ROD-KOHI SYSTEM DEVELOPMENT AND MANAGEMENT IN PAKISTAN – A NATIONAL PROJECT

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FOREWORD

The Rod-Kohi System Development and Management Project was initiated during January 1995, where field research activities were initiated in all the four provinces. The Target Areas are located in D.I.Khan, D.G.Khan, Barkhan and Thana Bouls Khan. The four locations named as Khan represent the ecology, where Rod-Kohi system is prevailing. The local name of the system varies from province to province but it is mainly based on the hill-torrent water.

The following officers contributed in the conduct of field research in the project.

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The contribution made by all the scientists is fully acknowledged as they worked in real difficult situation. Most of these officers have to stay in the field during the period of flood or during the period on interventions.

Dr. Shahid Ahmad
Coordinator
Rod-Kohi System Development and
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I. Non-Perennial Rod-Kohi Systems

1.1. Era, Location and Extent of System

Rod-Kohi (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. 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.

1.1.1. NWFP

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. 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.

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. The 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.

1.1.2. Punjab

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 agriculture (*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.

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.

1.1.3. Balochistan

Rod-Kohi system in Balochistan is named as *Sailaba*. 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.

Floods are crucial in *Sailaba* agriculture (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.

Most interesting system 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.

1.1.4. Sindh

The Kirther range, mountainous region of the Kohistan areas and parts of the Dadu division receive isolated small-scale hill-torrents, which are diverted for runoff farming. The exact area under runoff farming is not known due to scattered behaviour of farming. However, it is significant compared to rainfed farming in the province.

1.2. Issues

Technical

- Because of the inherent uncertainty of Rod-Kohi system, 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 Rod-Kohi system 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. Rod-Kohi 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.

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 Rod-Kohi 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 Rod-Kohi system. Furthermore, co-ordination among various public sector institutions is non-existent.

Economic

- In Rod-Kohi 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.

- Despite the marginal returns from Rod-Kohi, 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. 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 Rod-Kohi systems resembled those for perennial flow systems, and did not accommodate the capricious nature of the Rod-Kohi 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.

2. Perennial-Rod Kohi Systems - *Kalapani*

2.1. Era, Location and Extent of System

The perennial Rod-Kohi systems are located in Western Dry Mountains and Sulaiman Piedmont. The perennial supply spate-irrigation system is known as *'Kalapani'* or black water, on account of its clear colour, to distinguish it from the '*Sufaidpani'*, or white water, the later being the discoloured silty water that issues after rain.

2.1.1. NWFP

Kalapani systems exist in the area before the introduction of Rod-Kohi. Large hill-streams have a small perennial flow, which is expended long before it reaches River Indus. These perennial springs are known by the local name of *'Zam'*. There are five *Zams* in the Division. The cold weather flow of these springs varies from about 6 m^3/sec in the Gomal *Zam* to from 0.6 to 1.2 m^3/sec in the Draban and Chaudwan *Zams*. Like floodwater, this *Kalapani* also, if left to it, would run to waste in torrent bed, leaving surrounding area as dry as before.

Dreary appearance of country is to some extent broken, wherever a perennial stream issues from the hills. Cold clear water running over its shingle bed is caught in small embankments of stones and brushwood, and led away from stony torrent bed to the side. Where cutting in clay soils bring it down to the cultivated fields. Heads of these channels are generally bordered with *'Shisham' (Dalbergia sisso)* trees, which grow to a fair size, and here and there are little water mills with a row of willows along each side of the millrace. Recently, some of the diversion structures have been built with stone/brick masonry.

Kalapani cultivation is of two sorts – '*Tand'* or '*Tandobi'* and '*Vichobi'*. In *Tand* cultivation, water is laid on to open fields divided into strips and plots with small ridges between, like those used in well cultivation. *Vichobi* cultivation resembles ordinary hill-torrent cultivation, to which expression is often applied. Embankment fields are filled up with water, which is allowed to soak in, after, which field is ploughed and sown. As a rule, *Tand* cultivation is only carried on near the head of a stream. It gives less trouble, but requires more water, as crop has to be irrigated every 10-14 days. Where water of a stream belongs to a tribe or shares, bulk of *Kalapani* is used in *Tand* cultivation, whereas surplus being employed in *Vichobi* cultivation. Often after rain, amount of *Kalapani* increases greatly. Though the water can still be kept in hand and distributed in ordinary *Kalapani* fashion, but there is a point when it is impossible to distinguish *Kalapani* or dry weather flow, from *Rod-Kohi* flow. When the torrent comes down in force, they usually carry all the little embankments for diverting *Kalapani*, and the whole water supply sweeps away through the main channel. By cutting deep heads, however, to their side channels, *Kalapani* proprietors can generally ensure a sufficient and sometimes an over-abundant supply, even during the continuance of a flood.

Laths (bunds) around the fields used in *Vichobi* cultivation are generally smaller than in torrent cultivation, but fields are watered oftener. *Kalapani* water brings little or no silt. While, the *Rod-Kohi* lands can be cultivated continuously, without any deterioration in the natural luxuriance of crops. *Kalapani* lands, especially when cultivated in *Tand* fashion, require constant falloffs. As a rule, people in the past try to leave *Tand* land fallow for two years out of three. In consequence of this, even the *Kalapani* irrigated tract do not look as green as might be expected, and country, owing to large amount of fallow, has a half-cultivated look.

Now farmers use chemical fertilisers in *Kalapani* system to ensure continued cropping. Vegetables are commonly grown on *Tand* irrigated *Kalapani* lands. Crops grown on *Vichobi* lands as much more same as *Rod-Kohi*.

2.1.2. Punjab

In Punjab, perennial-spate-irrigation systems go backs as early as the period before the Christ and provided economic basis for some of the early Hindu civilisations. *Kalapani* tract comprises land, which at the point of issue from hills of the Kaha torrent in the Jampur receives perennial irrigation from that stream. It is led away from torrent by water-cuts at a point considerably above the place, where embankments are made to guide autumn *Rod-Kohi* in to distributaries. Crops grown in *Kalapani* are: a) rice of a superior quality in *Kharif;* b) wheat in *Rabi;* and c) fallow. *Rod-Kohi* water does not reach this tract. Date trees flourish on this soil, and bearing fruits. Vegetables, oilseeds, cotton and fruits are also grown.

Other isolated locations, which exist in the Division, are found in Vihowa and Mithawan commands. Mithawan *Kalapani* command is located in the highland. Highland systems are small and much easier to manage but terrain is very rugged. These isolated highland systems are subjected to damage during summer season by *Rod-Kohi* floods, and water users have to rebuild these systems almost every year.

Most of the small-scale *Kalapani* systems can be regarded as a case, where potential for expansion of command area is limited. Thus, these systems can be viewed as an example with adequate availability of water. If water is in excess, then no rotation is practised at the diversion structure, which provides water to more than one channel serving various sub-commands. However, a rotation is practised for each of the sub-commands to provide water to the water users. Therefore, these systems are described as continuous flow, non-rotational channel diversions, rotational for distribution to users, and water rights based on prior appropriation.

Large-scale continuous flow systems are being operated under a fixed rotation of 7 to 10 days interval for various sub-commands. The water user can get his turn after a period of 7 to 10 days. The rotation is practised, as there has been many fold expansion of the command area during the last 3 decades. Still there is a potential for further expansion of the command area. The unit discharge available during the dry period varies from 20 to 30 litres per 100 ha, which is almost in line with the allowance of the irrigated areas, especially of perennial canal commands in the Punjab province.

2.1.3. Balochistan

Perennial water systems exist in two forms. Firstly, perennial streams where water is diverted from the riverbed to irrigate the command area. The most modern form of these systems is now referred to Minor Irrigation Schemes. Secondly, perennial springs in highlands, where water is diverted in streams to irrigate the command area. This is accomplished by raising level of water by temporary diversion structures using stones. These schemes are quite established and scattered. High value fruits and vegetables are grown due to comparative advantage of weather. Apples, apricot, pomegranate, almonds are commonly grown fruits, in addition to potato, onions, tomatoes and seasonal vegetables.

2.2. Issues

Technical

- Kalapani systems are more reliable during winter season, whereas these systems are affected by torrents during summer season. Because of the inherent uncertainty of these systems in summer season, it is hard to predict the land that will be commanded during *Kharif* season.
- Risks in Kalapani systems are not 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 area to be commanded. The tail-end water users are affected in both the wet and dry years. Thus, there exists internal differentiation based on location and level of the command area.
- Stability of water conveyance system due to heavy breaches and landslides is a major concern in highland systems.
- Inadequate and inappropriate diversion of *Kalapani* caused inequity in distribution of sanctioned capacity or share of water to different nullahs. Water losses are common due to inefficient conveyance and distribution of water within the system. Shortage of water availability in dry spells or drought years is common especially in years when groundwater recharge is low.

Social and Institutional

- System deterioration 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.
- 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. Water rights in perennial-irrigation systems are not sharply defined. Water distribution is based on allocation rules rather than alienable property rights. Lack of improvements in water rights and water distribution rules is a major limitation to make these more responsive to equitable availability of water.
- Lack of public-sector institutional support to water users in technical backstopping and to resolve the conflicts was primarily due to lack of focus and priority assigned to Kalapani system. Furthermore, co-ordination among various public-sector institutions is non-existent.

Economic

- In Kalapani tract, medium-value crops prevail. These systems are still dominated by cereals, fodder, pulses, cotton and oilseeds. Even if optimal conditions were to prevail, crop returns would have difficulty competing with alternative sources of income.
- Lack of capital with farmers and joint action is a constraint in adoption of high efficiency orchards farming and vegetable production. Limited access to market is another reason.
- Despite the marginal returns from Kalapani systems, there has been some public investment in these systems in the last three decades. The failure rate of the schemes built by the public sector was high. The overriding factor behind the high rate of failures was the inappropriateness of the prevailing engineering concept. The technical designs for Kalapani systems resembled those for perennial flow systems, and did not accommodate the capricious nature of the Rod-Kohi system, which affects *Kalapani* during the summer season. Some of the structures were not able to

withstand the force of the violent peak floods of torrents. Therefore, these systems have to be designed and constructed with active participation of water users.

3. Project in Brief

3.1. Background

Rod-Kohi is a runoff farming system being practiced in piedmont plains. Runoff from hill-torrents is directed through a network of conveyance system to provide deep watering of 1-1.5 m depth to bunded fields. The water availability depends on the occurrence and distribution of rainfall and the hydrology of the runoff based on the watershed characteristics. The reliability, adequacy and predicting of the hill torrents are the major issues of these areas. The farming is practiced under conditions of floods and droughts - too much or too little water. During floods the excess water not only damages the crops but also affects the infrastructure.

The uncertain hill-torrents water cause floods or prolonged droughts. The distribution of water is variable along the command area. At the head the problem is too much water, whereas tail reaches receive water only if the quantity is in excess of the upper reaches. Some of the tail reaches receive water once in three years. The most critical element of the Rod-Kohi system is the earthen diversion dam built across the flow to divert water. If the bund resists the flow and stay until the command area is watered the farming is practiced otherwise, if the bund is washed prior to the water diversion and spreading than there might not be any irrigation during the whole season. Taking into consideration of these problems, a national research project was initiated during January 1995 in all the four provinces. The total cost of the project is Rs. 50 million.

3.2. Relevance of the Project with Sector Objectives

Eighth Five Year Plan had placed greater emphasis for the development of land and water resources to increase agricultural production/productivity particularly of the under developed regions (Rod-Kohi, Barani, etc.) through diversified efforts. The development and management of Rod-Kohi systems in the past have been based on piecemeal efforts. No comprehensive and integrated approach has been adopted.

System management and development efforts are mainly related to the construction of earthen and concrete embankments by the Provincial Irrigation departments without considering the systems perspective and farmers' participation.

