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Challenges of Irrigation Water Supply in Croplands of Arid Regions and their Environmental Consequences – A Case Study in the Dez and Moghan Command Areas of Iran

Lobat Taghavi and Najaf Hedayat

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***Abstract*—**Renewable water resources are crucial production variables in arid and semi-arid regions where intensive agriculture is practiced to meet ever-increasing demand for food and fiber. This is crucial for the Dez and Moghan command areas where water delivery problems and adverse environmental issues are widespread. This paper aims to identify major problems areas using on-farm surveys of 200 farmers, agricultural extensionists and water suppliers which was complemented by secondary data and field observations during 2010-2011 cultivating season. The SPSS package was used to analyze and synthesis data. Results indicated inappropriate canal operations in both schemes, though there was no unanimity about the underlying causes. Inequitable and inflexible distribution was found to be rooted in deficient hydraulic structures particularly in the main and secondary canals. The inadequacy and inflexibility of water scheduling regime was the underlying causes of recurring pest and disease spread which often led to the decline of crop yield and quality, although these were not disputed, the water suppliers were not prepared to link with the deficiencies in the operation of the main and secondary canals. They rather attributed these to the prevailing salinity; alkalinity, water table fluctuations and leaching of the valuable agro-chemical inputs from the plants' route zone with far-reaching consequences. Examples of these include the pollution of ground and surface resources due to over-irrigation at the farm level which falls under the growers' own responsibility. Poor irrigation efficiency and adverse environmental problems were attributed to deficient and outdated farming practices that were in turn rooted in poor extension programs and irrational water charges.

***Keywords*—**water delivery, inequity, inflexibility, conflicts, environmental impact, Dez and Moghan

I. Introduction

THERE is a universal agreement about the importance of efficient irrigation for improving food production and rural development in arid and semi-arid regions. Efficient and productive use of renewable water resources is vital for sustainable agricultural production and rural regeneration in arid and semi-arid regions [1]. The climatic, economic and environmental factors in these regions necessitate rational and systematic resource management as a means of averting potential water crises which as Tibor et al [2] points out is imminent if swift measures are not taken to manage the efficiently as opposed to developing the existing water resources which as Hedayat in 2005 [1] stresses would not be economically viable, at least not with current technology and costs. Sustainable food and fibre production, as it is implied, would necessitate efficient on-farm operations that in turn call for flexible and reliable water supply at the farm gates. The challenges in many modern irrigation schemes, such as the Dez arise not from inadequacy of water at headwork but due to unreliable delivery at farm gates. This is due to inappropriate water control system, poor conveyance that Lankford and Gowing in 1996 link to deficient or unsystematic maintenance of hydraulic structures [3]. These seem to have culminated in problems that call for performance evaluation of the canal systems in the Dez and Moghan command areas with the view of alleviating potential and real operational deficiencies in the water conveyance and distribution systems.

L.Taghavi is with Department of Environment and Energy, Science and Research Branch, Islamic Azad University, Tehran, Iran.(phone: 0098 912 807 75 79, e-mail: L60taghavi@yahoo.com).
N.Hedayat is the Dean, Faculty of Agriculture, Islamic Azad University, Dezful Branch, Greater Dezful, Iran.n.hedayat@yahoo.com.

II-Materials And Methods

The Dez and Moghan are modern irrigation and drainage schemes of about 120,000 ha gross were constructed to service predominantly large production systems in the form of agri-businesses. They were located in the southwest and northwest Iran respectively. The average annual rainfalls in both command areas were about 350 mm, which ranked slightly higher than the 250 mm national average. Both command areas have arid and semi-arid climate with average annual ET peaking at 4500 mm in hot summer months of July and August. The water distribution system in the pre-reform era was based on fixed rotation supplied to gates commanding a block of hundred ha. After the revolution, the agribusinesses were dissolved and their lands were redistributed among either the former employees of these agribusinesses or other private farmers and medium-size producers co-operatives. Some remained under the state control managed by the agro-industrial complexes in both schemes. The cropping pattern of the pre-reform era was predominantly cereals, fodder, sugar beet and sugar cane and cotton supplied to the market regulated by the state [1]. This was subsequently shifted to multi-cropping regime consisting of many vegetable varieties, sugar cane, sugar beet, citrus orchards, and flowers supplied to the free market. As a result of changes in the land tenure system, cropping pattern and the market, the water requirements has also changed. Intensive farming regime led to over-application of the chemical inputs and over-irrigation in some croplands with adverse environmental impact such as

