WATER MANAGEMENT IN THE HKH REGION: SPATE IRRIGATION SYSTEMS

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ABSTRACT

There is a wide variety of indigenous water harvesting systems prevailing in Pakistan. Indigenous systems differ significantly from the modern irrigation because flows fluctuate widely in space and time. Prediction of flows is difficult. Landholders are at the mercy of extreme events of floods and droughts. These systems are commonly found in Pakistan and can be characterised in five major categories like mountain irrigation systems; runoff farming systems; torrent-spate-irrigation systems; perennial-spate-irrigation systems; and riverflood-spate-irrigation system. Indigenous water harvesting systems have been practised in Pakistan since 3000 BC. In the beginning, only narrow strips of land along banks were irrigated. With the passage of time, irrigation was extended to nearby areas by breaching the banks or natural levies of rivers or nullah to bring water to the low-lying areas. This was done only during high flood periods.

Spate irrigation systems are mostly located in Sulaiman Piedmont, Western Dry Mountains and Dry Western Plateau. These systems provide livelihood for a large number of ecologically and economically marginal people in Pakistan. With the introduction of modern weir-controlled irrigation in the Indus basin during the 19th century, the priority was assigned to irrigated agriculture. In the last 30 years, the spate irrigation systems were deteriorated tremendously due to large-scale introduction of modern surface and groundwater schemes. For example, deterioration of spate irrigation systems in Balochistan is one of the major causes for affecting sustainability of valley based tubewell irrigated agriculture.

Government is now seriously thinking to accord priority to spate irrigation systems, to launch a concerted effort for production of wheat and oilseeds in these marginal ecologies for attaining self-reliance in food security. Poorest-of-the-poor live in these ecologies and thus demand high priority in initiating poverty alleviation programmes. Furthermore, it is not economical to grow wheat and oilseeds under tubewell irrigation, and these crops have to compete for water in the Indus basin with other cash crops like cotton, sugarcane, fruits and vegetables.

Major issues faced by the spate irrigation systems can be categorised under technical, social, institutional and economic. Major issues faced by these systems are related to predictability, reliability, equity and adequacy of water for irrigation. Other issues are related to productivity and sustainability of farming under different water harvesting systems. Traditional norms and rules for water rights are not being practised in spirit due to broken traditions of the tribal system and lack of joint action. The society is now moving very fast towards complete individualism.

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1. Introduction

1.1. Description and Classification of Water Harvesting Systems

Indigenous water harvesting systems of Pakistan differ significantly from modern irrigation systems, where flows of indigenous systems fluctuate widely in space and time. Prediction of flows is difficult as floodwater is coming from large catchments. Landholders are at the mercy of extreme events of floods and droughts. Indigenous water harvesting systems commonly found in Pakistan can be characterised in the following five major categories:

- Mountain irrigation system is based on snowmelt or streamflow or springwater, which is diverted along the mountain slopes through channels to foothills. Snowmelt systems are located in Northern Areas, whereas streamflow or springflow systems are located in wet mountains of NWFP.
- Runoff farming system is based on incident rainfall and supplemented by surface runoff, which is harvested from adjacent hillsides and run-on in the fields. This system is named as *Abraize* in Punjab and *Khuskhaba* in Balochistan. These systems are more sustainable compared to *Barani* farming.
- Torrent-spate-irrigation system is based on floodwater. This is named as *Rod-Kohi* in NWFP, Punjab and Sindh provinces and *Sailaba* in Balochistan. *Daman* area in D.I.Khan, *Pachad* in D.G.Khan, *Sailaba* in Loralai, Barkhan and Musa Khel are few examples of plains where floodwater farming is practised.
- Perennial-spate-irrigation system is based on surface or subsurface flows and located within the torrent-spate-irrigation tract. This is named as *Kalapani* in NWFP and Punjab province.
- Riverflood-spate-irrigation system is based on river floodwater peaks. This system is named as *Sailaba* in the Riverine areas, where recession agriculture is practised. *Kachi* tract in NWFP and Punjab province and *Kacha tract* in Sindh province are good examples.