Soil Conservation Directorates in the NWFP and the Punjab provinces construct field inlets where subsidy of around Rs. 6500 to Rs. 10,000 is provided to the farmers. The technology and methodology is obsolete and it will take around 6000 years to cover the Rod-Kohi areas of D.I. Khan with the present technology and financial resources available. Actually, the experiences of the Barani lands are being tried by the Soil Conservation Directorates. The OFWM-Punjab is providing support for lining of watercourses to the farmers, which have irrigation water. The donors are now considering financing Area Development Projects in D.G. Khan, D.I. Khan and Zhob, which will require appropriate and cost-effective technology and methodology for large-scale adoption.

The proposed project is based on comprehensive and integrated approach for system development and management for varying agro-ecological conditions. The purpose of the project is to develop cost-effective technologies for the development and management of Rod-Kohi system. The successful execution of the proposed project will not only develop technologies and methodologies to harness the water of hill-torrents which cause serious damages to the standing crops and livestock but also enhance the productivity and production specially during the drought period, improve the livestock productivity through introduction of better feeding strategies. Therefore, the objectives of the proposed project are in line with the objective of the agriculture sector.

3.3. Project Objectives

The primary objective of the project is to develop improved technology and methodologies for Rod-Kohi system development and management through productivity enhancement, management of natural resources and institutional linkages. The overall objective is poverty alleviation through improving system reliability to reduce migration of rural communities. Expected output in terms of quantitative terms would be provision of improved water harvesting/spreading technology on 5000 acres and uplift of 500 families. The secondary objective is to develop and manage the Rod-Kohi system to achieve equity, profitability and institutional strengthening. The specific research objectives are:

- Improvement of runoff farming through innovative water conveyance, spreading and conservation techniques to enhance productivity and alleviate poverty of the rural communities;
- Development of integrated crop-livestock-range systems for sustained agricultural productivity and production, and reduce migration of rural communities.

3.4. Project Target Areas

Project Target Areas were selected covering the prevailing systems and ecology of the Rod-Kohi areas. An interdisciplinary team of experts visited the selected Divisions mentioned in the PC-I. The study Team selected three sites in each Division and then comparison was made to select the best suitable site for the Project Target Area. The details of the Project Target Areas are given as under:

Province	Division	District	Location	System
NWFP	D.I.Khan	D.I.Khan	Yarik, Hathala, Gloti	Large non-perennial systems
Punjab	D.G.Khan	D.G.khan	Mithawan	Kalapani perennial systems
Balochistan	Zoab	Barkhan	Jhalwani	Medium non-perennial systems
		Musa Khel	Sirati	Very small non-perennial systems
Sindh	Dadu	Dadu	Thana Boula Khan	Very small non-perennial systems

3.5. Work Plan

- **Planning and Diagnosis**

  - Participatory Rapid Area Appraisal (PRAA).
  - Diagnostic Analysis for Assessment of System Performance
  - Resource Inventories and Database Development (GIS)

- Resource Use Planning (GIS)
- Prioritization/Ranking of Interventions

➢ **Interventions**

- Social Initiatives
- Linking Village Organizations with the R&D Agencies
- Water Harvesting, Conveyance and Application
- Improving Water Control and Application
- Land Forming and Contoured Alley Farming
- Improved infiltration of Ponded Water
- Development of Water Resources
- Improved Fodder and Silage Production
- Afforestation and Fruit Plants Production
- Integrated Livestock and Cropping System

3.6. Budget and Expenditure

3.6.1. Budget and Releases

The project was initiated during January 1995. The allocated budget for the first year was just as a token allocation of Rs. 1.132 million. The second year budget allocation of Rs. 9.375 million was in line with project requirement and releases were also sufficient. Five vehicles, eight motorcycles, survey and office equipment and other fixed assets were purchased. Field offices were also established. During the next four years, the releases were in the range of Rs. 2 to 3 million, which were insufficient to have the full scale project activities as per project PC-I. This affected the progress tremendously. Rather Project staff has developed a level of sustainability, where they can perform with the constraints. The budget was increase during 2000-2001.

The noise in the budget and releases affected the planned activities. However, targets were reduced through a process of re-planning and re-fixing the targets. Even inter-province priority was defined to have meaningful outcome.

The allocation of budget for the year 2001-2002 is around Rs. 10.0 million.

Budget and Releases of Rod-Kohi Project.

Year	Allocated Budget	Revised Budget	Releases
1994-95	1.132	-	1.132
1995-96	12.500	-	9.375
1996-97	8.000	-	3.193
1997-98	4.340	-	2.329
1998-99	6.000	4.200	3.748
1999-2000	3.000	-	1.980
2000-2001	10.500	7.000	7.224
Total	**45.472**		**28.981**

3.6.2. Expenditure

The total releases were Rs. 28.981 million, whereas the total expenditure was Rs. 24.856 million. This shows that only 50% project budget has been spent by the end of the June 2001.

Expenditure under Rod-Kohi Project.

Year	Releases	Expenditure (Rs. in million)				
		Establishment	Operational	Fixed Assets	Capital Work	Total
1994-95	1.132	0.007	0.414	0.078	0.000	0.499
1995-96	9.375	0.325	0.729	6.391	0.029	7.473
1996-97	3.193	1.322	1.418	0.154	0.208	3.103
1997-98	2.329	1.281	1.432	0.039	0.232	2.984
1998-99	3.748	1.332	1.604	0.004	0.158	3.098
1999-2000	1.980	1.517	1.227	0.002	0.062	2.807
2000-2001	7.224	1.136	2.557	0.086	1.112	4.892
Total:	**28.981**	**6.920**	**9.381**	**6.754**	**1.800**	**24.856**

3.7. Manpower

The sanctioned posts for the project are 38 and details are provided in the Table. At present, 14 persons are in place and getting their salary from the project. The turnover of project staff is higher due to contract employment. Considering the high turnover problem, some of the regular staff of the WRRI-NARC was deputed at the Project Target Areas. At present, seven persons have been deputed from WRRI-NARC to Target Areas – three senior scientists and four staff persons. Further project appointments will be made based on the extension of the project.

S.No.	Name of Post	BPS	Number of Posts	
			Sanctioned	Actual
1.	Senior Scientific Officer	18	5	1
2.	Scientific Officer	17	10	5
3.	Office Assistant/Accountant	11	3	-
4.	Survey Assistant	11	5	1
5.	Field Assistant	8	4	1
6.	Typist	5	3	2
7.	Driver	4	5	3
8.	Chowkidar/Baildar	1	3	1
	Total:		**38**	**14**

3.8. Constraints

- Noise in budget allocation and releases affect the progress of the project and field officers try to ensure running of the project within constraints.
- Appointment of staff is difficult on contract basis as the project locations are away from large towns. Thus turnover of manpower is higher.
- Mobility is limited as there is only one vehicle in each Target Area. Motorcycles have limited use under the field conditions.

4. Major Accomplishments

4.1. NWFP

Target Area in the D.G. Khan district is comprised of three major locations namely the Yarik Target Area, Hithala Target Area and Gloti Target Area. The size of the Target Area is around 600 ha. The word 'command area' is used exclusively for the non-perennial Rod-Kohi systems of Rod-Takwara and Nullah Gomal representing the lowlands served by the non-perennial hill-torrents.

4.1.1. Low-cost Technology for Earthen Diversion Bunds

The diversion structure is an essential element of the Rod-Kohi system, as watering of fields is a function of stability of the diversion structure. If the structure could not resist the pressure of water, farmers are unable to irrigate. **Considering the importance of the diversion structure, at the Yarik Target Area the existing large diversion structure having length of 2000 m and height of 20 m was renovated and the low-cost technology was developed for the sensitive reaches.**

The sensitive reaches of the structure, where loose fill material is used for construction or renovation are subject to failures during the flood. Therefore, sensitive reaches were identified to test the LDPE plastic film as a barrier to control flow of water through the structure. **The LDPE plastic film of 1000 m long and 4 m wide was placed in steps constructed like stairs so that soil can be easily placed over it. The cost of plastic film is around Rs. 20 per m^2.**

In most of the cases farmers use the sediments available in the upstream area to build the diversion bund. Normally the soil is in layered form having different textures. Farmers were given awareness regarding the varying textures of the layered soils. The fine textured soil can be used to create a barrier for the control of seepage. This is most economical but time consuming technique and requires trained bulldozer or tractor driver for the construction of the bund. There is a need to arrange large-scale training programme both for the tractor/bulldozer drivers and farmers.

4.1.2. Remodelling of the Water Conveyance System

Target Area selected at Hathala represents the excellent layout of the Rod-Kohi sub-command of the Nullah Khore, which is a tributary of the Nullah Gomal. The water is diverted from the diversion bund named as 'Ghandi' and then conveyed from smaller canal named as Khula. There are minor channels used for diverting water to fields.

The remodelling of the sub-command was accomplished to improve the overall hydraulic regime of the conveyance system. **Around 4500 m length of the conveyance system bund was renovated and raised to a height of 1.5 m. The total length of system rehabilitated was 6200 m, where gradient of the channel was improved.** This is one of the most promising interventions in the project where farmers participated and there is a wide scope for extension of the technology.

4.1.3. Monitoring of Flow of Nullah Khore

The discharge measured at main Gandi during medium flow regime was 630 cusecs, whereas the discharge during the low-flow regime was about 42 cusecs with the

velocity of 4.1 and 2.4 ft/sec, respectively. In the low-flow regime, the streamsize was too small, therefore sufficient area could not be watered for cultivation of crops. The extreme variability in flows is a distinct character of the Rod-Kohi system.

Rod-Kohi system flows fluctuate widely in space and time. This system of farming is characterized by extreme events of floods and droughts. Landholders are at the mercy of these extremes. Predictability of flows is difficult as floodwater is coming from large catchments. The Target Area is located at middle-tail section of the nullah Khore. Due to little rain the floods are of short duration, lasting from one to three days usually. The floodwater is utilized firstly by the farmers located at the head and onwards as defined in the water rights of the Rod-Kohi system.

The extreme variability in size of flow poses serious constraints to design structures for reasonable performance during high and low flows. This is the major focus of research in this project to design structures to meet the needs of hydraulics of low- and high-flows.

4.1.4. Sedimentation in the Command of Nullah Khore

Sediment deposition in the fields, Khula and in the main nullah Khore was measured during both the low- and high-flow regimes. The estimation of sediment deposition was made with reference to the permanent benchmarks before and after the floodwater. The floodwater velocity was low but it carried more sedimentation load. **The sedimentation in the nullah Khore ranged from 40 to 42 cm depth, whereas the sedimentation in right and left banks of Khula ranged between 27-30 cm. Sediment deposition in bunded units/cropped fields ranged between 2.4-3.2 cm depth. The sediment deposition in the earthen ponds was also recorded, which ranged from 1.9 to 2.5 cm depth.** The low rate of sedimentation in the pond was due to setting of sediments in the field and then water with less sediment was allowed to enter the pond.

For the construction of structures, two parameters are essential. Firstly the structure should respond positively under both the low- and high-flow regimes. Secondly, allowance should be made for sedimentation. In the natural systems, hydraulic equilibrium prevails and thus sedimentation is in equilibrium. Any obstruction not in line with the flow conditions will reduce the velocity of water and thus excessive sedimentation might occur.

4.1.5. Water Diversion and Control Structures

Water Diversion and Distribution Structures

Nine diversion and distribution structures were constructed at the Target Areas with a discharge capacity of 250-400 cusecs. Brick masonry was used for the construction of diversion and distribution structure with active participation of the local community. The cost of the first structure was around Rs. 12500. Initially the structures were built with only the labour support from the farmers. Later on their contribution was increased gradually and also the design was modified to reduce the cost. **The cost sharing by the farmer was is in the form of labour cost (skilled and unskilled) and tractor charges for land development. These structures can irrigate an area of around 16 ha.**

Performance of these structures was evaluated during both the low- and high-flow conditions. These structures helped to regulate water during both the flow regimes. Thus watering intensity can be improved with added advantage of improved control, which avoided the damages during the high-flow conditions.

