actions and ecological systems, and decisions at one scale influence results at multiple scales. This paper shows how to consolidate and analyse impacts from different scales through a new tool, the Scale-Descale-Rescale (SDR) that addresses the key questions of how to measure scale sensitivity, incorporate stakeholder views and their actions at multiple scales, both to better inform policy making and implementation.

MATERIALS AND METHODS

Description of Study Area

The Indus River is a transboundary river basin shared by Afghanistan, China, India and Pakistan with a total area of 1.1 million square kilometer (Figure 1). The Upper Indus Basin originate in the Hindu Kush, Karakorum, and Himalayan Mountain ranges. The Lower Indus Basin drains through the plains in Pakistan into the Arabian Sea. The largest portion of the basin flows through Pakistan territory (65%) in the provinces of Punjab and Khyber Pakhtunkhwa and most of the territory of Sindh province and the eastern part of Baluchistan province.

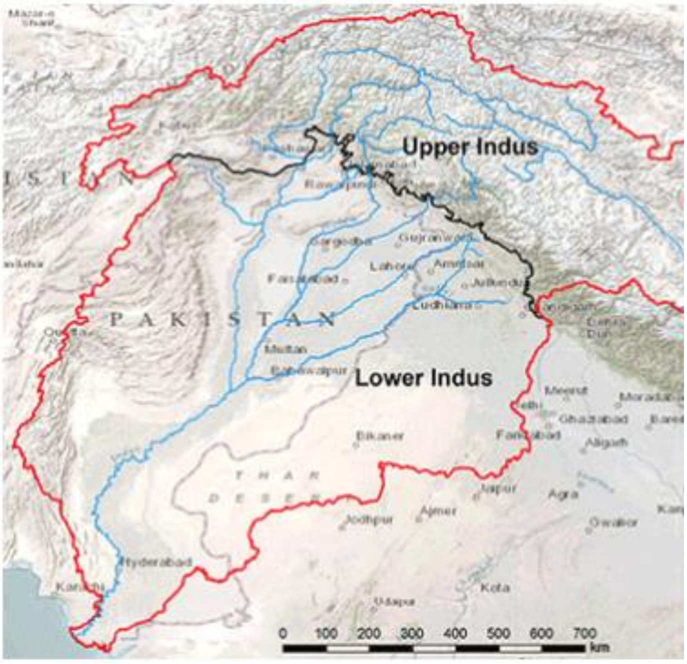


Figure 1. The Indus River Basin

The Indus River is the twelfth-largest drainage basin in the world while its irrigation network – the Indus Basin Irrigation System (IBIS) – is by far the largest contiguous irrigation system in the world, comprising 3 storage reservoirs, 19 barrages, 12 inter-river link canals, 40 major canal commands and over 120,000 watercourses. While the IBIS is recognized for its elaborate distribution network, the storage capacity remains low at only 18% of the potential developed so far which is about 30 days of annual flow – nearly 30 times less than that of other large river basin systems such as the Colorado Basin and Murray-Darling Basin (Condon *et al.,* 2014).

Given that nearly 65% of the country area of Pakistan is irrigated through the Indus Basin, (47% of the Basin area), the water demand for irrigated agriculture is understandably more significant for Pakistan. This study, therefore, focused on Pakistan part of Indus. Using quantitative and survey methods, data was collected through a questionnaire, and the population was 170 farmers in the provinces of Punjab and Sindh in Pakistan part of the Indus Basin. Sampling method was stratified. A semi-structured survey was conducted to collect data on water and land use practices from different irrigation canal command areas (CCAs) for two Kharif (summer) crops of 2016 and 2017. Survey respondents were identified through the provincial on-farm water management departments in each province which maintains the lists of farmers currently benefitting from the government subsidy program for adoption of high efficiency irrigation technologies. In Punjab, 3 CCAs where program is currently under implementation were identified for farmers' survey: (1) Thal canal on the main Indus River; (2) Lower Jehlum on the Jehlum River; and (3) Hakra branch on the Fordwah Eastern Sadiqqia Canal on the Sutlej River. In Sindh, a focus group discussion with held using the survey questionnaire with farmers from lower-Sindh districts which covered the CCAs of Phuleli and Pinyari canals. In Punjab, 6 districts across 3 canal command areas were survey through farmer surveys and field observations to study the impact of HEIS interventions (drip irrigation technology). In case of Sindh, the survey was administered randomly in 3 districts (Figure 2). Information on farmers' profile in terms of farm location, total landholding size, landholding with drip irrigation, and water use before and after drip adoption was acquired from the on-farm departments in Punjab and Sindh. The survey asked additional questions regarding farmers' decision-making process for water and land use, their knowledge about water and land use of farmers from other locations, what influenced them to participate in government's program, and their desire to learn about similar programs in other CCAs or across provinces. The geographical locations of the surveyed farmers spread across 5 districts in Punjab and 3 districts in Sindh province. A total of 170 farmers – 152 in Punjab and 18 in Sindh.