Mountain irrigation systems are reliable than any other water harvesting systems, whereas reliability in spate irrigation systems is higher than *Barani* and *Khuskhaba* systems. These systems differ widely. The main parameters are hydrological (catchments characteristics, rainfall pattern), geographical (location and level), hydraulic (type of diversion and size of command area) and sociological (land tenure, social structure and degree of public intervention).

1.2. Historical Perspective of Water Harvesting Systems

There is evidence that indigenous water harvesting systems have been practised in Pakistan since 3000 BC (Dennell, 1982; Jarrige, 1985; Meadow, 1991). In the beginning, only the narrow strips of land along banks were irrigated. With the passage of time, irrigation was extended to nearby areas by breaching the banks or natural levies of rivers to bring water to the low-lying areas. This was done only during high flood periods.

First evidence of perennial irrigation on any of the Indus system rivers dates back to early 17th century. When 80 km long canal was constructed by the Mughal Emperor Jahangir (reigned 1605-27) to bring water from right-bank of Ravi to pleasure gardens near Lahore. Irrigation system, which exists today, was started in 19th century under the British administration. In the early 19th century, there were numerous inundation canals leading from

River Indus and its tributaries. These were remodelled and fitted with permanent headwork and new canals with weir-controlled supply were constructed during the middle of the 19th century.

Historic development of canal system illustrates that mountain and spate irrigation systems were the most important agricultural system until the end of the 18th century. Systematic canal development in Indus basin shifted focus from mountain and spate irrigation, when large numbers of inhabitants were settled in canal commands to earn better and sustained livelihood.

In the early 20th century, the British administration appointed first administrator in district of spate irrigation D.I.Khan, after completion of land settlement and establishment of water rights. Similar activities were undertaken in D.G.Khan and Zoab. Management of these systems was improved after fixing operational procedures, which were printed and named as *'Kulliat-a-Rod-Kohi'*. These procedures were followed strictly until late 60s of the 20th century. Participatory actions were much more common during the tribal system, which was abolished during mid 70s. Later interference of large and politically influenced water users has resulted in increased number of diversion structures and violation of water rights. Co-ordination among water users was also less effective compared to the tribal system.

1.3. Farming System

In perennial (mountain irrigation and *'Kalapani'*) systems, high value crops including fruits and vegetables are grown in addition to food grains. In the torrent-spate-irrigation, wheat, gram, rape and mustard are grown in *Rabi* season. Whereas in *Kharif* season, farmers try to have dual purpose mix cropping system i.e. sorghum mixed with mashbeans and mungbeans to have both grain and fodder. Yields are normally low but some of the progressive farmers are getting more than 3 tons of wheat without any fertilisation in a wet year, due to deposition of fertile sediments with irrigation. Fodder is a priority in these areas because they contribute significantly towards livestock production.

Watersheds and rangelands constitute about 65 to 70 percent of the country's area (Ashraf 1987). These areas are in depleted condition and far below their productive potential. This is because of continued misuse through deforestation, unchecked grazing and lack of appropriate management of steep slopes for cultivation. Watersheds have been severely damaged with the result that agricultural productivity has been considerably decreased.

1.4. Institutional Change

In the local water resource management of the indigenous water harvesting systems, the public sector is considered as an external player. Indigenous systems are being managed completely by the local water users' institutions. Therefore, for any change, there is a need to have clear focus on resource users' institutions itself and see what factors influence change, stagnation or sustainability. Furthermore, it is also useful to define role of public sector in setting more transparent conditions for change, stagnation or collapse.

Transaction costs are the cost of arranging, monitoring and enforcing contracts. In local water resource management these are often social contracts, regulating access and usage of the resource within group of resource users. This is referred to first order transaction costs related to management of the indigenous systems in traditional framework. The second order transactions costs deal with institutional or technological change.