Low-cost Pacca Inlet Structures

Pacca inlet structures being used traditionally in the area are rectangular weir-type inlets constructed using the brick masonry. The cost of these structures is beyond the reach of the common farmers even if the government provides 50% subsidy. Therefore, three different types of structures were developed and tested during the project period. These include: a) low-cost brick masonry structures; b) pre-cast concrete Pipe-Nacca structure; and c) GI Sheet Structure. In total, fourty-four structures were constructed under these three types and tested during the last five years.

Rectangular Weir-type Brick Masonry Structure: **Twenty-three structures were constructed in the Target Area. The design discharge of these structures ranged between 30 to 40 ft^3/sec and normally constructed for fields of around 3 ha. The cost of these structures ranged between Rs. 1500 to 5000 per structure based on the size and capacity of the structure.** The farmers contributed around 50% of the cost of structure in the form of mason and labour.

Performance of pacca inlet structures constructed in the Hithala Target Area was evaluated under the flow regimes, high- and low-flows. Most of these structures performed well and safely passed the floodwater under both the flow regimes. Minor damages occurred to few structures was observed and appropriate actions were taken subsequently, especially the improved earthwork and compaction was required around the structure. **The velocity of flow was non-erosive, as it was around 3 ft/sec, and thus there is a scope for sedimentation in the conveyance system and command area.**

Pipe-Nacca Inlet Structures: **Nineteen Pipe-Naccas inlet structures were installed in the Target Area considering the area to be irrigated and amount of water required in a short period.** The critical points were surveyed and marked considering the Khula and field elevations at each field, which can be used to irrigate the desired area. **One to two Pipe-Naccas were installed from field to field and Khula to field.** The soil surface was compacted. The extra strength was provided by putting iron bars at both the upstream and the downstream sides to avoid displacement. The diameter of the Pipe-Nacca was 15-20 inches. **The cost ranged between Rs. 350 to 600 per structure and suitable for fields of smaller size where farmers want to divert smaller flows of water.**

G.I Sheet Inlet Structures: Two GI Sheet structures were constructed in the Target Area. The cost of G.I sheet inlet structure was around Rs. 400. The structure is of low cost and easy in operation and handling. The structure's capacity is around 20 cusecs and can irrigate 2 ha. The installation of the structure is very simple and no masonry work was involved. Corrosion of sheet will not happen, as it is galvanized iron sheet. The structure was anchored with wooden pegs at the bunds and at the bed.

4.1.6. Water Harvesting, Storage and Sand Filter for Multiple Water Use

D. I. Khan despite located on the bank of river Indus, the large area of the district is facing shortage of water both for domestic and stockwater use. The water-table outside 10 kilometers circle of the city is much below the exploitation level and at certain places even if accessible, it is brackish in quality due to presence of salts and minerals in the sub-strata.

The community usually uses earthen reservoirs for drinking water. The reservoirs are filled either with rainwater or by runoff water. The livestock of the area also drink water from the same ponds, which lead to health hazards, like development of Guinea worm in the body, which is commonly known as '*Naroo*'. Dysentery, dyspepsia and enteric fever are the reported diseases in the area.

Keeping in view the intensity of the problem, the project developed and/or renovated the two water-harvesting systems in the Jandar area and one system in the Gloti area. Sand filter was constructed to provide clean and safe water. The cleaning of sediments around the sand filter is required after two to three storms.

For the underground tanks, which were closed from all the sides provision for cross ventilation was made. The tank was cleaned and application of bleaching powder was made as per prescribed dose to remove the odour and to kill the germs. The chemical analysis of stored water was carried out before the treatment in the Gloti area. The total dissolved solids in the stored water were 300 ppm, pH 7.9 and SAR 2.2. Thus water was safe for drinking purposes based on the chemical composition.

A galvanized iron sieve was installed in front of the inlet and gravels were arranged according to their size and shape i.e. small and big size gravels were arranged layer by layer and about 25-30 cm layer of clean sand was spread over the gravels in the inlet. The total cost incurred on the installation of sand filter ranged between Rs. 500 to 1000 depending on the size.

The first sand filter was installed in1996 at the Jandar village, which is working satisfactorily since the last five years, and the community is looking after the covered tank and the catchment area is also free from vegetation and shrubs. The underground tank had 4-5 feet depth of clean water for domestic use.

Five sand-filters and hand-pump based systems were successfully installed in the Hathala Target Area, which are being used to pump clean and safe water. This intervention seems very promising for provision of water for domestic and stockwater use from the existing earthen ponds. It is not possible to kill the harmful microorganisms in water with sand filter because chemical or UV treatment is required. However, insects, wastes and sediments are filtered with the use of sand-filter and hand-pump.

4.1.7. Crop Productivity

Crop-livestock is a dominant production system of the Rod-Kohi ecology. The cropping system, selection of crops and cropping/harvest indices depend on the availability and utilization of runoff water. **The bunded unit size is around 3 ha or more and surface is unleveled. Seedbed preparation in larger fields is not accomplished in a particular day because of extreme variation in soil moisture at the field level. Thus planting in field is also dependent on the preparation of seedbed (partial/complete). In fact, it takes days and depends on the depth of watering and evaporation and seepage rate.**

Seed Cleaning and Grading and Introduction of Improved Varieties of Crops

Experiments for productivity enhancement were conducted on millets, wheat and chickpea crops using simple and practical interventions. The interventions include: a) evaluation of yield performance of farmers ungraded seed; b) farmers graded and cleaned

seed; and c) seed of an improved variety.

The women folk in the Yarik Target Area were organized and desired training was imparted for the manual cleaning of seed of wheat, chickpea, millets and sorghum. **The cleaning and grading of farmers' seed helped to increase the yield of crops by 10-24 %, whereas improved varieties increased the yield by 25-37% for wheat, chickpea, millets and sorghum.** The increase in yield due to cleaning and grading is a function of the level of quality of the seed stored by the farmers. There are higher chances of increases for farmers whose seed is of lower quality having more impurities and weeds. **The cleaning and grading of farmers seed is a practical intervention, which can be adopted by farmers through motivating and organizing the women folk. Around 100 demonstrations were arranged during the last six years.**

Yield and Harvesting Index of Selected Crops at Farmers Fields

In Rod-Kohi areas, farmers are practicing traditional agriculture in three distinct conditions: a) Rod-Kohi system with water spreading; b) Barani agriculture; and c) Supplemental irrigation using lift pumps. The Target Area is located at middle to tail reaches of the non-perennial Rod-Kohi system, where the tail-end farmers some times do not receive any flow for watering of their fields. During certain years, the Target Area did not receive any flow at the time of wheat sowing and only few farmers cultivated their lands. Same situation was observed with other crops. **However, the harvesting index data were collected to evaluate percent of cropped fields matured with economic harvests. In total sample of 45 farmers was used for study during the crop-growing season.**

Millets: **Harvesting index and yield data of millets for eight selected farmers of the Rod-Kohi system indicated that average harvesting index was about 80% with average grain yield of 864 kg/ha (ranged from 653 to 1086 kg/ha) at the Hithala Target Area. .**

Wheat: **Crop yield and harvesting index data for wheat were collected from ten selected farmers of the Rod-Kohi system at the Hithala Target Area. The data revealed that the average harvesting index was about 83% with average grain yield of 2113 kg/ha (ranged between 1740 to 2513 kg/ha).** The farmers of the study area applied brackish water to their fields before crop sowing, which affected germination of wheat and thus the yield was low.

Crop data were collected under supplemental irrigation for only three farmers at the Yarik Target Area. The farmers applied supplemental irrigation to their fields from the nullah's bed where water was retained in depressions for a longer period. Some of the farmers used the ponded water, which could be utilized for the crop. **The average harvesting index was about 84% with average grain yield of 2438 kg/ha (ranged from 2250 to 2833 kg/ha).** The farmers applied only one irrigation. Yield under supplemental irrigation was 15.4% higher than Rod-Kohi system, which justifies supplemental irrigation. Furthermore, sometime these fields do not receive any Rod-Kohi water.

Under Barani farming system, about ten farmers at the Yarik and the Gloti Target Area were selected. The average harvesting index was about 76% with average grain yield of 1243 kg/ha (ranged 1056 to 1786 kg/ha). The low yield of crop was due to less rainfall during the crop-growing season.

Average Barani yield was 1243 kg/ha with harvesting index of 76%. The Rod-Kohi watering increased grain yield significantly to the average of 2113 kg/ha with harvesting index

of 83%. With supplemental irrigation, the grain yield was increased to 2438 kg/ha and the harvesting index of 84%.

The most important aspect is that the potential of wheat productivity is higher in Rod-Kohi system compared to Barani. However, the area which could not be harvested was 24, 17 and 16% for Barani, Rod-Kohi and supplemental irrigation systems, respectively. **The Rod-Kohi and supplemental irrigation yields were 70 and 96% higher than Barani wheat yields.**

Chickpea: **Harvesting index and grain yield data of chickpea were collected from Hithala, Yarik and Gloti Target Areas.** The crop under Rod-Kohi system was damaged due to the application of brackish water before sowing.

Harvesting index data of ten selected farmers were collected from the Rod-Kohi Target Area. The average harvesting index was around 80% with average grain yield of 1468 kg/ha (ranged between 1266 to 1666 kg/ha).

Yield data under supplemental irrigation was collected for five farmers at the Yarik Target Area. The grain yield ranged between 1306 to 1660 kg/ha with an average harvesting index of 77%. Due to the unevenness of the cropped fields and low rainfall during the cropped season the yield of the crop was affected. Farmer applied only one irrigation to their crop at the time of sowing. The average yield was 1511 kg/ha, which was around 5% higher than the Rod-Kohi yield.

Crop yield and harvesting index of chickpea were estimated for ten selected farmers in the Barani area. The average harvesting index was around 79% and grain yield ranged 1250 to 1686 kg/ha. The average Barani yield was around 1468 kg/ha, which was comparable to the Rod-Kohi farmers.

In summary, for chickpea, yield under Barani, Rod-Kohi and supplemental irrigation systems were almost same statistically. Thus, chickpea can be grown under Barani farming in an average year. However, supplemental irrigation can help to increase yield during dry years. **Therefore, concept of supplemental irrigation for chickpea must be based on the objective of planting chickpea at optimal sowing time and critical growth stages where life saving irrigation can either save crop or increase yield tremendously.**

Melons: Melon crop is a short season crop of about two months. Usually, it is grown in between the *Rabi* and the *Kharif* seasons to get extra income from the cultivated lands if sufficient carryover moisture is available. The crop was sown in the middle of April and harvested during the middle of July. The early season crop gets higher prices in the local market, whereas the late picking gets low prices.

Eight farmers were selected in the Target Area to estimate harvesting index and crop yield. The crop was sown on about 48.57 ha; whereas 40.46 ha were harvested. The average harvesting index was about 84%. The attack of fruit fly during crop season was reported and crop was damaged slightly. The crop yield ranged 1139 to 2372 kg/ha. The average yield was 1543 kg/ha with an average income of Rs. 3884 per ha. The low yield was due to Rod-Kohi farming, where water was a limiting factor. There was extreme variability in selling price of melons, where it varies from Rs. 1 to 4 per kg.

Plantation of Arid Plants in the Command Area

Natural vegetation in the area is scanty, because of free grazing. Furthermore, the location of the Target Area is middle to tail reaches of the command and most of the times the area remain dry and hardly any crop is grown. Animals' grazing is free in the cultivated fields and farmers browse the trees manually to feed their animals. The survival of young plantation in the area is very difficult. The farmers' active participation for the forest/fruit plantation is a pre-requisite. **About 2000 forest plants were planted in the Target Area**.