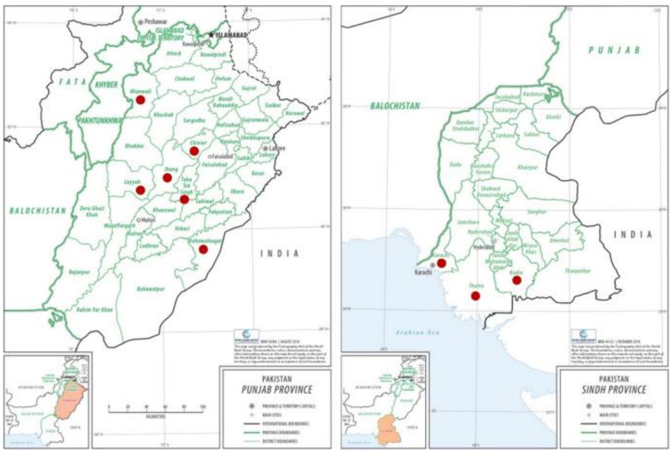


Figure 2. Location of study districts in Punjab and Sindh

Methodology

Scale-Descale-Rescale Analysis Tool

Global water governance literature acknowledges issues of competing interests among multiple actors with little agreement on how to incorporate these into policy action (Lebel *et al*., 2005; Gupta and Pahl-Wostl, 2013). History of water governance policies in the Indus Basin is no exception to the complexity of interconnected issues that are spread over wider political, socio-economic and governing systems and compete for priority status. What is common between water governance policies in the Indus Basin and any other large transboundary basin are the aspirations of implementing the principles and attributes of equitable delivery of water services, participation of stakeholders in the policy process, while operating within political, social, economic and cultural constraints (Groenfeldt and Schmidt, 2013). Often sectoral policy making to operationalize the overall water governance is considered the best way to perceive and address desired principles into policy design and implementation (Pahl-Wostl *et al.,* 2008). While the process of deconstructing water governance into sectoral segments of irrigated-agriculture, domestic and urban water supply, sanitation, industrial supply, and environmental services, etc. might provide better context for decision making, sectoral policies are often limited to governing units for implementation (Norman *et al.,* 2013; Norman and Bakkar, 2015). In this deconstructed approach of sector-specific water governance policy making, the issues of scale-fit are critical to formulate procedures and mechanisms for reaching agreement among actors across various jurisdictions (Moss, 2012). To achieve optimal performance, matching the scale of governance with scale of resource being managed (Ulibarri and Garcia, 2020) is an important consideration in policy formulation.

The complexities of designing institutions and vertical and horizontal flows of information across multiple scales is problematic due to lack of any systematic way to integrating multiple scales within policy designs and implementation (Syed *et al.,* 2020). To delve into the types of problems created due to such scale misfit, the Scale-Descale-Rescale (SDR) analysis tool is used (Figure 3). The SDR analysis tool first establishes the current scale (S) at which a given policy applies; it then descales (D) the policy to multiple scales and levels followed by a reconstruction (R) at basin scale to identify the cumulative outcomes from a rescaled policy perspective.

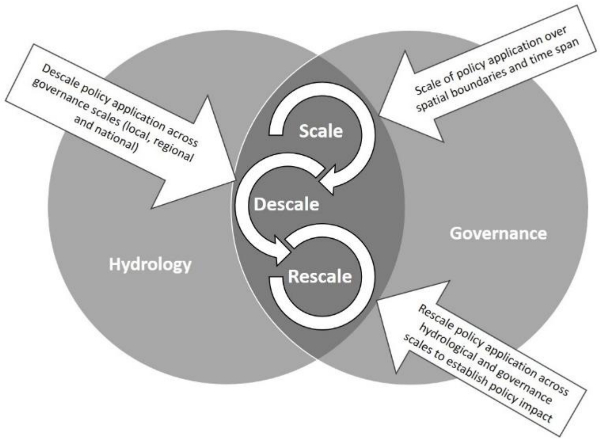


Figure 3. Scale-Descale-Rescale Analysis Tool (Syed *et al.*, 2020)

In the absence of a well-established analytical approach to operationalize scale-sensitivity assessment of water governance policies, SDR provides a reframing of scale issues by breaking up the current scale into multiple smaller and larger units for understanding what scholars call the vertical interplay between different levels of governance (Young, 2002). The SDR analysis presents the issues around multilevel governance and the wider range of actors operating at different jurisdictional levels in a consolidated manner by considering interactions among actors at multiple levels within a given governance or resource scale as fundamental to understanding the decision-making process behind their actions. The SDR builds on the premise that solutions to policy harmonization are seldom available at one scale and often involve a process of matching multiple levels of one scale with multiple levels of another to address the spatial mismatch of environmental governance policies (Young *et al.,* 2006). The SDR provides the analytical means for recognizing scale mismatch between policy impacts at multiple scales to assess the attainment of the expected impacts in a differentiated and cumulative manner.

In this paper, the authors considered the interactions between farmers as water and land users interacting with the on-farm water management departments of the provincial ministries of agriculture in Punjab and Sindh in the context of Indus Basin. We examined the existing irrigated-agriculture policies as the broad set of water governance policies in the Basin and use information on farmers' water and land use practices at the on-farm level to describe the implications across multiple scales.

RESULTS AND DISCUSSION

Water Governance Policy and Scale Implications in the Indus Basin

There is a growing debate on whether a perfect scale-fit exists in water governance of large river basins especially the transboundary basins (Termeer and Dewulf, 2014; Moss, 2003). To fully appreciate and adjust for scale-fit of water governance policies, the key is to determine the rationale for choosing specific spatial units over others (Daniell and Barreteau, 2014). In the absence of such rationalization, new boundary problems are likely to emerge if policy planners and water managers replace existing institutional structures with new ones, thus creating potential new scale misfits.

For the Indus Basin, this debate is relevant because the Indus remains a heavily engineered basin for distribution of water supply that has created overlapping social, economic, political and governance boundaries within the basin. The spatial units created in the Indus Basin for irrigated agriculture are classified into canal command areas (CCAs) representing a catchment management approach (Hussain *et al.,* 2007). On the other hand, the water governance policies for the Indus Basin rest on political administrative units of national and provincial governments whereas implementation of the policies occur within the CCAs. However, the CCAs are not formally recognized as water management units in the Indus Basin and any given CCA falls under multiple districts and tehsils which constitute the administrative units.