Second order transaction costs are generally high in comparison to first order transaction costs. Institutional change requires learning rather than information collection, and bargaining rather than contract preparation. Moreover, institutional change is not repetitive, but incidental. Its outcome is uncertain and the behaviour of various actors cannot be predicted. Whereas at the level of institutional management interests are often defined by the institutions and a status quo exists, in institutional change interests are open. They may differ and conflict and complicated negotiation is necessary. The costliness of institutional change explains why some changes – although they could improve resource utilisation – do not take place at all. There are several examples of institutional stagnation in local water resource management in Pakistan that can be attributed to high second order transactions costs. The failures of groundwater management regimes in most valleys of Balochistan, the inability to reach agreement on water rights in new agency-developed systems, and the lack of adjustment in water delivery schedules in perennial-spate-irrigation systems are the few examples (Steenbergen, 1997).

1.5. Future Prospects

Importance of agricultural sector in economy of Pakistan results from the fact that it accounts for 25 % of the gross domestic product and provides job opportunities to 55 % of the labour force. It also accounts for 80% of the total export earnings. Within the agricultural sector, irrigation plays a predominant role in industrialisation process of Pakistan with production of cash crops (cotton, sugarcane, citrus, mango) and dairy cattle.

With a population estimated at more than 132 million inhabitants today that is likely to reach 171 million by the year 2010, the demand for food products is expected to continue to grow. Thus, unless there are significant improvements in agricultural productivity and total production, imbalance between supply and demand of basic agricultural goods is expected to increase in future, and to threaten self-reliance objective of Pakistan.

Country's food imports are currently around US$ 2.0 billion. Government is now seriously thinking to accord priority to spate irrigation for both torrent and riverflood systems, to launch a concerted effort for production of wheat and oilseeds in these marginal ecologies for attaining self-reliance in food security. Poorest-of-the-poor live in these ecologies and thus demand high priority in initiating poverty alleviation programmes. Furthermore, it is not economical to grow wheat and oilseeds under tubewell irrigation, and these crops have to compete for water in the Indus basin with other cash crops like cotton, sugarcane, fruits and vegetables.

2. Torrent-Spate-Irrigation Systems

2.1. Era, Location and Extent of the Systems in D.I.Khan

In NWFP, torrent-spate-irrigation systems go back at least as early as 330 BC and provided economic basis for some of the early civilisations. Alexander the Great, according to *Arrians,* sailed down the river Jhelum to its junction with River Indus. His land forces marched in two bodies on either side of the river. They noticed some form of torrent agriculture although in a very poor state than present but exist in few locations of the Sulaiman piedmont (Figure 2). Heavy rains in the catchments, which extend up to Balochistan, Afghanistan, Sulaiman Range, Shirani Hills and Bhattani Range result in water rushing into various torrents in the foothill plains, named as *Daman* area, where torrent agriculture (*Rod-Kohi*) is practised.

Large and major torrents in D.I.Khan Division are named as *'Zams'*. Principal *Zams* include Tank, Gomal, Choudhwan, Daraban and Shaikh Haider. Takwara is the principal hill-torrent, which collects floodwater from Tank *Zam* and some other passes, and irrigates northern portion of the tract. Luni hill-torrent, which is the largest of all, and which, issuing from Gomal Pass, takes a southeasterly course, and fall into Indus some 24 kms below the town of D.I.Khan. Vihowa hill-torrent waters southern portion of *Daman*, around the towns of Dera Fateh Khan and Vihowa (Figure 5). Few of these streams have a clearly marked channel of their own for any distance from the hills. Owing to the irrigation system in force, waters of one are thrown into another, until channel form a complete network. Because of this, original name of a stream is, as a rule, very soon lost. Its waters get sub-divided and carried off in different channels, where they mix with those of other hill streams, and each of these channels gets a local name of its own. The nomenclature, therefore, becomes somewhat confusing. Hardly, a single stream is known by the same name for its whole course from hills to River Indus (PARC, 1990; GOP, 1884).

This system is mainly practised in D.I.Khan Division by five *Zams* and twenty nullahs. *Zams* are perennial streams in a limited context as they provide *'Kalapani'*, while nullahs receive water only during the flood season. Seasonal hill-torrents result from two-peaked rains of almost 125-mm each in spring and summer. Probability of torrents is also two-peaked, one from mid-February to mid-April and other from mid-July to late August. Summer torrents are the major ones (Khan, 1990).