At the Hithala village, a water point is located at farmers' fields, which receives water every season. The plantation was carried out around the earthen reservoir. **Reverse slope terraces were constructed manually.** The height and width was kept 1 m each and eucalyptus, guava, bakain, citrus and zizyphus plants were planted. The low survival rate was mainly due to application of saline water and arid climate. The good quality of floodwater in the Target Area is available only during the storm duration.

EM Bio-Compost Development

In the Rod-Kohi areas of the D.I. Khan, a large number of livestock heads exist in the area. Animal wastes are not collected for the preparation of compost because farmers are not involved in stall-feeding and they are normally involved in free grazing of animals. Farmers of the area do not use chemical fertilizer for their crops. Due to non-availability of cow-dung the farmers are unable to use EM for organic compost. However, the scope of EM compost was worked out with the commercial plant nurseries and they were ready to use the EM compost for their nurseries. Two nurseries were chosen for intervention.

EM was applied to animal wastes and vegetative materials for efficient fermentation. The material was thoroughly mixed and was covered with PE black plastic film. The compost material was mixed three times for effective fermentation. The compost was ready after 25 to 28 days. The graded material was sieved through a sieve of 1/6 inch mesh size and results are as under:

The objective of the study was to: a) reduce time required for decomposition/ fermentation of materials; b) enrichment of compost in terms of nutrient status; and c) fine-grade particle size to increase uptake of nutrients by plants. **The results indicated that three things are essential for having improved compost formation i.e. optimal temperature between 25-45 °C; optimal moisture contents and anaerobic conditions. Temperature inside compost is a function of depth of compost and the ambient temperature. The increase in depth of compost results into increase in temperature. Higher depths are not preferred because increase in depth would certainly results in burning of organic matter if temperature goes beyond 60 °C**.

4.1.8. EM Bio-Generator for Amending Sodic Groundwater

A farmer's field was selected at Ahmad Khel model farm, Dera Banu Road, D.I. Khan. The farmer had installed a tubewell and the groundwater was brackish and the EC, pH of tubewell water was 3000 ppm and 8.7, respectively. Similarly, the EC and pH of the soil was 850 µmho/cm and 8.5, respectively. The farmer had already sown the wheat crop. Farmer constructed the EM Bio-generator on cost-sharing basis. **The size of the Bio-generator was 10' x 10' x 4.5'. The total cost incurred for the construction of EM Bio-generator was around Rs. 10485. Out of which 55% of the total cost was shared by the farmer in the form of labour and skilled labour and digging of tank, whereas 45% of the total cost was borne by the project.** Germination, emergence, crop stand and yield were increased significantly after fertigation using amended groundwater. Two more systems were installed after the initial testing.

The EM bio-fertigation using the brackish groundwater helped to reduce the pH and to manage high bicarbonate waters. The microbial action in water is sustainable for 30 days. Thus every alternate irrigation has to be treated. The amended water helps to maintain the microbial activity in the soil. Thus soil quality can be maintained even with the use of brackish quality groundwater. Presence of organic matter provides food for bacteria and nutrients to crops.

4.1.9. EMz Ceramics for Improving Fuel Efficiency of Diesel Pumpsets

Initial testing of EMz ceramics on diesel pumpsets having different size were carried out at WRRI, NARC Field Station and after the encouraging results and successful testing of EMz ceramics on diesel pumpsets, the technology for improving fuel efficiency was transferred to Rod-Kohi Development project Field Stations. The fact that ceramics are solid is one of the major advantages, because they will last and continue to be effective almost indefinitely. The magnetic resonance produced by these ceramics not only improves combustion efficiency but even cleanup exhaust gases.

The longer life of EMz ceramics made these very economical for application in Pakistan, especially for the diesel pumpsets, where: a) 2 ceramics were needed for diesel engines of less than 16 hp; b) 6 ceramics are needed for diesel engines of 16-30 hp; and c) 10 ceramics are required for diesel engines beyond 30 hp.

Eight diesel engines operated pumpsets were selected for testing the effect of EMz ceramics on fuel consumption. The size of the diesel engines selected for the study was 12 and 22 hp because these are normally used in the Target Area. The diesel engines are operating in Katcha area of the Indus riverbed and are functional throughout the year for cultivating crops. The water table is accessible within the range of 10 to 15 feet. The area is located 15-20 kilometers in south-east of D.I. Khan and diesel pumpsets are installed permanently. The diesel engines are old and locally termed as peter engines of Chinese origin. Later on six additional pumpsets were included in the study.

The engine tank was filled with diesel. The coolant temperature was recorded. The engine speed was kept constant at a marked point. The engine was operated for 1 to 2 hrs duration. The tank was refilled with the diesel. The quantity of diesel used was measured and average consumption of diesel was estimated as baseline, prior to the addition of EMz. After establishing the baseline, two and six EMz ceramics were added in the 12 hp and 22 hp diesel engines, respectively. The fuel consumption after 30 days period was collected and difference in fuel consumption was measured after the addition of EMz ceramics.

The results indicated that the reduction in fuel consumption ranged 19.4 to 25.77% and 17.0% under 12 hp and 22 hp diesel pumpsets, respectively. The manufacturer reports life of EMz ceramics for an indefinite period but this has to be verified under the Pakistan conditions. Systematic work is in progress at the WRRI-NARC Field Station.

4.1.10. Agro-meteorological Data

Agro-met data were recorded at AZRI, D. I. Khan during the last six years covering air temperature, relative humidity, pan evaporation, wind velocity and rainfall. The project strengthened the observatory of the AZRI and being used for project.

4.2. Punjab

Mithawan watershed Target Area is comprised of five Mauzas with command area of around 600 ha (340 ha of cultivated land and rest as rangeland). The total land area is around 2900 ha. Word 'command area' is used both for *'Kalapani'* area and the rangelands. Rangeland is important from two standpoints. Firstly, it provides water to the small storage ponds for livestock. Secondly, it provides forages for livestock and serves as grazing land. The terrain is rugged and mountainous, thus interventions represent both highlands (rangelands) and lowlands (Kalapani).

4.2.1. Water Harvesting and Use in Small Catchments

Two small catchments were selected and gauged in the Target Area for monitoring of rainfall, runoff and sediment load. Automated Meteorological observatory was installed at the Site Office. In addition to the experimental catchments number of small catchments were selected, where physical interventions were introduced to harness runoff water, reduce flow of sediments and erosion processes, increase surface cover through ponding of water and improved productivity of grasses and fuelwood. Aridity and free grazing are the major concerns; therefore biological interventions were adversely affected resulting in extremely low survival rate.

Catchment Interventions

Conservation Structures: The upstream areas are having slope of around 40 percent and subject to severe soil erosion because of lack of vegetation cover. **Contour trenches (40) were excavated in staggered form to harvest and store runoff. Loose stone check dams (72) were constructed to trap silt in the upstream area. The downstream area is now safe from further erosion, whereas the upstream area was filled with debris and gravels and thus checks dams were further raised.**

Eyebrow terraces (1300) were constructed in selected catchments. Deposition of soil sediments occurred in the eyebrow terraces due to the ponding of runoff. These terraces were very successful in harvesting runoff and trapping the sediments, which ultimately helped to improve the ground cover.

Biological Interventions: **Multi-purpose forest plants were introduced in the eyebrow terraces of the catchments**. Some of these plants could not survive due to harsh climatic conditions or grazed by animals due to open grazing. Consequently, these plants were replaced during the subsequent years. **In addition, seeds of *Acacia nilotica* and *Dodonaea viscosa* were also broadcasted in the fenced boundary of the experimental catchments and unfenced upstream contoured trenches, respectively, to promote the regeneration of these species.**

Monitoring of Hydrological Data

A long-term activity to monitor hydrological parameters at two paired degraded

catchments is underway since 1996. Rain gauges, both recording and non-recording were installed. Automatic water level recorders were installed to measure flow of runoff using 'H' type flumes at the concentration points of both the catchments. The data revealed that no surface runoff was recorded for a storm depth of less than 10 mm rainfall. This is the only gauged catchment in the semi-arid and arid environment of Pakistan.

4.2.2. Water Conveyance, Control and Application

Water Conveyance

Irrigation in the command area is dependent on perennial *Kalapani* flows of springs. However, the discharge of these springs fluctuates with rainfall and availability of stream flow. Discharge of water was measured at the head and tail of the four Mauzas i.e. Dholi, Kothi, Sohrbun and Khand to assess existing water conveyance losses in each Mauza and to introduce appropriate interventions, accordingly. **The water conveyance losses ranged between 30 to 40 percent**.

As in the *Kalapani* area, no support is available from the OFWM for the lining of watercourses. Furthermore, farmers can't afford to have standard 9-inch brick lining as practiced by OFWM. Therefore, following **three types of lining were evaluated with active participation of the farmers. Stones, labour and other support was provided by the farmers, whereas bricks, cement or plastic film was provided by the project.**

- 4.5-inch brick masonry lining for 75 m length of watercourse;
- Stone masonry lining for 110 m length of watercourse;
- LDPE plastic film lining of 250-micron thickness for 470 m length of watercourse.

The stone masonry lining is cumbersome, whereas bricks have to bring to the project area from close by kilns, and due to rugged terrain the transportation charges are higher. However, 4.5-inch brick lining is still 40% cheaper than the 9-inch brick lining. But the resource poor farmers cannot use it due to lack of affordability.

The LDPE plastic lining is most economical compared with other techniques, as it does not require skilled labour and construction materials. The cost per m^2 of plastic film is around Rs. 20. Furthermore, complete elimination of water losses through the use of LDPE plastic film helped to control waterlogging in the adjacent fields.

The WRRI-NARC in collaboration with local plastic industry produced LDPE film of 250-micron thickness. Black carbon and UV stabilizers were added to control effect of aging due to ultra-violet rays. The first lined channel gave encouraging results because seepage was completely eliminated. Therefore, based on the experience, plastic lining was replicated at various places in the Target Area. This intervention is recommended for large-scale adoption in Kalapani areas.

Water diversion and control structures (5) using double panels were constructed. In addition, 30 cm diameter panel Naccas (49) were installed for diversion of water to smaller channels or fields.

Water Application

The soil texture is very coarse and thus the infiltration is very high. Farmers normally practice irrigation on very small terraced fields. **The application efficiency varies from 25 to 50% in the area**. **Farmers awareness meetings were organized to demonstrate the application of water on leveled and un-levelled fields. Farmers started improving the layout and level of the field.** However, farmers at the head face difficulty due to higher gradient, whereas in the tail end reaches fields are relatively large and easy to form. Farmers were also motivated to improve their water inlet structures.

Water Control

The main diversion structure is usually constructed by gravel and loose stones to divert water from Siri Nullah to the fields. Due to inefficient construction, the structure was unable to block water properly as it finds its way into the Siri Nullah through stones and gravels and ultimately reduces the diversion of water for irrigation. Existing construction methods need to be improved to enhance diversion of water for irrigation. **The LDPE plastic film was used to provide barrier for seepage and spills from the stone masonry structure. The increase in water diversion due to the introduction of plastic film was 9.3%, which is significant**. **In addition to saving of water, the elimination of seepage losses would help to sustain the structure and avoid damages.**

The excessive seepage causes waterlogging in the adjacent fields. This situation had encouraged the growth of weeds like *typha* and *Cyperus rotundus*. The critical section of the watercourse was lined with the polyethylene film. It helped not only to save 30-40% water conveyance losses but helped to reclaim the adjacent waterlogged fields. **Thus benefits are two folds. Saving in water conveyance losses helped to increase the irrigated area by over 30% and reclamation of waterlogged soils. Reclamation also helped to save extremely limited command area in the Mithawan watershed**.

4.2.3. Land Forming and Integrated Land Use

Farmers trainings and awareness programmes were organised with active participation of Mauza Organizations to initiate clearing of excessive stones from the fields, levelling using manual tools and front-mounted tractor blade. The fields are very small and soil texture is from extremely coarse to medium. Therefore, infiltration at the head is very high. Thus field levelling is very important to have better application efficiency.