To overcome the mismatch between water management and governance units, a decoupling of institutions is required since processes in one scale create flows or externalities that produce multi-level, cross-scale, or rescaling effects. An example of these flows or externalities is the upstream-downstream interactions that create unintended policy implications when water abstracted upstream is no longer available for use downstream. If the basin is considered a unified system, then actions in upstream are generating externalities in the downstream by changing the water flow (Daniell and Barreteau, 2014). This is relevant for the Indus Basin given the persisting tensions between Punjab as upstream and Sindh as downstream riparians over water availability in the canal distributions system. Such externalities may include political and social as well as some irreversible ecological effects such as flows including the time of passing, which lead to cumulative effects that are difficult or impossible to reverse (Daniell and Barreteau, 2014). In the context of the Indus Basin, the decoupling of institutions would require separating water and land users from irrigation managers and water governance policy makers. Each layer of these institutional tiers interacts across scales and levels thus creating a connected web of vertical and horizontal interplays between different institutional levels responsible for managing the resource (Young, 2006; Hüesker, and Moss, 2015).

The relationship between canal irrigation supply and groundwater use is another important consideration in the context of the Indus Basin. In most CCAs, the geographical overlap between groundwater aquifers and canal supplies is unevenly estimated, resulting in a misfit between resource availability and use. A descaled analysis of practices at on-farm water and land-use could provide clearer understanding of how farmers make certain choices in order to reduce the potential negative effects of existing policies. Thus, a reconfiguration of policy outcomes at multiple scales is needed to address these misfits and assess the need to create new institution or adjust existing ones to better align the water management units with governing units. In the following sections, the current scale of irrigated-agriculture policies in the Indus Basin is established followed by descaling of water and land use practices of farmers at CCA level. The purpose is to show what the key influencers for their on-farm practices are, and how these practices interact with policy design.

Current Scale of Irrigated-agriculture Policy

In the Indus Basin, the current scale of irrigated-agriculture policy design is most clearly driven by governance boundaries whereas implementation takes places at resource boundaries of CCAs. The policies are set at the provincial level with some differences allowed for a given location, water availability, and agronomic and climatic characteristics of different provinces. Punjab and Sindh follow similar policies for irrigated-agriculture that promote agricultural productivity and reduction in on-farm water use through land-levelling, efficient irrigation delivery and adoption of water-saving technologies. There is limited cross-provincial collaboration or coordination in policy implementation, with each province implementing programs to achieve policy outcomes independently of others. However, the intended policy outcomes in both Punjab and Sindh reflect that their current irrigated-agriculture programs will contribute to reducing the stress on Indus Basin's water resources by increasing water productivity at the farm level, thereby, ensuring food security, economic uplift of small farmers, and improving economy of the province and the country as a whole (GoPunjab, 2016; GoSindh, 2017).

The policy targets farmers' behavior for adopting practices that will promote efficient use of water and other farm inputs. These include adoption of high efficiency irrigation technologies such as drip and sprinkler systems, precision land levelling and improved water conveyance through lining of watercourses. Each province has set a target to achieve the current scale of policy implementation. Key program targets are presented in Table 1. The implementation of both government programs is focused at the farm level while the current scale of policy impact remains focused on the provincial level. The rational for maintaining this scale of policy implementation assumes that farm-level practices will collectively achieve reduction in water use as a desired outcome (that is, beyond a single farm or any number of farms) through collective action of farmers resulting in production of more food crops with less water and other inputs. Another significant feature of the irrigated-agriculture policies in Punjab and Sindh is the monetary incentive offered to farmers adopting these practices. The monetary incentive is almost entirely focused on adoption of drip and sprinkler irrigation technologies, with each provincial program offering 60 percent of the initial capital cost and the farmers contributing the remaining 40 percent.

Table 1. Irrigated-agriculture Policies in Punjab and Sindh

Irrigated-agriculture policy	Punjab	Sindh
Program timeline	2012-2021	2015- 2022
Area under water-saving technologies (acres)	120,000	35,000
Monetary subsidy for technology adoption (%)	60	60
Watercourse improvement (units)	5,500	5,500
Precision land levelling (units)	3,000	1,100

Overall, the policy targets and implementation timelines are similar between the Punjab and Sindh provinces. The provincial focus of irrigated-agriculture policy is rationalized by the National Water Policy which states that while water resource is a national responsibility, irrigation, and agriculture as well as rural and urban water supply, environment and other water related subsectors remain provincial subjects (GoPakistan, 2018). The National Water Policy even prescribes those provincial policies must reflect the concept of more crop-per-drop through measures including discouraging fold irrigation and promoting crop diversification to high yields, low water consumption, heat and drought tolerant, as well as disease and pest resistant crops (GoPakistan, 2018).

In line with the National Water Policy, the provincial policy in Punjab prioritizes demand management through water conservation, improving irrigation efficiency, increasing water productivity, adjusting cropping patterns, developing water-food-energy nexus and population control (GoPakistan, 2018). In the case of the Sindh province, while water policy is yet to be formulated, a consensus between various water management agencies in the province and civil society organizations exists with similar priorities for the province (CSCCC, 2018). In both provinces, the current scale of policy implementation is focused at the farm level while the desired policy impact is targeted at the provincial level. The current scale of policy design and implementation in Punjab and Sindh seems to be aligned with the concept of incorporating collective action approach in policy making, that is, the expectation that the combined effect of farmers' practices will result in the desired policy outcome. However, to know whether this assumption is achievable or not requires the unpacking of farmers' practices below the current scale of the province. This allows for identifying the actual impact at multiple scales both below and above the current scale.