These hill-torrents result from rains on Sulaiman Range in the west of Marwat Range on the north. The catchments of these ranges are without vegetation and steep slopes exist upstream and downstream of gorges from where torrents emerge. These hill torrents have steep gradients and high velocity. A large amount of sediment is picked up and deposited on flatter slopes. These hill torrents often change their course when in piedmont or flood plains and are thus likely to damage lands.

Each Z*am* and nullah commands a scheme. In total, there are 25 major schemes covering a potential command area of around 0.52 million ha, out of which around 0.26 million ha are normally commanded in an average year in D.I.Khan, Tank and Kulachi.

2.2. Era, Location and Extent of the Systems in D.G.Khan

In Punjab, torrent-spate-irrigation systems go backs as early as the period before the Christ and provided economic basis for some of the early Hindu civilisations. At the time of the first Muhammadan invasion, Elphinstone says, " the mountains of Mekran were inhabited by Balochis, and those of the Sulaiman by Afghans. With respect to the plain, if we may judge from present state of population, those between Sulaiman and Mekran Mountains and River Indus were occupied by Jats or Indians." The first appearance of the Mohammadans in India was in the year 44 of the Hijri (A.D. 664). These civilisations were dependent on spate irrigation for their livelihood (GOP, 1898).

Heavy rains in catchments of the west of Sulaiman Range result in water rushing into three large torrents. These torrents rising far to the west of the Sulaiman Range pierce through them from west to east through narrow and tremendous gorges. Most northerly, Vihowa, emerges from them into D.I.Khan but its floodwater reaches villages in the north of Sanghar. Sanghar emerges near the village of Mangrotha at the centre of the western boundary of Sanghar, and third, Kaha, near Harrand, which is similarly situated in Jampur.

With the exception of Vihowa, Sanghar and Kaha, one of the other torrents flows except when fed by rain in summer and autumn. They then come down in flood heavily laden with detritus washed from slopes of hills, which deposited year after year over space between base of hills and Indus has formed tract called '*Pachad'*, where torrent farming (*Rod-Kohi*) is practised.

Pachad is continuous from north to south of the district, and slopes vary gently from pebble-covered base of hills eastward to the river. From the method of its formation, it follows that soil is a rich loam, but rainfall outside hill tract is so small that cultivation is only possible with the aid of torrent-spate-irrigation. To catch water, embankments, sometimes of earth, sometimes of loose stone, are made in torrent bed, a little below the place where torrent issues from hills. Held up water is led by a system of distributary channels to fields. Each of which is surrounded by strong bunds, so as capable of taking a depth of 0.5-1.25 m of water, to thoroughly saturate and receive a good deposit of silt (GOP, 1898).

Each torrent commands a scheme. In total, there are more than 17 major torrents commanding torrent-spate-irrigation schemes and smaller nullahs covering a potential command area of around 0.41 million ha. Out of which around 0.20 million ha are normally commanded in an average year in D.G.Khan, Sanghar, Jampur and Rajanpur.

2.3. Era, Location and Extent of the Systems in Balochistan

In Balochistan, torrent-spate-irrigation systems go backs as early as 3000 BC and provided economic basis for some of the early civilisations. These systems are located in both the highland and lowland ecologies.

In highland, these systems are located in Khurasan Range, on eastern slopes of Sulaiman Range and Central Brahui Range. Lowland systems are located in vast Kacchi plain, Las Bela and Kharan basin. The distinction between highland and lowland systems is not absolute. Lowland systems with smaller catchments and in the upper reaches of flood rivers on the plain, in particular share many characteristics of the highland systems. On the other hand, highland systems are located in more temperate climatic zones; where precipitation is gentle and spread over a longer period, conform in some respects to the description of the lowland systems (GOI, 1920).

Floods are crucial in torrent-spate-irrigation, which rise primarily because of rainfall in mountainous watersheds. Their diversion is spectacular, as floods in many cases last between a few hours and few days only, and an entire season's irrigation supplies may pass in a very short time span only.