Mauza Organizations were encouraged to bring the fruit plants from reputable nurseries and sold to the farming community. Project is also maintaining the small-scale progeny garden and nursery, which farmers can use for stocking of plants during the planting season. Forest plants grown in the nursery were provided to the farmers for plantation.

Forest and fruit plants can provide some return to farmers even during the extreme drought periods. Furthermore, fruits have also improved the family nutrition. Similarly seeds of vegetables were also provided to farmers.

4.2.4. Diversion of Water and Development of New Command Area

Unlike the other Mauzas, Sohrbun is a relatively newly commanded Mauza and having better expansion capacity for additional command area. However, this Mauza is not having water rights. The farmers having water rights in other Mauzas can use their allocated time-share in this Mauza. One of the farmers at the Mauza Sohrbun cleared a segment of land for additional command area. An ephemeral stream intercepted the land. **An aqueduct of 46 m long was designed and constructed with participation of farmers to bring this newly cleared area under irrigation. The materials and skilled labour were provided by the Project** (Rod-Kohi and FAO) **and farmers provided the required labour**.

In continuation of the aqueduct, 25 m length of watercourse was lined with stone masonry to reduce water conveyance losses. Supply of water enabled to bring additional 1.6 ha of land under irrigation. Farmer is exercising integrated land use activities including establishment of small-scale fruit orchards, growing of vegetables and range management practices like raising of multi-purpose tree species and protection of natural grasses. There is a fare chance to bring additional area under irrigation in the downstream command area.

The crop yield was extremely low due to lack of appropriate land forming, layout and irrigation water application. Therefore, it was essential to initiate land development activities, which include: i) fields layout; ii) land leveling; and iii) terrace formation. **Farmers were assisted through provision of technical support and earth moving machinery i.e. tractor with dozer blade. Soil conditions were extremely poor and demand improvement through biological means. Thus Guar seed was arranged by the Project as a first crop for soil improvement, which yielded 277 kg of Guarseed worth of Rs. 4016.**

Eight ha of new land was developed using earthen watercourse construction of 258 m and lined watercourse of 42 m. Additional area can be brought under irrigation by construction of earthen watercourse and lining of sensitive reaches. This is most economical compared to aqueducts but has limited application.

4.2.5. Small Earthen Reservoirs for Stockwater

Water shortage for livestock is a major concern in the catchment area. Animals have to walk long distances for want of water. Farmers were motivated to build small and medium size earthen ponds for storage of water. Critical input of bulldozer was provided to the farmer as the terrain is rugged and construction of main earthen structure was not possible with ordinary tractors.

One earthen reservoir was constructed in the catchment area with farmers' participation. Natural spillway was preferred to reduce the cost of the reservoirs. The reservoir now provides water throughout the year to meet the stockwater requirement. Some of the farmers have also experimented fish raising in the existing reservoirs, which were also renovated. Farmers have planted the forest trees around the periphery of these reservoirs.

4.2.6. Sprinkler and Trickle Irrigation Systems

Micro-Sprinkler Irrigation System

The micro sprinklers irrigation system was installed for nursery to overcome problems of water shortage and labour problems. The locally manufactured micro-sprinklers irrigation system provides overhead spray to saplings as per requirement of nursery plants to have higher survival rate and growth of plants even under very harsh environments. Pacca water tank was built to provide water for irrigation or fertigation.

Trickle Irrigation System

Trickle irrigation system was installed at the nursery compound to provide localised irrigation to fruit plants of the progeny garden. The locally manufactured trickle irrigation system components were used. Flushing of pipes to avoid blockage and replacement of micro-emitters, whenever necessary, was undertaken periodically. **Another trickle irrigation system was installed on farmer's lands at Fort Manro, where farmer paid 100% cost of the system.** Routine maintenance training was imparted to the water users' for operational management of the system and it is performing satisfactorily for the last 4 years.

4.2.7. Improved Fodder and Silage Production

Seed and plants of improved fodder varieties were provided to farmers through Mauza Organizations. Demonstrations for cultivation of fodders and silage were arranged and desired trainings were provided. Now fodder is an essential element of the cropping pattern.

4.2.8. Afforestation and Fruit Plants Production

Plants of forest tree species were provided to the Mauza Organizations for distribution to the farmers. Most of these plants were multi-purpose to have both forage and fuelwood. Mauza Organizations were encouraged to bring fruit plants from the reputable nurseries for distribution to farmers on cost basis. Only technical support and desired information was provided.

In the Target area, now integrated land use is more strengthened compared to the start of the project. The integrated land use provides more profitable and sustainable system in the Target Area. Some of the farmers are now selling their fruits in the area or in the nearby market. **The critical input in this intervention was the organization of farmers, awareness and motivation.**

4.2.9. EM Bio-Composts

Development of Bio-compost at the Farm Level

EM bio-compost development was introduced in the project area to demonstrate the need and benefits of natural fertilizers and enrichment of farmyard manures. This would help to improve soil health of extremely coarse textured soils and increase profitability of farming. Farmers having better farming capabilities were selected and given on-farm demonstrations for EM bio-compost formation and their use.

EM solution of 1:100 ratio (EM:water) was applied to animal and plant wastes at farmer's fields of the Mauza Kothi. The material was covered with thick black plastic film to provide anaerobic conditions and to maintain optimum temperature required for microbial activity. However, it was thoroughly mixed after every four days to have uniform fermentation and decomposition.

The EM composting and clod breaking helped in formation of quality compost and reduction in duration of composting. **The time required for composting was 15 days with temperature of 38 °C. The higher temperature helped to have higher percent of particle size of less than 1/8 inch, as 74% weight of compost was having particle size of less than 1/8 inch**. The higher percent weight of smaller particle size was also due to the reason that only cow-dung was used and no plant materials were included in the ingredients.

In summary, 15, 37 and 38 days were required for composting at mean ambient temperature of 38.5, 28 and 20.3 °C, respectively. Thus it can be concluded that 20-40 days will be required to have quality composts based on ambient temperature. In winter time required for composting will be higher than summer. Furthermore, in extreme hot months white plastic films may be used instead of black plastic films, otherwise the temperature will increase to even 60 °C or more inside the compost. **The higher temperatures beyond 60 °C are not conducive for composting as organic matter will burn**. Thus optimal temperature should be maintained. In summer, depth of the heap can be reduced to maintain the compost temperature. However, in winter season, depth of the heap can be increased to maintain the optimum temperature. **Thus temperature is also a function of the depth of the heap. Heaps less than 4 feet depth are not effective even in the summer season**.

Effect of Bio-compost on Yield

EM bio-compost was applied to vegetables. Onions were grown, where one Kanal was treated with EM bio-compost while the other was left untreated. It was observed that yield of onions obtained from the treated area was more than double (255 kg) compared to that of untreated (110 kg). In addition, the size of onions from treated portion was considerably large as compared to that of untreated. In addition to the increase in productivity, water retention in EM treated field was much better than untreated as the soils are of extremely coarse textured.

4.3. Sindh

4.3.1. Target Area

Target Area of Bachu Hamalani consists of about 500 ha of culturable land and is situated at a distance of 16 kilometres from Thana Boula Khan town. Both Sailaba and dugwell irrigation is practiced in the Target Area. Due to a continued dry spell of six years, Sailaba farming is no longer in practice and only 100 ha are under cultivation using dugwells. The water level in the dugwells has also receded from 10 m to 35 m during the past six years. The farmers are digging new wells to cope with the drought. In most of the cases, the well water becomes brackish below the depth of 35 m. The total population of village is about 560 persons. Most of the population is directly or indirectly involved with agriculture. During the current year 2001, three rainfall storms were received, which have provided enough watering for Sailaba agriculture.

Farmers do rear sheep, goat, cattle and poultry for their domestic use and income generation. On the average there are 3-5 small ruminants and 2-3 large ruminants per household. The cattle mostly depend on grazing. The continued long dry spell has reduced considerably the grasses and other palatable species in the Target Area, which is affecting both the health and number of livestock. Two rules of tenancy prevail in the Target Area.

First rule deals with the Sailaba farming, where all agricultural inputs (seed, fertilizer and pesticide) are shared by landowner and the tenant on fifty percent basis; whereas operations like primary and secondary tillage, sowing, irrigation, fertilizer and pesticide application are the responsibility of the tenant. Cotton-picking charges are shared on fifty percent basis. *Ushar*, Income tax, local tax, *Abiyana*, etc, are borne by the landlord.

In the second case, where the source of irrigation is dugwell, seed, fertilizers and pesticides are shared on fifty percent basis. Tenant is responsible for tillage and sowing operations and has right to get 44% of gross marketable produce. In this case the expenditure involved in irrigation like fuel, oil, maintenance of engine/pumps is borne by the landowner. In case the tenant is agreed to pay the half of expenditure incurred on fuel, sowing operation and other labour work, he is entitled to get fifty percent of gross marketable product.

4.3.2. Remodelling of Sailaba System

Sailaba systems of the Target Areas are small and isolated thus these are easy in management compared to the systems of D.I. Khan and D.G. Khan. The selected systems of the Target Area were remodeled during the initial years to improve the conveyance, control and application of water. But performance of this activity could not be ascertained due to the prolonged drought conditions. During the current year there were three heavy storms, which have provided sufficient flow to water the fields. This activity will be strengthened during the current year. **Farmers have to be motivated continuously by the District Agriculture to manage the Sailaba farming, which is essential for recharge of groundwater; otherwise desertification of the area is expected**.

4.3.3. High Efficiency Irrigation Systems

Trickle irrigation system was installed in the Target Area and local species of *Zizyphus* were planted. Plant-to-plant and row-to-row spacing is 6 m. The overall condition of plants is good. Emitters have to be replaced, as there was loss of emitters due to vandalism. Flushing of pipes and replacement of blocked emitters was made at regular intervals for smooth running of the system.

Sprinkler, hosefed and furrow irrigation systems were installed at farmers' fields to irrigate crops, vegetables and fruit plants. Furrow and border irrigation helped to save water compared to flood irrigation, which have been adopted in the Target Area. Sprinkler and hosefed irrigation systems further improved the water use efficiency.

4.4.4. Reducing Conveyance Losses in Dugwell Irrigation System

Based on the results of studies conducted in D.G. Khan, the LDPE plastic lining was most economical compared with other techniques, as it does not require any skilled labour and construction materials. The cost per m^2 of plastic film was around Rs. 20. Furthermore, complete elimination of water losses through the use of LDPE plastic film helped to reduce the energy consumption in terms of hours of operation of the pumping system.

The LDPE film of 250-micron thickness with black carbon and UV stabilizers were used to line the farmers channel in the Target Area. The seepage losses were completely eliminated. Farmers also purchased the low-quality PVC films and lined the channels, but

these films could not resist the UV rays and degraded quickly.

4.4.5. EMz Ceramics for Improving Combustion Efficiency of Diesel Pumpsets

Combustion efficiency study was carried out on selected diesel pumpsets in the Target Area. Before putting the EM_z ceramics, baseline fuel consumption was estimated at medium speed under optimum operational conditions. **Thereafter, 6 EM_z ceramics were placed in the diesel fuel tank.** For determining the hourly consumption, fuel tank was filled and initial time was noted. The pumpset was operated for a sufficient period. After stopping the engine, the final time was noted. The fuel tank was refilled to the marked position and the quantity of fuel in litres was noted. This quantity of fuel in litres was divided by the operating time, which gives unit fuel consumption. Same procedure was continued until a constant value of fuel consumption was achieved. From the baseline and final fuel consumption values, the reduction in fuel consumption and increase in engine operational time was estimated. Actually farmers are interested in increase in engine operational time. Because they look from the angle of their expenditure on irrigation. **Maximum increase in engine operational time of 37% was observed**.