A closer look at the irrigated-agriculture policies in the context of Indus Basin shows that the current policy design remains along governance boundaries of province. On the other hand, to implement provincial policies, all actions are designed at local scale with CCAs as the main resource boundaries for farmers' practices (Figure 4). The current policies are also guided by the boarder vision of water governance for the Indus Basin set at the national level with aspiration of basin scale impacts. Whether the basin scale impacts are achievable through current policy design can be best answered through unpacking the current implementation arrangements to see how these contribute towards a basin scale impact.

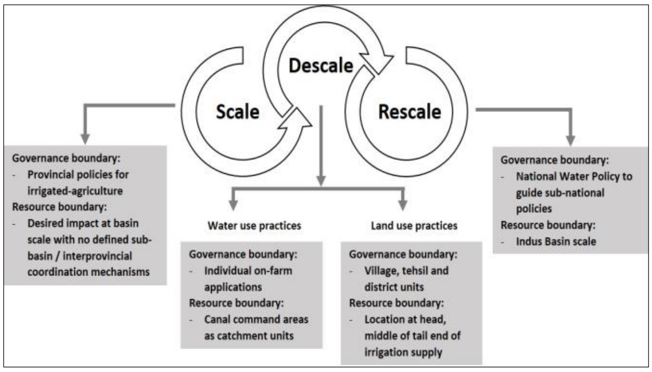


Figure 4. Scale-Descale-Rescale Analysis in the Context of Indus Basin

Descaling Water Governance at Multiple Scales

For a descaled analysis of the water governance policies in the Indus Basin, the study considered the existing programs for implementing the irrigated-agriculture policy in Punjab and Sindh. It examined differences along CCAs since these represent key catchment units at sub-basin scale in the Indus Basin.

At the time of the survey, the farmers have been implementing the government programs of adopting water efficient technologies, for at least one cropping season. Farmers reported having installed drip irrigation technology prior to the 2016 Kharif season and successfully operated the drip system during the 2017 Kharif season. To compare the water usage before adoption of drip irrigation technology (pre-adoption), the famers provided information on water use from 2016 Kharif season. The water use data for 2016 Kharif season is based on self-reporting of on-farm application, while data for 2017 Kharif season is based on actual meter readings from drip pumps. To ensure consistency of the units measured, landholding under flood irrigation prior to drip adoption was excluded. Landholding installed with drip system is the only area that was considered in order to register the before and after adoption effects. For this study, given the governing scale of a province, the information from agricultural water and land use survey is used for descaling the current policy implementation to lower resource use levels at individual CCAs.

Descaling Water Use

The survey shows that the water and land use vary among the farmers in each canal system. Water use in two (2) CCAs in Punjab (Thal and Hakra canals) was reduced after farmers adopted water efficient technologies. However, water use increased in the Lower Jhelum CCA after the adoption of similar irrigation technologies. Farmers could report actual water use with a higher degree of confidence due to the built-in gauge in drip irrigation filters for measuring actual water quantities, used from one application to another. Farmers also reported changes in crop type -- from water intensive wheat and rice to high value horticulture crops comprising of vegetable and fruits.

In the case of vegetables, the farmers also reported the additional benefit of shorter cropping cycle as an opportunity to increase cropping intensity and to produce multiple crops in a single cropping season. However, conventional irrigation through the flood method continues, and farmers tend to increase cropping intensity as well as the area under irrigation after their adoption of drip technology. Figures 5 (a), (b) and (c) present the changes in water use prior to and after technology adoption in each command area.

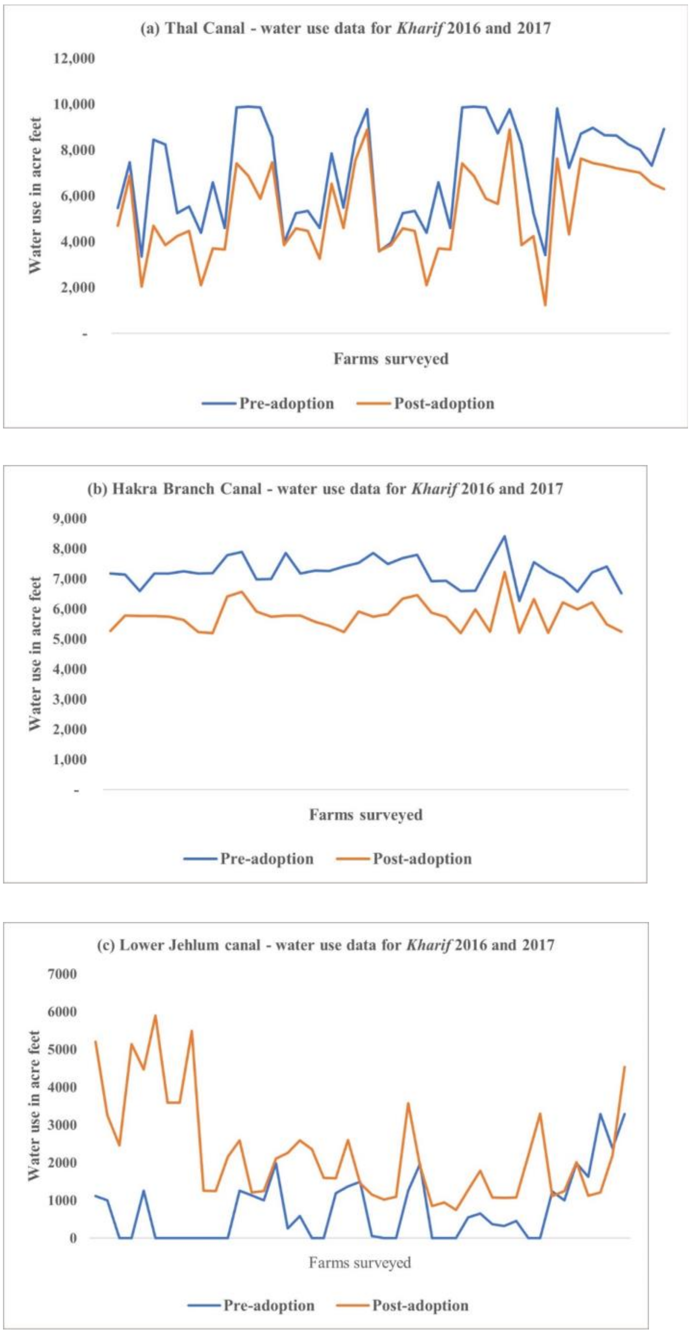


Figure 5. Water use pre- and post-adoption of water efficient technologies. (a) Thal canal; (b) Hakra branch canal; and (c) Lower Jhelum canal