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soil salinity, alkalinity, soil dispersion, rise of the water table and pollution of the surface and underground water resources. Both schemes are managed by the governmentally-controlled water agencies. Both secondary and primary data sources were used. Primary data were obtained from four workshops to get a closer understanding of major water delivery-related issues that were then explored by survey and systematic on-farm interviews. The participants in the survey were comprised of farmers, agricultural extensionists, water suppliers and some independent academics. Survey and interview were used conjunctively in order to generate valid first-hand data [4]. The idea for the research was conceived during professional visits to large schemes, where it was observed that water distributed to downstream farmers was less than theoretical water allowance of 1 liter/second/hectare, which was causing major on-farm tillage problems. Subsequent field visits led to the selection of the Dez and Moghan as the case studies, where preliminary investigations and on-farm observations indicated a conspicuous inequitable and inflexible water distribution. The latter were in turn causing upstream-downstream conflicts and adverse environmental impact. The latter manifest itself in soil salinity and alkalinity which render them infertile, water logging and rise of water table on the other. These were then conceptualized into an "input-throughput-output" conceptual framework of the "open-system" model, around which the primary data were collected through, on-farm observations, stakeholder's survey and on-gate interviews of the water users and suppliers. This method helped develop an analytical framework for a survey of a sample of 200 stakeholders equally selected from the Dez and Moghan. Using the SPSS statistical techniques [5] and the stakeholder analysis to analyze and synthesize the data [6].

III-Results and Discussions

A. Problems of Water Delivery

Results (table I) suggested that inequity and inflexibility of water delivery were the overwhelming problems faced by the crop producers, factors which the observations single out as major causes of poor crop yield quality. This analysis was not shared by the water suppliers who disputed any deficiency in water delivery system. They rather highlighted the group conflicts over water use which in their view arise from over-irrigation (water logging, drainage problems and water table rise) by some and under-irrigation (crop failure due to crop stress) by others. These, as observations suggest, was the underlying cause adverse environmental impact that prevails in most croplands particularly in Moghan.

TABLE I
MEAN RANK SCORES ON MAJOR PROBLEMS OF WATER DELIVERY (1=MOST IMPORTANT, 5=LEAST IMPORTANT)

Major problems	Farmers		Extension officials		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Inequity of water delivery at farm gates	1.58	1.66	2.14	2.27	3.22	2.57
Group conflicts for water	2.58	2.64	2.75	2.40	1.17	2.25
Inflexible water delivery	2.33	2.00	1.69	2.20	3.11	2.75
Environmental impact	3.50	3.70	3.42	3.23	2.67	2.43
None of the above	5.00	5.00	5.00	4.90	4.83	5.00

B. Equity of water allocation and causes of inequitable use

A clear unanimity among most producers in both schemes was shown to indicate that inequitable and inflexible water delivery frequently prevails during cultivating seasons. Although water suppliers did not dispute such analysis, were nonetheless reluctant to attribute these to inadequate abstracted and conveyed quantity in conveyance and distribution systems. What in their view, might have led to such shortcomings, if any, was to do with deficient allocation regime among water users themselves which as they explicitly expressed, was rather attributed to poor on-farm extension than any other techno-operational actors as critics seem to claim (table II).The farmers in the Dez blamed over-abstraction and unlined canals, while those in Moghan viewed unlined canals and dilapidated state of hydraulic structures as the most important causes of inequitable delivery at farm-gates. Results further indicated that unlined conveyance and distribution canals coupled with low water charges are the underlying causes of inequitable distribution, which water agency should have taken care of. Water agencies did not see any deficiency in the original design features of the hydraulic structures which are considered to be operationally sound and if there are a few operationally deficient cases, they are linked to unlined canals where seepage is prevalent and present water charges would not be sufficient to venture on further modernization. Results support by Hedayat [1] findings which show that where poor water allocation is acknowledged on farm gates , they are attributed to over-abstraction by some upstream users and flow disruption and regulation in some farm gates due to dilapidated state of hydraulic structures in the conveyance and distribution networks.

TABLE II
MEAN RANK SCORES ON EQUITABLE WATER DELIVERY AMONG FARM GATES.