4.4.6. Dugwells and Command Area Development

Horizontal Drilling in the Dugwell to Increase Well Yield

During the last six years no significant rainfall was received throughout the hilly areas (Kohistan) of Sindh, including Thana Boula Khan. Due to this extended drought, the groundwater level had fallen upto 35 m. After 35 m, the groundwater becomes brackish. This water is harmful to crops and adversely affects the soil health. Haji Nisar-ud-Din Palari agreed for horizontal drilling instead of deep vertical drilling, which provides brackish water from deeper depths. **For this purpose, horizontal drilling was done at three different angels. The horizontal drilling was performed at a depth 30 m from soil surface. Three horizontal bores, one of 63 mm diameter and 60 m length and two others of 75 mm diameter and 75 m length each were made in the dugwell. The rate of drilling was Rs. 200 per m, which was borne by the landowner**. The horizontal drilling resulted in considerable increase in water availability and farmer is continuously pumping at a depth of 30 m even under drought conditions. Otherwise, in most of the dugwells water level has dropped below 30 m.

To increase yield of dugwells in areas where specific yield of wells is extremely low, now farmers are using the horizontal drilling technique. Furthermore, farmers can harvest relatively sweet water from shallow depths. The WRRI-NARC is already working on skimming wells for the Indus basin to pump relatively fresh water from shallow depths under the NDP. Similarly, such studies will be extended to Thana Boula Khan to develop design criteria for skimming wells with horizontal drilling.

Water Analysis of Selected Dugwells in the Target Area

At the Thana Boula Khan Field Station, most of the farmers irrigate their lands from dugwells. For determining the quality of dugwell water, the water samples were taken from 25 dugwells in the Target Area. These samples were collected in running position at a depth of 25-30 m. **The water analysis report showed that out of these 25 dugwells in the Target Area, 21 dugwells contain water fit for irrigation and water in remaining 4 dugwells is marginal in quality.** As the soil of the Target Area is sandy, so the effect of this marginal groundwater is nominal on soil health and yield of crops. **However, due to prolonged drought, the groundwater quality was deteriorated to a level where majority of wells started receiving the marginal to brackish quality groundwater below 35m depth**.

Dugwell Command Area Development

About 4 ha of new agricultural land were developed for cultivation in the Target Area. This agricultural land is situated on the bank of a torrent bed, near Thana Boula Khan town. Here sweet groundwater was available at a depth about 24 m from soil surface.

Pump of 75 mm suction and 63 mm delivery was installed on the dugwell. The water column in the dugwell is about 6 m and the diameter of well is 3.7 m. A flywheel type engine was installed for pumping water from dugwell. The land levelling was done for improving the irrigation efficiency. The cotton crop was grown on this land on an area of about 2.5 ha.

4.3.7. Meteorological Data Collection

Meteorological data were recorded at the Weather Observatory of the Target Area. Different climatological parameters like minimum and maximum air temperature, dry and wet air temperature, relative humidity and rainfall were recorded.

Rainfall was not received during the last six years, which is a good indication of continued drought in the area. The drought has affected the groundwater, where there is no recharge and pumping has resulted in mining of fresh groundwater. Water table in the Target Area is continuously lowering and thus pumping cost has increased, which affected the profitability of agriculture in the area. The recent rains during 2001 started recharging the groundwater.

4.3.8. Introduction of Cotton Crop in the Target Area

Cotton crop was first introduced in the Target Area during 1997 *Kharif* season by the Rod-Kohi project. At that time only one farmer agreed to grow this crop. Impressed by the prospects of cotton crop in the Target Area five more farmers cultivated cotton crop in their fields on an area of about 10 ha. More farmers were interested in this crop, but can't grow it due to non-availability of sweet groundwater during the summer season.

Cotton crop was sown on ridges, with a seed rate of 7.5 kg/ha. Initially irrigation was applied on weekly basis. About 10 to 12 irrigations were given to the crop. To save crop from pest attack 4 to 5 sprays of pesticides were also applied.

Yield of cotton crop was recorded, which varied from 1433 to 1778 kg per ha. Farmers got a gross income of about 343824 to 426816 per ha against gross expenditure of Rs. 21106 to 22539 per ha.

4.3.9. Harvesting Index of Onion Crop

Onion is a major cash crop in the Target Area, where dugwells are used as a source of irrigation. The harvesting index and yield data of 25 farmers of the Target Area was collected. The data indicated that harvesting index varies from 85% to 96%, with application of fertilizers and pesticides. DAP was applied at a rate of 125 kg per ha at the time of sowing and Urea was applied at a rate of 250-371 kg per ha with first, third, and fifth irrigation. The loss of 4-15% of planted area of onion was due to the reason that it could not mature because of water shortage. This is a serious concern related to mining of shallow groundwater.

About 4 to 6 sprays of pesticides were applied to get healthy crop. Yield of onion crop varies from 18278-19760 kg/ha. The gross income per ha varied from Rs. 73112 to Rs. 79040, if the rate is Rs. 4 per Kg. This is due to special microenvironment prevailing in the Target Area.

4.3.10. Livestock Health

Village Bachu Hamlani is situated on a difficult hilly tract and at a distance of around 25 kms from the district headquarters. Therefore livestock health and extension service personnels are neither based in the Target Area nor they visited the area regularly. No proper guidance and service is imparted from any governmental department regarding preventive or curative animal health measures. Meetings of Veterinarian were arranged with educated and trained livestock owners of the Target Area about the importance of preventive health measures for their animals. **Farmers were informed and trained about importance of regular preventive vaccinations and regular treatment against parasitic diseases especially when they bring their animals from low-lying areas after rains. Many contagious diseases were found to be recurring among livestock of the area, especially, Black Quarter in large ruminants, Enterotoxaemia and contagious caprine pleuropneumonia in small ruminants. Sporadic cases of Anthrax were also reported. Vaccinations were provided against these diseases.**

Cases of parasitic diseases were also found, especially Fascioliasis, Ascariasis, and haemonchoses. Drenching against these diseases were carried out, which affects the animal productivity adversely. Some cases of Trypano-somiasis and mange were also detected in camels and donkeys and treatment was arranged.

4.3.11. Development of Small Earthen Reservoirs for Stockwater

Water shortage for livestock is a major concern in the Target Area. Animals have to walk long distances for want of water. Farmers were motivated to build small and medium size earthen pond for storage of water. Critical inputs were provided to the farmer. The cost of earthwork was taken care by farmers.

One earthen reservoir was constructed in the Target Area with farmers' participation. The reservoir now provides water to meet the stockwater requirement. Natural spillway in the rocky formation is used for overflow to avoid the extra cost of structure. The ponded area is over 2 ha and depth varies considerably. This is the first reservoir in the area. The loss of seepage water in future can be harvested using dugwells.

4.4. Balochistan

4.4.1. Target Area

Target Area consists of two villages namely Jahalwani in the district of Barkhan and Sirati in the district of Musa Khel. Both are part of the Zoab division. Jahalwani Target Area consists of six settlements and Sirati Target Area consists of three settlements. The main source of livelihood is agriculture.

Jahalwani Target Area is 'Sailaba' using runoff from two catchments. Both the catchments have distinct command areas. The farmers of the area manage the system on participatory basis. The project staff has provided them technical support for development of Sailaba agriculture through management of water distribution and conveyance system. Management of the system was done with active participation of local farmers. System development and management techniques were elaborated to the farmers of the Target Area.

Sirati Target Area is largely commanded by small-scale isolated Sailaba irrigation systems, however some area is also irrigated by dugwells. Due to low rainfall during last few years, shortage of water is prevailing in the Target Area, which has resulted in low crop yields and adversely affected the productivity of Sailaba agriculture.

4.4.2. Water Distribution and Control Structures

Water Diversion and Distribution Structures

Sailaba system of the Jhalwani Target Area is small to medium in size and easy in management but less reliable compared to the larger systems. Water dietribution is the most critical activity faced by the farmers of these systems. Farmers are still practicing the age-old system of water distribution as the water rights are not sharply defined. The distribution of water is based on the allocation of width of streamflow proportionate to the water right. Thus farmers fix the divide using loose stones. However, due to the deterioration of the system, the parameters like velocity of flow, channel gradient and erosion in the downstream channel are affecting the equity in distribution of water.

Due to the unreliability associated with the Sailaba system, farmers are hesitant to adopt high cost structures; therefore, approach of low-cost using locally available stones was used. Critical elements where farmers can contribute were identified. Farmers contributed fully in collection, dressing and loading/unloading of stones at the construction site. Furthermore, all the labour support was provided by the farmers. The major cost is the labour cost. Thus the key point for designing of any distribution structures is to keep the material cost as low as possible.

Twenty distribution structures were constructed in the main channels of the Sailaba systems of the Target Area. Before the construction of these structures, there was lack of proper distribution of water among farmers and farmers were facing conflicts on sharing of water. **The discharge of runoff water at these structures ranged from 150 to 250 cusecs. These structures were grouted with cement only on its nose and the rest were built using stone pitching to reduce the cost tremendously. The material cost of**

structures varied from Rs. 1500-3000, out of which around 30% was borne by the farmers. The farmers' participation in cost sharing would help in transfer of technologies on large scale. However, there is a need to have reasonable level of motivation. These structures experienced around 4-7 floods every year and hydraulic performance was satisfactory. The flood passed safely and no damages were observed.

In addition to the distribution structures, eight (8) diversion structures were also constructed in the Target Area for diversion of water.

Construction of Check Dams

Equity in distribution of water demand that the channel gradient and velocity of water is regulated. This would also help to reduce the chance of channel erosion. **For reducing the velocity of flow and to stabilize the channel gradients, twenty eight (28) check dams were constructed in the Garabacha and Khanki channels especially at the head reaches**. **Check dam was constructed in a three-step design to reduce velocity of flow. Height of check dams was around 1 m. Cost of construction of check dams ranged between Rs. 1000-2000, out of which farmers contributed around 30%.**

Construction of loose-stone check dams is possible and cost can be reduced tremendously with active participation of farmers. These check dams helped to manage the velocity of flow, which resulted in control of channel erosion. The distributed sedimentation in the channel also helped to control the velocity and thus water control was easy without any damage.

Lining of Check Dams with Plastic Film

Maintaining the sensitive reaches especially at the bends is a difficult task. Breaches are common at these sites because of light textured soils. **Polyethylene plastic film was used to construct check dam to reduce chances of failures due to soil erosion.** The soil was compacted. This structure could not hold itself and was damaged in floods. Later on, it was fine-tuned. A discharge of 150 cusecs passed safely through it.

Drop Structures

To reduce the velocity of flow in smaller channels, six (6) drop structures were constructed with loose stones. The height of these structures was less than 1 m. These structures remained intact during the floods. Silt deposition was observed in the upstream areas. This further stabilized the loose stone structures.

Pipe-Naccas

Forty seven (47) Pipe-Naccas of 15-inch diameter were installed in the fields at various locations in the Jahalwani Target Area. Some of these Naccas were used to drain excess water from the fields and others were used to divert water for irrigation. Most of them were installed in the bunds, to save breaches during the floods. Naccas were also installed in the Garabacha channel to divert water into the field.

4.4.3. Dugwell Irrigation Systems

Irrigation System at the Hyder's Farm

A 4-inch diameter RCC pipe irrigation system was designed and installed at Hyder's farm. Improved varieties (Punjab 96 and Inqlab 91) of wheat were provided to the farmer. The farmer was advised to use FYM, which showed improved results. The experiment was carried out on an area of one acre. Expenditure and income were calculated. Mot grass was sown as well in the farm, which gave good results. **The well is operated by a camel, which runs the well 3 hours daily. The water level of the well is declining with time due to continued dry spell**. Area irrigated during the *Rabi* season was 0.4 ha, where wheat was grown under organic conditions. Farmers do not use any chemical fertilizer.