The survey findings revealed significant water use reduction in the Hakra branch canal at 67 percent followed by 38 percent reduction in the Thal canal. Given the poor quality of groundwater, farmers mainly relied on canal supplies and precipitation for crop production. Thus, crop yields remain highly varied between seasons due to water availability. With drip irrigation, the crop water requirement is optimally defined for root-zone application, and therefore, with the same quantities of water as used for flood irrigation, farmers are now able to produce crops with higher yields. Out of the total 82 farmers surveyed in these two canals, nearly 52 percent (43) are located at the tail-end of canal system (Table 2). On the other hand, farmers surveyed in the Lower Jhelum CCA, reported an increase of 46 percent after the adoption of drip irrigation technology, even though, out of the 70 farmers surveyed in this canal system, nearly 53 percent (37) are located at the tail-end of the irrigation supply.

Table 2. Number of farmers located on head, middle and tail-end of canals

Irrigation Canal	Head	Middle	Tail
Hakra branch canal	2	7	27
Thal canal	12	18	16
Lower Jhelum canal	9	24	37

In the Lower Jhelum canal, the increase in water use is also associated with farmers' ability to bring larger land parcels under cultivation after the adoption of drip irrigation technology. These farmers reported using flood irrigation method to irrigate their crops but could not cultivate consistently each season due to fluctuations in water supplies. With drip irrigation, these farmers changed to production of horticulture crops mostly vegetables while continuing to use flood irrigation method for wheat and rice. On the other hand, farmers in Hakra canal reported acute water shortages in canal supplies and farmers often mixed surface water with groundwater without much consideration of the resulting quality of water and its effects for crops and land salinity. This practice led to higher salinity in the area (Hussain *et al.*, 2007) and consistent degradation of irrigation water quality in the command area was assessed to be much higher than the international standard of good quality irrigation water.

Despite the increased water use in the Lower Jhelum canal, the cumulative water use between the three studied canals studied show a decrease by nearly 25 percent. The inter-canal command variation in water use not only show how individual farmers decide to make use of available water for irrigation but it also reflects a deeper expression of class politics. In addition to the farmers' water use decisions, the class politics are also expressed through the farmers' total landholding sizes and how much risk they are their willing to take by converting portions of land to drip irrigation. Therefore, farmers' water use and technology adoption practices need to be seen in conjunction with their land use patterns to fully understand the implication for irrigated agriculture.

Descaling Landuse Pattern

To understand how class differences among farmers relate with scale misfit in the irrigated-agriculture policy, a descaled analysis of farmers land use practices pre- and post-adoption was also conducted. Farmers located close to the head or middle of the irrigation supply system versus those located at the tail end, made decisions regarding land use differently. In both the Hakra branch and Thal canals, most farmers were smallholders with 50 acres or less landholding size. However, in the Lower Jhelum CCA, landholdings varied significantly with farm sizes ranging between 30 to 200 acres with several large-holders having holding sizes of over 150 acres. The survey results show a clear inclination of higher risk-taking behaviour among the smallholders. As most of the smallholders surveyed are located at the tail end of the irrigation supply, these farmers reported irregularity of canal supplies, poor groundwater quality and significantly lower per capita water requirement for drip system as the key reasons for their decision to adopt the drip systems. The peer-to-peer demonstrative effect among smallholders was another key factor reported by farmers for their decision to install drip irrigation. On the other hand, land conversion from flood to drip irrigation varied among smallholders and large farmers as shown in Figure 6 below. Majority of smallholders decided to convert major portion of their total landholding under drip system compared to the larger farmers from the Lower Jhelum canal. While a higher portion of landholding is brought under drip irrigation by the smallholders, the large farmers continued to rely on flood irrigation on parcels without the drip system.