Equity of delivery	Farmers		Extension officials		Water agency staff	
	Dez %	Moghan %	Dez %	Moghan %	Dez %	Moghan %
Equitable delivery	5.6	8.0	22.2	20.0	88.9	50.0
Neither equitable nor inequitable	27.8	40.0	66.7	60.0	11.1	42.9
Inequitable	66.7	52.0	11.1	20.0	0	7.1

TABLE III
MEAN SCORES ON UNDERLYING CAUSES OF INEQUITABLE WATER DELIVERY AT FARM GATES

Causes of inequitable delivery	Farmers		Extension officials		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Over-abstraction by upstream water users	1.72	2.56	2.44	2.61	2.67	2.46
Unlined conveyance and distribution canals	1.81	1.83	2.17	1.93	1.94	2.38
Present water charges	3.44	3.54	2.19	2.43	1.94	1.73
Poor hydraulic structures	3.03	2.10	3.19	3.04	3.61	3.42
None of the above	5.00	4.96	5.00	5.00	4.83	5.00

C. Flexibility of water delivery and potential causes of inflexibility

Results (tables IV and V) suggest prevailing inflexibility of water distribution which the suppliers, unlike the water users dispute. They seem to stress that adequate water flow is diverted in the canal network, which the data from the pumping stations and water intake structures [7]. However, the observed inflexibility was allegedly blamed on poor allocation among water users than the inadequacy of supply as farmers explicitly claim. The overwhelming view was that unlined canals and dilapidated conditions of hydraulic structures lead to inflexibility which farmers and agricultural extensionists trace the root causes to deficient management of main and secondary canals. The water suppliers in turn trace the root causes of inadequate allocation to poor management of tertiary canals that the water users and agricultural extensionists are blamed for.

TABLE IV
MEAN SCORE ON FLEXIBILITY OF WATER DELIVERY SYSTEM ON THE FARM GATES

flexibility of water delivery	Farmers		Extension officials		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Flexible supply services	5.9	8.0	16.7	26.7	44.4	50.0
Neither flexible nor inflexible	47.1	40.0	55.6	40.0	55.6	35.7
Inflexible supply services	47.1	52.0	27.8	33.3	0	14.3
Total	100	100	100	100	100	100

TABLE V
MEAN SCORES ON CAUSES OF INFLEXIBLE WATER DELIVERY REGIME

Causes of inflexibility	Farmers		Extension officials		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Upstream water control system	3.50	2.94	3.15	2.96	2.94	3.07
Dilapidated state of hydraulic structures	1.74	2.12	2.03	1.92	2.33	2.64
Unlined conveyance canals	1.56	2.08	1.59	2.50	1.78	1.75
Rigid rotation scheduling	3.21	2.86	3.26	2.65	2.94	2.54
None of the above	5.00	5.00	4.97	4.96	5.00	5.00

The delivery regime was in the view of water suppliers more flexible at farm gates than it was claimed. From the point of view of water users, the dilapidated conditions of hydraulic structures (in main and secondary canals) are the cause of inflexibility. However, feedback received from water suppliers suggested that poor O&M of tertiary and quaternary canals, as opposed to alleged inadequacy in the main and secondary canals ,are to blame forinflexible delivery regime, which Hedayat [1] substantiate.

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TABLE VI
MEAN RANK SCORES ON CAUSES OF GROUP CONFLICTS OVER WATER USE

Major causes of group conflicts	Farmers		Extension officials		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Upstream water control system	2.68	3.00	3.12	3.10	3.17	2.88
Absence of conjunctive use of surface and ground resources	3.09	3.20	3.26	3.10	2.94	3.15
Unreliability of water delivery	1.82	1.80	1.65	1.63	2.00	2.54
Inequity of water delivery	2.44	2.00	1.97	2.43	2.33	1.42
None of the above	4.97	5.00	5.00	4.73	4.56	5.00