Pipe Irrigation System at the Mir Qalam's Farm

A 2-inch diameter PVC pipe was installed at the Mir Qalam's farm to carry water from well to fields. The discharge of well is 0.03 cusec (0.84 lps). The pipe was installed to reduce seepage, water conveyance losses and labour saving. The length of pipe was 125 m from the well to the field. Two air valves were fitted to remove air blockage in the pipe. The Project's Team provided technical assistance and the laying of the pipe was completed by the farmer himself. The field is planted with 70 fruit plants along with wheat and vegetables.

Pipe Irrigation System at the Bukhtiar Khan's Farm

A survey was conducted to design a pipe irrigation system at Kingri. The water source is a perennial stream on which a weir is constructed for ponding the water. **The ponded water is lifted through a 12-hp diesel engine operated pump to a 12-meter high hill. From the hill a 3-inch diameter RCC piped-channel was laid to take water on the other side of the hill with natural gradient**. The Project Team conducted the survey, whereas the pipe was laid out with the collaboration of the Provincial Water Management Project. The objective was to extend technical assistance to the participating farmers and the collaborating agency.

Lining of Dugwells

Two dugwells were lined using stone masonary to a depth of 3 m with an objective to avoid caving of the well. Farmer contributed in lining of the well. The lined dugwells provide demonstration for farmers for low-cost lining of wells in non-consolidated formations.

Performance of Dugwells

Two dugwells located at the Hyder's and Mir Qalam's farms were selected for conducting a study on drawdown, discharge and water level.

The data showed that depth of water column is considerably decreasing, mainly due to decrease in recharge and increase in water consumption. Decrease in recharge was mainly due to drought conditions prevailing in the Target Area. However, the depth of water column was extremely low in the dry months of April to June. This is a serious concern because the decline of water table is not only loss of water yield but it also increases the pumping cost. Therefore, sustainability of dugwells is a serious question in the Target Area.

Physico-chemical analysis of water collected from two experimental wells and a stream was conducted to assess the quality.

4.4.4. Earthen Ponds and Utilization of Water

Earthen Ponds and Sand Filter for Multiple Water Use

Three earthen ponds of the Target Area were renovated. One of the earthen ponds was selected for the development of sand filter for multiple water use. Water from the earthen pond was conveyed through gravity to a sand filter, where firstly water was made available for drinking purposes and secondly for livestock. Provision was also made for washing of clothes by the women folk. The domestic water facility was very much appreciated by the community but they were unable to control the entry of animals to the ponded area to avoid entry of livestock wastes in to the pond. This requires commitment and motivation on continued basis.

The increased capacity helped to retain water for longer periods. This intervention is very promising for areas where earthen ponds are used for multiple purposes. The sand filter can provide clean and relatively safe water for drinking.

Two hand pumps were also installed at the dugwells to provide water for multiple uses.

Earthen Ponds, Tanks and Water Utilization

Farmer Sher Muhammad has a diesel engine operated 12 hp turbine. He wanted to construct an earthen pond for irrigation of upland area. Technical support was given to him for construction of the pond. Design was made and given to the farmer. The pond was 60 m away from the well. A 4-inch diameter PVC pipe was installed for conveyance of water. Area of pond is 205 m^2.

A concrete pond measuring 2.2 x 2.0 m was constructed at the Jamshar's farm, which has a 18 hp diesel engine operated tubewell. The discharge of the well is 0.20 cusecs. Three 4-inch diameter outlet Naccas were installed at the three sides of the pond. Total cost of construction was Rs. 2505, out of which the farmer provided Rs. 320 and rest was borne by the project.

4.4.5. Lining of Pond and Channel with Plastic Film

A channel of 50 m length was lined with polyethylene (PE) plastic film at Wali Muhammad's farm. The well water is pumped using a 12 HP diesel engine. The well was discharging water in a close by earthen pond. High seepage was not only wasting water but also damaging the walls of the well. To overcome this problem, **PE plastic film was used for lining of a 3 x 5.5 m pond. Then a layer of 40 mm clay was laid on the plastic film and compacted**.

Discharge before and after the installation of the plastic film was measured, which resulted in considerable reduction in the seepage. This intervention was further tested in number of locations because of the cost effectivity.

4.4.6. EMz Ceramics for Improving Fuel Combustion Efficiency of Diesel Pumpsets

Effect of EMz Ceramics was studied on selected diesel engine pumpsets in the Target Area to evaluate the effect on fuel consumption and engine operational time. Initially, results of two diesel pumpsets were available, where 30-40 days were required to have the full benefit of EMz Ceramics. **A decrease in fuel consumption of 14 and 18% was observed. Smoke level of engine has also decreased considerably**. The diesel engines were operated at a speed of 1200 rpm.

Consumption of diesel engine before and after the addition of EMz Ceramics was recorded and difference was calculated. The farmers of the Target Area showed their keen interest in using EMz ceramics in their engines.

4.4.7. EM Composting and Foliar Application

Development of EM Bio-Composts

EM experiment was conducted at different farmer's fields in the Target Area to document benefits of EM composting. Data were recorded and it was observed that the use of EM effectively reduced the time required for decomposition from 9-12 months to 25-30 days.

The results indicated that 72.5% weight of compost consists of particle size of less than 1/8 inch. Thus quality of compost was extremely high and therefore uptake of nutrients by plants will be reasonably high. The loss in weight due to composting was around 25%, which is mainly due to loss of water.

Foliar Application of EM to Fruit Plants

Foliar application of EM was applied on experimental basis for pomegranate and apple fruit plants in the Target Area. Although the experiment was started a bit late before fruiting yet good results were obtained. Twenty pomegranate and apple plants were selected, out of which 10 plants were treated with foliar application of EM and rest were kept untreated. Foliar application of EM was applied to pomegranate and apple fruit plants. The experiment was started just before fruiting.

Amount of extended EM was used with a ratio of 1:200 (Extended EM:Water), where 0.5 litre of the solution was used. The plants selected for study were around 7 years age and height varied from 3 to 4 m for apples and 2 to 2.5 m for pomegranate. Only 3 EM applications were employed before the maturity of the fruits. The foliage was comparatively greener as compared to control treatment. Flowers of both apple and pomegranate observed significant change as the number were higher. The size of fruit was also improved in apples and pomegranate.

On fruiting it was observed that the fruit plants sprayed with EM were slightly better in colour, size and weight. Only four foliar applications of EM were possible before fruiting.

4.4.8. Wheat Production in the Jahalwani Target Area

Data were recorded covering all farmers of the Jahalwani Target Area about land owned, type of wheat seed used and wheat production. Farmers of the Target Area, applied a seed rate of 100 kg/ha. Most of the seed used was traditional which is called 'Mulki'. Varieties of wheat Inqalab-91, Punjab-96 and Sariab-92 were introduced in the Target Area, which were accepted by the farmers. **Average yield of wheat ranged between 1.76 to 1.98 tons/ha**.

The yield of wheat was reasonable under Sailaba conditions as the wheat-growing season was relatively dry. **The surveyed area was 90 ha and the average yield was 1.89 tons/ha. Farmers are normally not using any chemical fertilizer due to sedimentation in their fields, which is enriched with nutrients**.

4.4.9. Monitoring of Catchments

Soil Conservation Measures

The area of experimental Catchments 1 & 2 was badly affected by open grazing and soil erosion. Sediment load from the area was very high. **For reducing the soil erosion and loss of surface runoff about 422 eyebrow terraces were constructed in the catchments and farmers were motivated to control grazing in the area**. About 330 plants were also planted in eyebrows. Due to shortage of rainwater as runoff in eyebrows, some grasses have also been grown around them and erosion is controlled due to ponding of surface runoff.

Plantation in the Catchments

Three hundreds and thirty (330) different varieties of plants were planted in two catchments of the Sirati Target Area. Most of them are *Accacia modesta*. Almond, apricot, pistachio and pomegranate were also planted. Survival rate range between 30-50% due to open grazing and low rainfall. Still farmers are trying to protect them. **Apart from it, 422 eyebrow terraces were constructed to save the natural vegetation in the hilly slopes of the Target Area**. The farmers now are developing interest in conservation of natural vegetation and plantation of arid horticultural plants.

4.4.11. Meteorological Data Collection at the Target Area

Meteorological data were collected at the Weather Observatory installed at the Rarkan during the report period. Air temperature (Min. & Max.) humidity, evaporation and rainfall data were recorded.

4.5. WRRI-NARC

4.5.1. Development of Plastic Films and Geo-membranes as Liners

The WRRI-NARC in collaboration with the local plastic industry produced the LDPE plastic film of 250-micron thickness. UV stabilizers and black carbon were added as amendments to resist the ultra-violet rays and the light. The black carbon helped to eliminate the formation of algae, which is directly a function of light. The cost of LDPE 250-micron thick film is around Rs. 20 per m^2. This film was used at various Target Areas of the project for large-scale testing as liner for channels and earthen reservoirs. It was also tried for the diversion bunds as a barrier to eliminate the chances of water seepage and breaches.

The LDPE film was produced using a process of extrusion, which has certain limitations. For example it was difficult to maintain the thickness of the film within the prescribed range. Thus collaboration with Engro Asai was initiated to identify the calendaring industry to produce non-reinforced geo-membranes. The material produced was used to line a channel at NARC having a thickness of 500 micron. This membrane was produced using the locally produced PVC resin and UV stabilizer and black carbon was added. The cost is around Rs. 70 per m^2. The cost of PVC geo-membrane of 250-micron is around Rs. 35 per m^2.

The 500-micron thick PVC geo-membrane used at WRRI-NARC was not covered with soil, with an objective to study the aging of the membrane as PVC has more aging problem compared to the LDPE. Furthermore, the cost of PVC membrane is more than the LDPE film.

4.5.2. EM_z Ceramics for Improving Fuel Efficiency of Diesel Pumpsets

In Pakistan there are over 500,000 tubewells and pumpsets (Agri. Statistics, 1998). The annual growth rate varied between 5-10 percent in the last decade. Out of this, 76.5% tubewells are operated by diesel pumpsets. The annual growth rate of diesel pumpsets is around 10% whereas there is no growth rather there is a reduction in electric tubewells since 1994. Actually, the increase in electricity prices has forced farmers to replace the electric prime movers with diesel.

Two diesel engine operated pumpsets were selected for testing the effect of EM_z Ceramics on fuel consumption and engine operational time. **The sizes of the diesel engines selected for initial testing were 3 and 8 hp, for Jack pump and sprinkler irrigation systems, respectively**.

A 3-hp air-cooled Chinese imported engine coupled with Jack pump was used to test fuel consumption and engine operational time. The initial fuel consumption was 0.333 litres/hour for the new engine. Four readings were taken to establish the baseline of 0.111 litre/hr/hp.

After establishing the baseline, two ceramics were added in the fuel tank and 50 ml of EM_z fluid in the engine oil to evaluate the effect on combustion efficiency. The accurate measurements of fuel consumption to a one mili-liter level were made for about 494 days.

A eight hp water-cooled Chinese imported engine coupled with high-pressure pump of sprinkler system was used to test fuel consumption and engine unit operational time. The initial consumption was 1.38 litre/hour for the old engine. Four readings were taken to establish the baseline of 0.1725 litres/hour/hp for the old engine.

After establishing the baseline, two Ceramics were added in the fuel tank and 50 ml of EM_z fluid in engine oil to evaluate the effect on combustion efficiency. The measurements were made for about 315 days.

Air-Cooled Diesel Engine Pumpset

The reduction in unit fuel consumption of three-hp air-cooled diesel engine was gradual but distinct where it started with first filling of the fuel tank. **The reduction in fuel consumption was around 7% and then reached to a maximum of 34%. The noise in data indicated that stable decrease was around 31%. This was achieved in 38 days and it was increased further to 34% that decrease of upto 50% or even more is possible in fuel consumption**.

Maximum increase in engine unit operational time of 51.7% was achieved. This is a practical indicator that EMz Ceramics can increase the engine operational time by 52%. Farmers are more concerned about engine operational time.