Several indigenous engineering techniques have been developed to divert the temporary flow. In general, their occurrence depends on local topography. Where, land gradient is relatively steep and channel bed is shallow. Floodwater flows at high speed and is best diverted through free intakes. These intakes are generally higher than riverbed, and water starts to flow in channels, as soon as flood has reached a certain level. Where gradient is less steep, a second type of diversion is found. It consists of deflectors, made of brushwood and stones, to guide water to the off-take channels. A third type of diversion structure is found on alluvial plains of lowlands, which are created at tail of the flood rivers. Slopes are flat and water flows slowly. These conditions allow construction of barrages, make up of fine material of riverbed on the plains, called Ghanda in Balochistan and Ghandi in D.I.Khan. The barrages block flow completely and pond-up water which then flows into a number of flood channels, upstream of the diversion structure (GOI, 1920).

Most interesting system of indigenous spate-irrigation is that prevailing in Kacchi plains, where water users, under an organised action, construct annually immense earthen dams in the Nari River for raising water to the surface. An expert water user, known as '*Raza*', is selected to superintend the work, and water users' living for many kilometres along bank of the river are called in with their bullocks to construct the dam. Some of these dams are over 300-m long, 60 m wide at bottom, and 20 m in height. Every village has to supply its quota of men and bullocks/tractors, or, should it fail to do so, has to pay a proportionate amount in cash. There are many of these dams in the Nari River, and in July and August, when the flood comes; the upper dams are broken as soon as sufficient water for the area irrigable by each has been received. Still, much water runs to waste due to lack of appropriate system development and management.

Potential area of torrent-spate-irrigation is around 1.07 million ha. Out of which, around 0.20 million ha are commanded in an average year.

3. Issues and Imperatives

Variability of flood supplies has a number of implications. One implication is that area cultivated is subject to wide fluctuation. The consequence is that the groups of landholders that receive irrigation supplies differ from year to year. The interests of management of spate irrigation are not uniform, because probability of irrigation varies throughout command area. Because of these different probabilities of irrigation, not only will the interest in spate irrigation vary between different parts of the command area, but the economic capability of landholders in different parts of the command area will vary too (Steenbergen, 1997).

Another implication is that agricultural production follows limits of what is productive and what is not productive. Crops that grown are of normally low value and risk of crop failure, particularly at periphery of the command area, is significant. Net benefits of spate water management are small under any circumstance. In contrast to the large perennial systems, for some of the users the returns to spate irrigation may be so marginal that they will voluntarily give up their entitlement. Bargaining of accessed rights will be relatively relaxed (Steenbergen, 1997). Technical, social, institutional and economic issues related to past and present use of torrent-spate-irrigation system are:

31. Technical

- Because of the inherent uncertainty of torrent-spate-irrigation, it is hard to predict the land that will be irrigated. Furthermore, it is also not possible to predict how much land will be irrigated during a particular storm or within a season.
- Risks in torrent-spate-irrigation are high, but they are not equally distributed throughout the system. Within a command area, there may be land with high, medium and low probability of irrigation. Thus, there exists internal differentiation based on location and level of the command area.
- Gully formation is common due to inherent erodible lands, and silting of nullahs leading to flood hazards. Spate-irrigation schemes are subject to process of active land formation, due to both scour and siltation. The impact of these processes differs between the various systems. One variable is the amount and composition of the sediment load that a river carries which depends on rainfall pattern and characteristics of catchment area; its geology, morphology, and vegetation cover. Farmers, however, are not passive actors in these scour and siltation processes, but often actively manipulate land formation. However, in the public-sector initiatives these processes were not understood clearly and resulted into hydrological imbalance.
- Inadequate and inappropriate diversion of floodwater caused inequity in distribution of sanctioned capacity or share of water to different nullahs. Loss of water is common due to inefficient conveyance, distribution and spreading of water within the system. The tail-end water users are affected in both the extremes of flood and drought.