D. Adverse Environmental Impact and their Causes

Results show that adverse environmental impact in the form of soil salinity, soil alkalinity, soil dispersion, soil infertility, rise of the water table and pollution of the surface and underground resources due to over-irrigation practices and over-application of chemical agro-inputs are the major problems. Analysis further (table VI) suggest that over-irrigation by upstream farmers and excessive water seepage/percolation through the permeable soil profiles particularly in parts of command areas where the conveyance and distribution canals are unlined, adversely affect the physical environmental. The water suppliers' critics overwhelmingly point at the dilapidated conditions of hydraulic structures and poor state of conveyance and distribution networks as the fundamental causes of environmental degradations. While the water suppliers dispute such analysis, point at inadequacy of the water charges which encourage the farmers to indulge in over-irrigation practices coupled with over-application of chemical inputs by crop producers which in their view are the major environmental problem areas. These problems as the water suppliers view them arise from deficient on-farm practices associated with the intensive farming. These environmental challenges, as observations confirm are emerging as serious agronomical and environmental problems that merit attention. The fact that the government have taken measures to rehabilitate the affected croplands by constructing lateral and collector underground drainage systems, lining the tertiary canals, complemented by extensive on-farm modernization in Paarsabad and Bilesavaar are in response to such challenges. Much of the command areas which were observed to be afflicted by water-logging and drainage problems had experienced considerable infertility problem. These were the underlying reasons for extensive land reclamation program to discard much of the soil salinity and alkalinity by systematic leaching to pave the way for more productive cropping pattern. The post-rehabilitation observations by the authors show a marked improvement in irrigation application efficiency and relatively better crop yield and quality compared with the pre-rehabilitation program.

TABLE VII
MEAN RANK SCORES ON CAUSES OF ENVIRONMENTAL IMPACT

Observed environmental impact	Farmers		Extension officials		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Over-irrigation practices by upstream farmers	1.56	1.96	2.22	2.50	1.72	2.50
Absence of a rational system of water charges.	3.22	3.36	2.28	2.07	1.89	1.93
Excessive seepage/percolation	1.89	1.58	2.25	2.00	3.44	3.00
Overuse of chemical pesticides and fertilizers	3.33	3.18	3.28	3.43	3.00	2.57
None of the above	5.00	4.92	4.97	5.00	4.94	5.00

IV. DISCUSSIONS

In the light of what was observed, the techno-managerial deficiencies in main and secondary canals were the underlying causes of inequitable and inflexible delivery regime. The physical infrastructures as the water suppliers view them are designed to pump sufficient water is the network, yet under circumstances where poor distribution prevailed; it would have nothing to do with operation and management of the network. The users on the other hand would stress for example, that present upstream water control systems are no longer responsive, some structures in both schemes are dilapidated, and a large numbers of canals (particularly in Moghan) are still unlined. The view expressed by water users echoed observations by Lankford and Gowing in 1996 [3] in Malaysia, where inappropriately designed and constructed hydraulic structures were reportedly the major problem areas. These deficiencies in the canal operations had led to inaccuracy of control and conveyance systems. Field observations by Bhutta and Van Der Valde [8] in Punjab substantiate these, where they report that almost all operational deficiencies arise from lack of systematic maintenance. The implication of having unlined canals, inappropriate design features and poor maintenance of hydraulic structures would, as these findings indicate, be far-reaching for reliability and equity of water delivery. Observations by Bhutta and Van Der Velde [8] in Punjab also support claims expressed by the water users that water allocation is substantially inequitable even when the distributaries were operating at full supply. This was also shared by the World Bank observations of similar schemes [9,10] that traced these widespread deficiencies to poor management of main and secondary canals. Although water suppliers did not dispute the problems posed by unlined canals and poor maintenance, they nonetheless, tended to link these to reluctance of farmers to pay higher charges. That in their view, was a major contributing factor to conveyance deficiency and for that matter, the prevailing inequity and inflexibility at farm gates. The paper acknowledges the prevalence of water distribution problems in the Dez and Moghan, though disagrees with farmers, agricultural