Water-Cooled Diesel Engine Pumpset

The tests indicated a similar trend where decrease in fuel consumption of 25.3% was achieved in 85 days. The noise in the data was much less compared to 3 hp air-cooled engine.

Maximum increase in engine unit operational time of 33.9% was achieved. This is a practical indicator that EMz Ceramics can increase the engine operational time by 34%. Farmers are more concerned about engine operational time.

Decrease in Fuel Consumption

The testing of EMz Ceramics for 3 and 8 hp engine pumpsets provided decrease in fuel consumption of around 25-34%. Thus, the resource-poor farmers can use EMz Ceramics.

The farmers must keep it in mind that the effect of EM_z ceramics will be gradual and thus they have to wait for at least 80 days to experience reduction of around 30%. However, the actual decrease would depend on the type and state of the diesel engine and pumpset.

Increase in Engine Unit Operational Time

The testing of EMz Ceramics for 3 and 8 hp engine pumpsets provided an increase in engine unit operational time of around 34-52%. This showed that resource-poor farmers to increase operational time of diesel engine pumpsets with the same amount of diesel could use EMz Ceramics.

The farmers must keep it in mind that the effect of EM_z Ceramics will be gradual and thus they have to wait for atleast 80 days to experience increase in engine operational time of around 34-45%. However, the actual increase in engine operational time would depend on the type and state of the diesel engine and pumpset.

4.5.3. Testing of Magnetic Technologies

Magnetic fuel modifiers were used for improving combustion efficiency of the diesel pumpsets. An increase of 20% in combustion efficiency was observed. The cost of the magnetic fuel modifier is around Rs. 3000, which is not economical considering the cost the diesel pumpsets. However, the cost of EMz Ceramics is only Rs. 150 for a set of 6-Ceramics, with an increase in combustion efficiency of 34%. Thus EMz Ceramics can be extended to farmers on large-scale basis.

Magnetic device was also used for experiments on wheat crop during 2000-2001 where treatments of magnetic and non-magnetic water were carried used along with seed treatment. **There was 20% increase in yield of wheat crop in treatments where magnetized water was used. The pH and EC of the water was reduced slightly. The device will be transferred to field stations for amending the sodic groundwater**.

4.5.4. Development of Low-Cost Biogas Generator

A survey was conducted to identify the reasons for the failure or low popularization of biogas generators in Pakistan. The major reasons identified are as under:

- The livestock management is a women activity, and thus any programme of installation and management of biogas has to be developed around women and by women folk. Men do not even touch the animal waste;
- The cost of the floating drum biogas system is higher i.e. Rs. 35,000 to 40,000 per unit; which is not in the reach of the farmer. Furthermore, the metallic drum gets rusted after a period of 2-3 years and leakage of gas is a common feature from the drum;
- System is not environment friendly as animal waste is open all around the system;
- Difficult to maintain the temperature of the system during the winter season.

Taking in to consideration of these factors, an innovative system was designed and manufactured with the help of local plastic industry. **A black PE tank of 1200 litres capacity was used. After adding the water and animal waste, 20 kg of lime was added to maintain an alkaline environment. The methogenic bacteria work under alkaline environment. The black colour of the drum helped to maintain the temperature. The gas was stored around a distance of 300 m away from the generator, where used tubes of tractor were used for the gas chamber. It was very easy to maintain the pressure by imposing load on the tubes**.

The locally produced gas burners were adjusted for low-pressure of the gas. The system is completely environment friendly and the price ranges between Rs. 8000 to 9000 per unit depending on the quality of the plastic drum and the tubes.

4.5.5. EM Bio-Generator for Amending Sodic Groundwater

Groundwater in the Indus basin contributes around 35% to the total water available for agriculture and the water quality of 60% area is marginal to brackish. The government has initiated SCARP programmes in 60s to control waterlogging and salinity but the use of saline-sodic and sodic groundwater resulted into secondary salinization. Furthermore, due to continued pumping of deep groundwater, there have been serious concerns regarding deterioration of groundwater quality because of the intrusion of brackish water into freshwater zone. The continued use of marginal quality groundwater also resulted into recycling of salts in the groundwater.

Biological interventions have to be linked with chemical interventions to enhance and sustain soil quality. EM is an abbreviation for "Effective microorganisms" or more accurately for the group comprising a heterogeneous collection of microorganism that affect the world of nature in a positive manner and coexist harmoniously in a liquid state. EM comes in four varieties which; for convenience; are numbered EM #1 to #4. Each type has distinct feature and properties. EM #2 features mainly gram-positive actinomyces; the major content of EM #3 is photosynthetic bacteria; and of EM #4 lactic bacteria and yeasts. EM #1 exhibits all the properties found in EM #2 to #4. EM #1 is the latest formulation and was used in the development of bio-generator.

Research hypothesis is that biological reactions are more sustainable than chemical reactions. Moreover, there is a possibility to make these reactions cost-effective as the propagability of EM is expected to be much higher than any other reaction. The initial work done by the Technology Development Unit (TDU), WRRI-NARC produced very promising results and thus there is a strong justification to initiate systematic research on this priority research area. The EM Bio-generator technology, after the successful results, has been transferred to the Rod-Kohi components for further extension and dissemination to the farmers. This technology would have direct impact on profitability of agriculture and environmental sustainability.

The EM Bio-generator is based on the concept of having extension of EM for three generations using ratio of 1:1:20 (EM:Molasses:Water). Around 1000 litres of extended EM are needed for the reclamation strategy, whereas 500 litres are needed for alternate irrigations to amend the sodic water. EM will not amend the total salinity, thus more effective for sodic waters.

4.5.6. Comparison of EM-biogenerator, gypsum and sulfuric acid for amending sodic groundwater

After completing the trials on propagability of EM, a comparative study was designed to evaluate the performance of supra-extended EM with the traditional amendments like gypsum and sulfuric acid. Following treatments were used:

- Control treatment using water only to document changes, if any
- Application of gypsum to water using Gypsum:Water in a ratio of 0.6:100
- Application of supra-extended EM to water using supra-extended EM:Water in a ratio of 2.4:100
- Application of supra-extended EM:Gypsum:Water in a ratio of 1.2:0.3:100
- Application of sulfuric acid to water using H_2SO_4:Water in a ratio of 0.007:100

Five treatments were used to evaluate the effectivity of supra-extended EM in comparison with the traditional amendments of gypsum and sulfuric acid. The solubility of gypsum is a serious concern, whereas, application of acid is hazardous. Furthermore, any addition of gypsum to the soil will further add salts in soils, which are already saline to a varying extent. Therefore, supra-extended EM was used to improve solubility of gypsum.

The acceptance of EM is still a question in the country as specialists have serious concerns about the viability of this material. However, the Pakistani farmers have performed much better as they started using the material without any governmental support. The scientists still believe that there is no substitute for the traditional

amendments. Therefore, a study was conducted to compare the supra-extended EM with gypsum and sulfuric acid.

Sodic groundwater of 9.6 pH was used for five treatments of:

a. Control water only;
b. Gypsum:water with a ratio of 0.6:100;
c. Supra-extended EM:water with a ratio of 2.4:100;
d. Supra-extended EM:gypsum:water with a ratio f 1.2:0.3:100; and
e. Sulfuric acid:water with a ratio of 0.007:100.

The solubility of gypsum is low as instantaneous reduction in pH of only 0.17 units was observed. However, a reduction in pH of 2.0 units was observed after 10 days and continued to 30 days. The supra-extended EM performed tremendously better than gypsum as instantaneous reduction in pH of 1.0 unit was observed, whereas it was reduced to 2.2 units after 30 days. The reaction was stable both for gypsum and supra-extended EM.

Further improvements were observed, when supra-extended EM and gypsum were used conjuctively. This also resulted in reduction of dose to half for both gypsum and EM. **The instantaneous reduction in pH of 1.11 units was observed, which was highest in all the treatments. It was further decreased to 3.27 units after 30 days, which was also highest among all the treatments. This shows that EM and gypsum co-exist. Thus supra-extended EM can be used for increasing the solubility of gypsum, if needed. Otherwise supra-extended EM is the most economical and safe amendment.**

The sulfuric acid performance was strange. The instantaneous reduction of 0.97 units in pH was observed. However, this reduction after 10 days could not be sustained. Commercial grades of sulfuric acid were used, which are commonly used by farmers for reclamation purposes. The poor performance of sulfuric acid shows that claims made in the past by the scientists need further validation regarding the effectivity of commercial-grade sulfuric acid over gypsum.

The supra-extended EM performed in a similar pattern with groundwater of 7.4 pH. Gypsum did not perform positively. The response of sulfuric acid was also not positive, as the reaction was not stable. **Therefore, for managing acidic environment of soils for tea and other tropical fruit plants, only EM is effective with freshwater**.

4.5.7. EM Based Green Grass and Kitchen Waste Extracts for Foliar Application and Bio-fertigation.

Green matter extracts were made from locat, mint and grasses using a ratio of extended EM (10 litre): water (100 litre): green matter (20 kg). The details of the treatments are as under including those of molasses and water also.

1. Locat + 10% Extended EM solution
2. Locat + water only
3. Locat + 10% molasses solution
4. Locat + 10% extended EM and molasses solution
5. 10% extended EM solution only

6. Mint + 10% extended EM solution
7. Grass + 10% extended EM solution

All the treatment used for preparation of extract with EM provided total nitrogen in the range of 28-56 mg/100 ml, whereas protein N ranged between 28-42 mg/100 ml. The most interesting results were for control treatment, where EM was not used. This extract does not have any contents of microbial dry matter, total nitrogen and protein nitrogen. Therefore EM helps to extract total and proteinous nitrogen from green waste materials. The foliar application of extract to the plants helped to improve the growth. The green grass extract can be used (green grass extract:water) in a ratio of 1:200 to 1:500. **The green grass extract can serve as a foliar bio-fertilizer or natural foliar fertilizer**.

5. Options for Large Scale Adoption

Based on major accomplishments, most practical interventions are listed as under, which can be considered by development projects, NGOs and rural communities.

- Training of drivers of earth moving machinery and farmers organisations in identification of fine- and coarse-textured materials for construction of large earthen diversion bunds and laying of LDPE plastic films as a barrier for sensitive reaches.

- Low-cost water distribution and control structures to manage water in small channels under low- and high-flow conditions.

- Loose stone structures and check dams with or without nets can provide cost-effective mean of stabilizing the channel gradient, non-erosive and non-scouring velocity of water for sustainability of highlands Rod-Kohi systems.

- Low-cost inlet structures can be constructed using brick masonry, pre-cast concrete pipes or GI sheet based on the discharge and size of the bunded units.

- Recycled plastic pipes or pre-cast concrete pipes are cost-effective for construction of dugwell based water conveyance systems in Balochistan and Sindh.

- LDPE or PVC plastic films or geo-membranes can be used to line smaller channels in extremely coarse textured soils.

- Hosefed irrigation system for orchards and vegetables can be used as a first step prior to the introduction of drip irrigation system for orchards in areas where dugwell water is used.

- Fodder legumes can help to improve soil health alongwith the use of organic manures enriched using EM or other microbial amendments, especially for Kalapani systems, which do not bring sediments.

- Women folk may be organised to initiate systematic activity for cleaning and grading of seed of wheat, chickpea, sorghum, millets and beans. Chajs can be used as a starting intervention and later motorized cleaners can be introduced.

- Eyebrow terraces can be used in upstream areas and highlands for in-situ conservation of runoff and plantation of forest/fruit plants and regeneration of range grasses due to ponding of water.

- Sand filter can be used to provide safe and clean water for domestic and stockwater purposes. Handpumps can be used to pump water from sand filters placed in earthen ponds.

- Multi-purpose forest trees may be introduced in rangelands and cultivated areas to provide forage for livestock especially in dry spells.