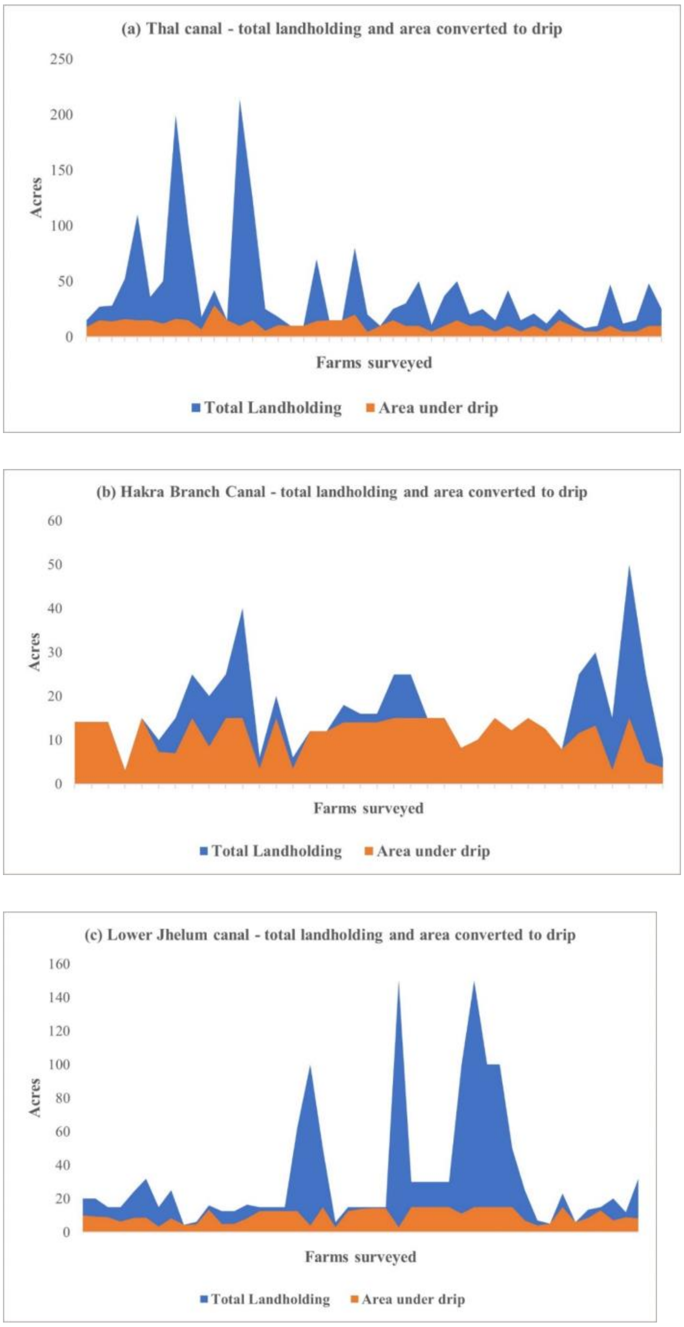
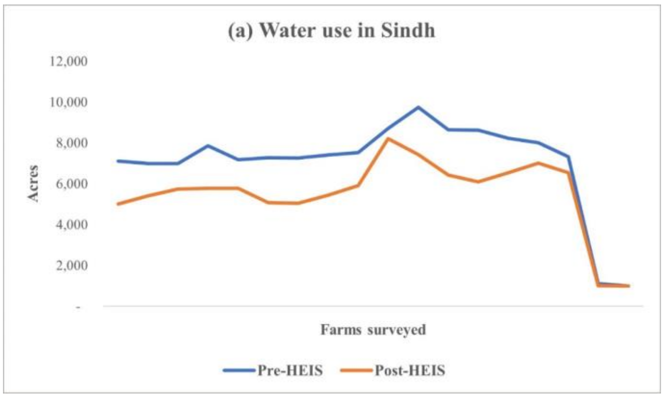


Figure 6. Total landholding and area installed with drip irrigation. (a) Thal canal; (b) Hakra branch canal; and (c) Lower Jhelum canal

While most farmers in the Thal and Hakra canals were smallholders, however, when compared for their decision to convert land parcel under drip irrigation, farmers in the Hakra canal showed a higher inclination towards risk taking by converting a larger portion of total landholding under drip irrigation (Figure 6b). On the other hand, most farmers in the Lower Jhelum canal were medium to large-holders and they show a more cautious approach of converting smaller parcels of their total landholding under drip irrigation. The farmers in Lower Jhelum canal reported that despite the available subsidy from government, converting a larger portion of land required higher upfront investment which discouraged farmers from converting more substantive portions of their landholding under drip. At the same time, farmers report additional social and economic benefits including crop uniformity, effective weed control, reduced soil erosion, reduced labor cost for production, and recued electricity cost in operating drip irrigation pumps as opposed to tube wells.

Rescaling to the Basin Scale

To rescale the water and land use practices to a higher governance scale than the provincial, similar data was collected from farmers located in 3 districts of Sindh. Using the same agricultural water survey, a focused group discussion with 18 farmers was held in collaboration with the Sindh on-farm water management team. In the case of Sindh, the rate of adoption of drip irrigation technology was lower than in Punjab. Combining the findings form 3 CCAs in Punjab with that of Sindh, a similar trend is observed. Farmers in Sindh reported reduction in water use post-adoption of drip irrigation system with a cumulative decrease of nearly 22 percent (Figure 7a) and conversion to drip irrigation on a small portion of their total landholdings to test the drip system (Figure 7b). Thus, factors contributing to farmers' decision of technology adoption in Sindh remained similar to those in Punjab. Sindh farmers also reported the influence of demonstrative effects after observing neighbouring farmers who enjoyed higher yields and incomes post-adoption.



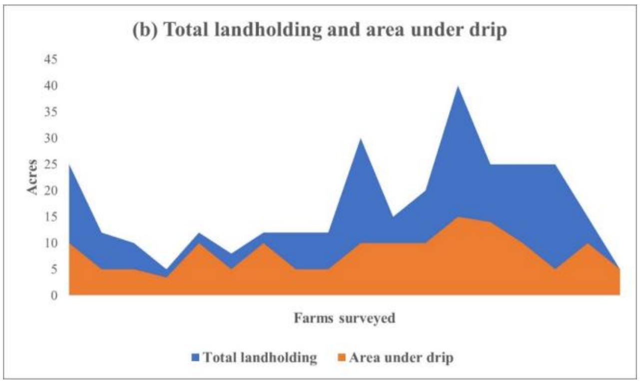


Figure 7. (a) Sindh - water use pre- and post-adoption of drip irrigation technology, (b) Sindh - total landholding and area installed with drip irrigation

The farmers surveyed in Sindh were all smallholders with an average landholding of 17.1 acres. Most farmers engaged in horticulture crops and stated insufficient canal supplies to irrigate the entire landholdings. With the adoption of drip irrigation, these farmers reported their priority would be to expand the area under irrigated agriculture to their entire landholding. The Sindh farmers expressed an interest in learning about the impacts of drip technology in Punjab as well as other districts in Sindh and reported that the farmer-to-farmer interactions has been the key influencing factor in their decision to adopt drip irrigation technology. Unlike farmers in Punjab, some farmers in Sindh stated that government subsidy was an attractive consideration in their decision. However, financial constraints limited their ability to convert a significant portion of their landholding under drip. The Sindh farmers also stated that irrespective of proximity to the canal system, the uncertainty of water availability and increasingly dwindling supplies were constant risks they face, and after testing the drip system on a small parcel, they may increase the land under drip.