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extensionists, and observations of some experts elsewhere [11] which exclusively point at mismanagement in a particular domain. The problems, as observations by the authors show, clearly arise from inappropriate design of hydraulic structures and deficient O&M of the main, secondary, tertiary and quaternary canals. The structures that were designed to serve the pre-revolution farming regime are manifestly no longer responsive to the complexity of new farming challenges. The private small farmers, who depend on producing high yield and quality cash crops for economic survival in the free-market competition, would obviously seek more flexible and equitable delivery scheduling with little or no upstream-downstream conflicts and none of the environmental impact that has challenged the viability and sustainability of their production units.The responses from the suppliers indicated that water delivery was flexible, though they were referring to main and secondary canals which they thought were operated and maintained efficiently. If there were cases of inflexible delivery at the farm gates they have to have their root causes elsewhere. What results did not dispute was the unanimous view that traced the causes of inflexible water delivery to unlined canals and poor state of hydraulic structures (albeit the suppliers meant the tertiary and quaternary canals as well as over-irrigation by some farmers). Concerns were expressed by the water users that conflicts arise from unreliability and inequity in supply as typified by upstream-downstream in the distributaries [12]. When water in canals is sufficient and managed efficiently, the farmers are more likely to receive their allocated shares. But upstream farmers in the Dez and Moghan, like their counterparts elsewhere [13,14], are allowed to tamper with the structures as a means of heading up the water with a consequence of cutting off and decreasing the quantity supplied to their downstream counterparts. This has major implications for the crops nearest to water supplies, as Beadle et al's study in Nepal suggests, enables these farmers to close off their water supply and let their crops dry out for the harvest. Over-abstraction practices by upstream farmers, as research by Burton and Chiza [15] in Tanzania suggests, disenfranchise downstream users [16,8]. These can become a source of frustration and sows the seeds for group conflicts by Rudge and Gowing [17] which, as author's observations particularly in the Dez command area suggest, leads to physical interference in the operation of systems, as Beadle et al [14] has also documented where flow disruption frequently recur and regulation often made difficult.Research further suggests that environmental impact is emerging as a major challenge to the sustainability of irrigated agriculture. Evidence suggests that current farming in many areas cannot be sustained much longer because, as Faeth [18] and Islam [19] point out, the soil and water resources are threatened or declining. This is clearly what has occurred in both command areas [1], which has necessitated extensive rehabilitation programs to make the schemes sustainable. Poor irrigation practices linked to deficient water delivery, as observations by Malano and Gao [20] suggest, often lead to water logging and salinity that the author's observations indicate has led to destructive soil profile in the vast tracts of lands in Iran, particularly in Moghan command area. This was also substantiated by Tanton, Wolff, and Clark [21, 22 ,23] whose observations in Kazakhstan found that widespread inefficient water use has led to environmental impact with major implication for sustainability of the irrigated agriculture in Aral Basin. These findings highlight the extent by which over-irrigation, as observed by Bhutta and Van Der Valde [8] is serious and as such, detrimental to downstream users. The findings also suggest that excessive seepage from unlined canals are seen as the major sources of water losses to water tables which in turn leads to salinity , alkalinity, water logging and drainage problems. The prevailing over-irrigation practices by some producers and adverse environmental problems have according to the water suppliers, their roots in poor allocation regime and inadequate maintenance practices. The underlying causes of environmental impact are seen by the farmers to arise from excessive seepage and deep percolation of water to underground water table which in their view leads to soil salinity and alkalinity on top of hosts of other factors which degrade their croplands. From their perspective, the prevailing management style and insensitivity of the suppliers towards imprudent on-farm practices are the main reasons for environmental impact particularly in Moghan. These assessments were hardly shared by the water suppliers whose view was that environmental impact arises from unlined tertiaries and inefficient farm operations. By focusing on deficiencies that are outside their responsibilities, the suppliers attempted to counter any criticism of their canal management style. In other words, they attempted to portray a picture that all was well with the ways in which they managed the O&M. Thus there was an explicit view that the environmental impact are emerging as serious challenges for the sustainability of irrigation and drainage networks, for which none of the groups were prepared to accept the malpractices.Field observations suggest that unrealistic water charges and over-irrigation by some producers with good accessibility to water are the most important causes of water logging, drainage, water table fluctuation and soil infertility. These echo studies in the Indus basin for example Van Steenburgen and Oliemans [24] suggesting that over-irrigation with associated high evaporation during summer spells are the major causes of environmental impact. It further suggests the extent by which mismanagement at supply and demand levels could threaten the physical integrity of environment that supports food and fiber production in both schemes. The authors believe that the extent of environmental impact and it seriousness for croplands is greater than what the formal appraisal reports seem to suggest. The present water consumption pattern in some parts of the Dez command area may have similar problems to that in Moghan but the authors disagree that the causes lay in one particular domain. They rather believe that system operators have systematically failed to update the conveyance and control systems as a means of ensuring efficient canal management and by so doing to preserve the physical environmental sustainability. By the same token, a great majority of the crop producers have failed to made appropriate use farm inputs. Although the subsidized farm inputs might have been justified in the past, research suggest that they cannot and should not be allowed to pollute the environment under any pretext. As long as generous input subsidies are provided, food producers might not be obliged to use them prudently. It is for this very reason that excessive water use which is often accompanied by high application of

agro-chemicals, as have been indicated by present findings, are a potential threat to what is considered by the paper as sustainable food and fiber production chain in a region that has to be protected for future generation. The paper concludes that irrigation efficiency and water use productivity are in line with and integral to the environmental protection approach which are arguably crucial for sustainable farming system under arid and semi-arid conditions like croplands of the Great Dezful food production bastion.

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