3.2. Social and Institutional

- Co-ordination among farmers is limited due to lack of appropriate organisation, which can ensure operation of the system in accordance with the established water rights and norms. Furthermore, deterioration of the system due to influence of large water users and notables, and lack of discipline enforced by the Provincial Irrigation and Drainage Authorities has reached to a level, where system could not be operated in accordance with established water rights as per *'Kulliat-a-Rod-Kohi'* in NWFP and Punjab.
- Water rights in torrent-spate-irrigation systems are reactive and are not sharply defined. They cope not only with the unknown proportions of the next flood, but also with the medium-term changes in the river morphology, due to scour, siltation and change of river course. Water distribution in the floodwater irrigation systems is based on allocation rules rather than alienable property rights.
- Out-migration is a common response to a period of dry years. In good years, the parameters are different and demand for labour will peak, in particular, during land preparation and harvest. Again this gives rise to flexible markets for labour and in the recent years mechanical traction.
- Depopulation is a constant threat to the farming communities. In particular, where farmers depend on each other in reconstructing large barrages, population figures might drop below the point where it is not possible to mobilise sufficient labour for these recurrent works. Similarly, a large landlord may be unable to find tenants to work on his land and help in the upkeep of the hydraulic structures.
- Lack of public-sector institutional support to water users in technical backstopping and to resolve the conflicts was primarily due to low priority assigned to torrent-spate-irrigation system. Furthermore, co-ordination among various public sector institutions is non-existent.

3.3. Economic

- Ø In torrent-spate-irrigated tract, subsistence and low-value cash crops prevail. It is still dominated by drought resistant crops like sorghum, millet, pulses, wheat, gram, guar and oilseeds. Most of the land is under local cultivars. Even if optimal conditions were to prevail, crop returns would have difficulty competing with alternative sources of income. Therefore, returns are marginal, as optimum conditions do not occur.
- Ø Despite the marginal returns from spate irrigation, there has been substantial public investment in these systems especially in Balochistan in the last three decades. The failure rate of the schemes built by the public sector was high (Groundwater Consult, 1991). The overriding factor behind the high rate of failures was the inappropriateness of the prevailing engineering concept, which was based on controlling the flow at a single point rather than managing the inherently varying flood rivers. The technical designs for spate irrigation systems resembled those for perennial flow systems, and did not accommodate the capricious nature of the spate systems. Some of these structures were not able to withstand the force of the violent peak floods. In other cases, headworks were by-passed by the braiding river that they tried to control. Moreover, the provision for sediment transport was insufficient and intakes silted up. Trying to avoid these pitfalls would have required substantial investments in large headworks, complex silt excluding devices and long marginal bunds. Though with these investments, it would have been possible to control the rivers at a single point, the low returns ruled against such high investments.

4. Potential Use and Imperatives

Torrent-spate-irrigation system of D.I.Khan is the most structured system compared to systems in D.G.Khan and Balochistan. However, there are many opportunities for further development and improvements.

Command area and watering intensity can be improved by three ways. Firstly, it can be achieved by reducing the outflow to the River Indus and/or Arabian Sea through diversion of additional water to the existing or new commands. Secondly, new water resources can be made available by reducing the existing losses within the conveyance network and thereby reducing the incidence of breaches and tail-water problems. Thirdly, the excess water in flood season especially in wet years can be stored in storage dams for carryover to subsequent months to ensure sustainability of torrent floodwater agriculture. The third option is capital intensive and has limited life of the storage dams due to heavy load of sediments in the floodwater, which will silt-up the dam quickly. In addition to these three options, there is a limited scope of groundwater exploitation in areas, where water of useable qualities is available.