The observability of on-farm level practices versus aggregated farmers' behaviors at higher scales creates an impression of successful policy implementation. For instance, all farmers surveyed reported that demonstrative effect of their neighbors having adopted drip irrigation and farmer-to-farmer exchange of information on the benefits of drip irrigation were the highest rated factors in adopting the drip technology. While this interaction is possible at lower scales – among farmers – for higher scale interactions among farmers and water managers, no specific mechanisms exist that promote information sharing and cross-scale communication among different stakeholder groups e.g. farmers, water manager, extension workers, input suppliers, and policy makers.

However, for cumulative effect of policy at multiple scales, implementation needs to be monitored at multiple scales and levels with systematic delineation of cross-scale effects of water and land use patterns. One way to monitor multi-scale impacts is through carrying out water and land accounting at each scale. Such accounting will include measuring water quantities extracted from surface and groundwater sources as well as land cultivation patterns from one season to another. In addition, to assess net reduction in water use at basin-scale, key constraints need to be addressed such as inadequate estimates of inflow and outflow at CCAs levels and changes in fallow land versus cropped land. Even with addressing these constraints, an inter-scale information flow mechanism would be required for cross-scale communication of data on water allocation, actual water availability, land holding and actual cultivated areas. While there is an acknowledgement among farmers to recognize basin-wide implications of their water and land use, the immediate objectives of achieving crop yields and increased income take precedence over long-term objectives of achieving basin-level water savings and the farmer-behaviour of reducing personal water use. In addition, certain inequity effects are created due to the scale limitation of current policy promoting technology shits. For example, without scale-specific information, the adoption of technology does not change the water status of farmers. Large landholders and rich farmers reap higher benefits from subsidies as compared to the smallholders. This finding is also substantiated by other studies such as Grafton *et al.* (2018) that show while subsidies for drip irrigation improved farm incomes for all participating farmers but for farmers with larger landholdings the added ability to use less water meant they increased the irrigated area as they saved costs on inputs. The smallholders on the other hand could only marginally increase irrigated area even with savings on costs on inputs. Furthermore, the problem of scale misfits undermines the long-term prospects of water sustainability, thereby, aggravating the inequities that are already present.

Scale Mismatch–key Insights from the SDR Analysis

Scholars have long advocated consumptive water use with combined accounting of surface and groundwater sources as an appropriate measure of resource availability and informing decision making processes (Carter and Driscoll, 2006; Chen *et al.,* 2018). Similarly, researchers argue that water cycle and land management are inextricably linked and that every land use decision is a water use decision (Bossio *et al.,* 2010). However, current water governance policies in the Indus Basin continue to lack evidence backed analyses. As can be seen in the SDR analysis, farm-level water and land use patterns are reflective of how famers as the key water users decide to use resources available to them. Understanding these patterns and the shifts that occur in water and land use are useful considerations for policy design. It follows that the underlying social, economic, political and institutional dynamics of land use need to be integrated with water use management (Bossio *et al.,* 2010). A deeper understanding of why farmers do what they do with regards to irrigating their crops and managing their land for agricultural and other uses is needed for informed policy design.

Problems of Boundaries and Interplays

In the Indus Basin, water and land use practices differ across CCAs resulting in varying degrees of water consumption and land management decisions that cascade up to sub-basin and basin scale. Evaluating the behaviour of water users is an important design feature to irrigated-agriculture policy as it shows that water use is not constant, as it varies from farmer to farmer and between one parcel of land to another, as well as on the social status of the farmer, soil conditions, weather condition and crop choices (Grafton *et al.,* 2017). For the farmers surveyed in this study, reducing water use is not the primary concern for farmers, even when they appreciate the significant drop in amount of water required for irrigating their fields after converting to drip irrigation. Decision to adopt efficient irrigation technology adoption is purely for economic gains and not resource conservation. The sense of entitlement of water allocation drives farmers' decision to use as much water as available to increase the total area under cultivation. The land use decisions are not aligned with issues like soil erosion, nutrient depletion and other forms of land degradation. Similarly, technology adoption for improving irrigation efficiency sometimes happens in a political and economic context where farmers adopt 'new technology' to either take advantage of the subsidies or to enhance their social status after observing neighbours' adoption and resulting increases in yields Grafton et al., 2018). In the absence of regulatory policies on groundwater and land management, farmers adopt efficient technologies in order to intensify production rather than to conserve water and land resources. Technology adoption is seldom reported as a means of controlling groundwater extractions or altruistic water savings for another user's benefit. When rescaled to the basin, these effects refute the intended policy objectives and render such policies practically ineffective (Wyborn and Bixler, 2013).