Presently, wheat, gram, oilseeds, sorghum, millets, guar, and melons are normally grown in these areas. Farmers are interested to grow multi-purpose varieties of fodder, as livestock provide a source of livelihood in years, when there are no crops due to droughts. There is a potential to focus this system to achieve self-sufficiency in wheat and edible oils. The imperatives for improving the torrent-spate-irrigation systems are:

- Within the framework of inherent uncertainty, at the most, probabilities can be established and the area that has a reasonable chance of being irrigated in, for instance, a ten-year period may be determined. This area may even be defined formally as an entitled command area. The fringe of the entitled command area can be defined in two ways and that the institutionalised relationship between the distribution of water and the cost contributions to maintenance is determined by how this fringe is defined.
- Institutional changes are required in local management of spate irrigation system through; a) changing the net benefits of resource use; b) subsidising the first and second order transactions costs; and c) direct participation of water users through co-management. The first order transactions costs are higher, but they are only partly born by the water users themselves. The second order transaction costs have to be subsidised from outside. Capacities of public-sector institutions should be strengthened for provision of technical backstop support in design, construction and operation of the system.
- A paradigm shift is necessary for development and operation of the torrent-spate-irrigation systems different from the modern irrigation schemes. This requires acceptance of water logic, which demands a flexible approach with direct participation of water users' to achieve economic sustainability.
- Ensure more reliable water supply by reducing the risk of failure in conveyance network and by increasing deliveries to various nullahs and commands. On-farm water management should be given priority for diversion, distribution and application of water for integrated land use (crops, livestock, forestry, pastures and arid horticulture). This will ensure risk aversion due to droughts and floods, as the tail-water can be ponded in low-lying areas to grow forest plants and forages.
- Introduction of micro-water development schemes is needed for conjunctive use of water through exploitation of shallow groundwater and storage of excess surface water in small earthen ponds for multiple water use (domestic, stockwater and irrigation).
- Development of reserves should be initiated for high value arid fruit progeny gardens and forest nursery, forages, and multiplication of promising crop cultivars for dissemination and transfer of production technology.

5. Recommendations

1. Institutional changes are required in local management of spate irrigation systems through; a) changing the net benefits of resource use; b) subsidising the first and second order transactions costs; and c) direct participation of water users through co-management. The first order transactions costs are higher, but they are only partly born by the water users themselves. The second order transaction costs have to be subsidised from outside. Direct participation of water users' should be ensured at all levels to achieve financial sustainability.
2. A paradigm shift is necessary for development and operation of the spate irrigation systems, which are quite different from the modern weir-controlled irrigation schemes. This requires improvements in water rights and allocation rules as water is at premium. In addition to this, capacities of public-sector institutions should be enhanced for design, construction and operation of these schemes.
3. Farmers are still trying, if possible, to extend their command area through clearing of un-commanded land having mutual agreement with the community. Thus, there is a potential to add more lands under command, where additional water can be made available. Use of improved seed and fertilisers helped farmers to increase productivity in mountain and

Kalapani perennial irrigation systems, where water is silt free. Whereas in *Rod-Kohi* and Riverine systems, farmers are not using any chemical fertilisers. Further, through land forming and development, crop stand has been increased tremendously. Therefore, both extensification and intensification strategies are being adopted by farmers and should be supported by the public sector.

4. Within the framework of inherent uncertainty, at the most, probabilities can be established and the area that has a reasonable chance of being irrigated in, for instance, a five to ten year period may be determined. This area may even be defined formally as an entitled command area. The fringe of the entitled command area can be defined in two ways and that the institutionalised relationship between the distribution of water and the cost contributions to maintenance is determined by how this fringe is defined. This can be accomplished by diverting the flows with layout, which will not be prone to flood damages.
5. Ensure more reliable water supply by reducing risk of failure in the conveyance network and by increasing deliveries to various commands. On-farm water management should be given high priority for diversion, distribution and application of water for high value crops, horticulture, forestry and fodder. Integration of crop and livestock production system will ensure risk aversion due to droughts and floods, as tail-water can be ponded in low-lying areas to grow forest plants and forages.
6. Introduction of micro-water resource development schemes should be given priority for conjunctive use of water through exploitation of groundwater and storage of excess surface water in small earthen ponds for multiple water use (domestic, stockwater, irrigation).
7. Development of reserves should be encouraged for high value fruit progeny gardens and forest nursery, forages, and multiplication of promising crop cultivars for transfer of production technology.

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