Problems of Cross-scale Communications

A cross-scale communication flow could resolve the dilemma faced by water resource managers in the form of successful reductions in water use at local levels with little cumulative outcome for overall policy success. Researchers refer to the requirement of establishing mechanisms such as stakeholder consultations, policy dialogues, and farmer-to-farmer exchanges, etc. can serve as cross-scale brokers for addressing communication challenges. These mechanisms are critical for policy design given that successful policy implementation depends on local support, thus requiring good communication between the different scales of planning and action (Levidow *et al.*, 2014). In the Indus Basin, while the famer-to-farmer interaction happens at CCA levels, no specific mechanisms exist for cross-scale communication between farmers from one CCA to another. This is not surprising, since, neither farmers nor irrigation managers are required to communicate in a cross-scale fashion.

Similarly, there is no provision for information sharing among different institutional tiers e.g. farmers, water manager, extension workers, input suppliers, and policy makers, neither in Punjab nor Sindh. Information regarding shifts in water and land use from one scale to another is not normally exchanged between provinces despite the apparent similarities in farmers behavior in each province. Neither the farmers nor the water managers have any means to appreciate the collective consequence of implementation actions at the CCA level. As a result, the disconnect persists between on-the-ground conditions and famers decision making behaviors as well as the information campaigns and extension services that are offered to the farmers.

To address the scale misfit, a concerted communication flow is needed to transfer knowledge across multiple CCAs and the provincial on-farm departments, which are the main custodians of policy implementation at provincial level. This can be carried out through a knowledge-exchange system that helps farmers and water managers understand the cumulative effect of their actions at localized scales. Such knowledge-exchange system will also address the consistency issues faced by famers in accessing information on crop-specific water use, actual irrigation applications, crop-specific yield response to different irrigation practices, and potential on-farm water-efficiency levels.

Problems of Class and Politics

When rescaled to higher spatial units, analyses of land and water management at multiple scales reveal new insights of human-environment interactions through identifiable patterns of social, economic, and political class differences [29]. Similarly, how institutions and other stakeholders interact with one another as well as behave within their own groups, can change the scope of influence that the stakeholders exert on natural resource systems. Yet there is a lack of systematic approach to categorize the actors and consequences of their behaviors according to their respective governance levels (Padt *et al.*, 2014). To adjust policy making a political economy perspective is encouraged by scholars, who argue that decisions related to natural resources are deeply entrenched in the political decisions of the different stakeholder groups each attempting to exert their control in the system (Bossio *et al.*, 2010).

The political economy of current irrigated-agriculture policies in the Indus Basin essentially incentivizes cropping intensification and extension of the irrigated area through high value crops resulting in a potential rebound effect that may increase water use. This is seen in the Lower Jhelum CCA where intensification and farmers ability to cultivate previously fallow land parcels resulted in increased water use (Grafton *et al.*, 2018). To adjust for such rebound effects, current irrigated-agriculture policies need to incorporate scale-specific data on land management with additional incentives for limiting intensification to levels that can sustain basin scale reductions. This is not an easy policy choice and the political and socio-economic implications of such policy directives can create conflicts between institutional tiers.

In the Indus Basin, as in many other river basins, the irrigated-agriculture policies are not politically neutral and will not lead to water saving behavior in the absence of new institutional arrangements that combine land management and groundwater regulations. A corresponding adjustment in the policy making institutions and processes will also be required. Keeping farmers engaged and informed on why these institutional adjustments are needed and how they will be applied are the critical tasks that water managers and extension officers will need to play. Keeping farmers informed of how these decisions are made, what decisions are appropriate for which parts of the system, and the actions required from farmers located at different points in the system, could all be steps towards increasing efficiency of the entire distribution system in an equitable and sustainable way.

Creating legitimacy for rational choices in policy design is key to addressing issues of scale-based class politics. For instance, the need to address the problem of salinity in Hakra branch canal, one option would be to make additional water supply available to middle and tail reaches by reducing the share of water allocation for farmers located at the head of the same canal. Farmers located at the head reaches should be encouraged through a concerted policy effort with adequate incentives to use more groundwater to meet their crop water requirements since the quality of groundwater at the head of canal is good and recharge is enough to replenish the groundwater withdrawals. Thereby developing an engaged dialogue among farmers to appreciate the consequences of their actions on farmers at other locations and vice versa.

CONCLUSIONS

The SDR analysis provided an expanded description of equity issues in the Indus Basin by showing the choices made by farmers for water and land use. The demographic issues of farmers' landholding sizes, proximity to irrigation supplies and quality of groundwater are important considerations for scale-alignment of policies. Through the unpacking of the current state of irrigated agriculture policies in the Indus Basin, the study found little appreciation of multi-scale perspective in how policies are designed and implemented. As a result, different institutional tiers make decisions and operate across spatial and governance scales in a seemingly uncoordinated and mismatched manner.

While the current policies remain focused on provincial level impacts for Indus Basin management, the actions taken at catchment (CCAs) level often counteracts to achieving these impacts at the sub-basin and basin scale. In addressing scale misfits in the policy design and implementation arrangements, the first step is to recognize the overlapping dynamics of how different actors located at different scales make decisions and take actions. These decisions and actions spread across water management units and governance boundaries in an overlapping and opposing patterns. Identifying and dealing with these patterns of actions across multiple scales is not an easy task. There are tradeoffs between what policy actions are appropriate at what scale due to the varied social organization operating at different scales. In striving for scale-fit in policy design the non-spatial misfits of institutional tiers and the ways in which these interact is often the critical missing link. The friction between how institutional structures are set up and how policy implementation is divided across these structures causes additional problems of misfit and thus need additional coordination mechanisms across scales as well as across levels within each scale.

The SDR analytical tool operationalizes the multiplicity of stakeholders and equity issues that blur governance and resource boundaries, that requires recognition early in the policy making process. The SDR tool is first such analytical method that provides a practical way to assess how well the natural scale of water resource and the politico-administrative scales of decision making are aligned or not.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

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