PHASE-I REPORT

KARKHEH BASIN FOCAL PROJECT IN IRAN

Karkheh River in the upper parts of the basin

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1. INTRODUCTION

BASIN FOCAL PROJECTS

The Basin Focal Projects (BFPs) are a new innovation designed to provide a more comprehensive and integrated understanding of the water, food and environment issues in selected Challenge Programme basins. In addition, in two and a half years, the BFPs will develop a much more nuanced understanding of the extent and nature of poverty within each selected basin and determine where water related constraints are both a major determinate of poverty factor and where those constraints can be addressed.

Karkheh Basin Focal Project (KBFP) is one of four pilot projects established by the Challenge Programme on Water and Food in late 2005. International Water Management Institute (IWMI) has been appointed to lead the work in this Iranian basin, which lies in the west of the country, bordering Iraq (Figure 1). Iranian partners include a selection of institutes under the Agriculture Research and Education Organisation (AREO), Universities and the Khuzistan Water and Power Authority (KWPA), a dynamic development enterprise belonging to the Ministry of Power.

Figure 1. Geographical location of Karkheh Basin in Iran

This document provides brief overview of Karkheh Basin and highlights the key issues related to sustainable land and water management. Moreover it summarizes the progress during Phase-I and plans for actual project implementation (i.e. Phase-II) and expected outputs.

2. PROJECT OVERVIEW

2.1 OBJECTIVES

The overall objectives of the Basin Focal Projects are:

- To reduce poverty and improve livelihoods amongst the poorest in the basin, especially those whose poverty is closely linked to a lack of water.
- To improve the overall productivity of water at basin scale by sustainable use of water resources.

The specific objectives of the BFP research in the Karkheh basin are as follows:

1. Understand the nature of the hydrology, agro-ecology and water balance of the basin, through a rapid but comprehensive natural resources management assessment.
2. Understand the nature and location of poverty.
3. Understand and 'map' the current status of water productivity in different agricultural systems across the Karkheh basin.
4. Assess the performance of existing agricultural systems, including land and water management, which in turn determines land and water productivity and understand the factors that affect them.
5. Seek and prioritise stakeholders' perceptions of research needs in the basin.
6. Identify suitable existing and new water-related interventions that could help in improving land and water productivity and reducing poverty.
7. To test (ex-ante) the impact of those interventions under different adoption scenarios.
8. Prepare comprehensive recommendations for different stakeholders and policy makers to improve future management of land and water resources for poverty alleviation in the Karkheh basin.

The long term objective of the project is to identify best-bet water related interventions to mitigate poverty or improve livelihoods and test their potential impacts using an integrating modeling framework. The project is developing methodologies to establish the nature and relationship of poverty and livelihoods to water and to understand water productivity across enterprises and farming systems. Best-bet interventions, whether policies or technologies, should both improve livelihoods, be sustainable and increase basin-average water productivity.

2.2 ACTIVITIES IN PHASE 1

The main aim of Phase 1 is the scoping of research issues in Karkheh river basin. The activities in Phase 1 include:

- Collection of background information to characterize natural resources management in the basin, its inhabitants, the current development strategy and identify and fill gaps;
- Collection of secondary data and spatial data related to land and water managements issues;
- Institutional mapping and identification of key stakeholders;
- Basin diagnostic tour to develop in-depth understanding of the land, water, environmental and livelihood issues confronting the KRB;
- Stakeholder consultation and Scoping of Key research Issues; and
- Finalization of methodology on water and poverty analysis.

2.3 SCOPING OF RESEARCH ISSUES

As a first step for the implementation of Basin Focal Project (BFP) in the Karkheh River Basin (KRB) of Iran, a diagnostic tour of the basin was conducted by a multi-disciplinary team in October 2005 to develop in-depth understanding and scoping of the land, water, environmental and livelihood issues confronting the KRB (see Appendix A). The members includes a agro-hydrologist & RS specialist (Mobin), a water resources management specialist (Asad), a social and poverty specialist (Alex), a river basin hydrologist (Francis), a hydrologist and PhD student (Ilyas), a socio-environmentalist and PhD student (Sara) and an irrigation specialist and basin coordinator for KRB (Ashrafi). In addition to this IWMI and CP team, a watershed management specialist (Mirghasimi) from Iranian Forest and Rangeland Organization (FRWO) also accompanied the team. The team was supported by a number of water resources experts, agronomists and socio-economists from local research organizations during the visit of different parts of the basin. During the basin tour, a stakeholders meeting was arranged in each of three major provinces of the KRB prior to the field visits. During these meetings, all partners were briefed about the purpose of basin tour and objectives of the BFP to get them fully acquainted with the program needs and requirements and to seek their cooperation for the implementation of BFP. These meetings proved very useful in getting to know each other, learning about capacity and resources available with different organizations involved in the land and water management of KRB. The areas and route of this tour is present in figure 2.

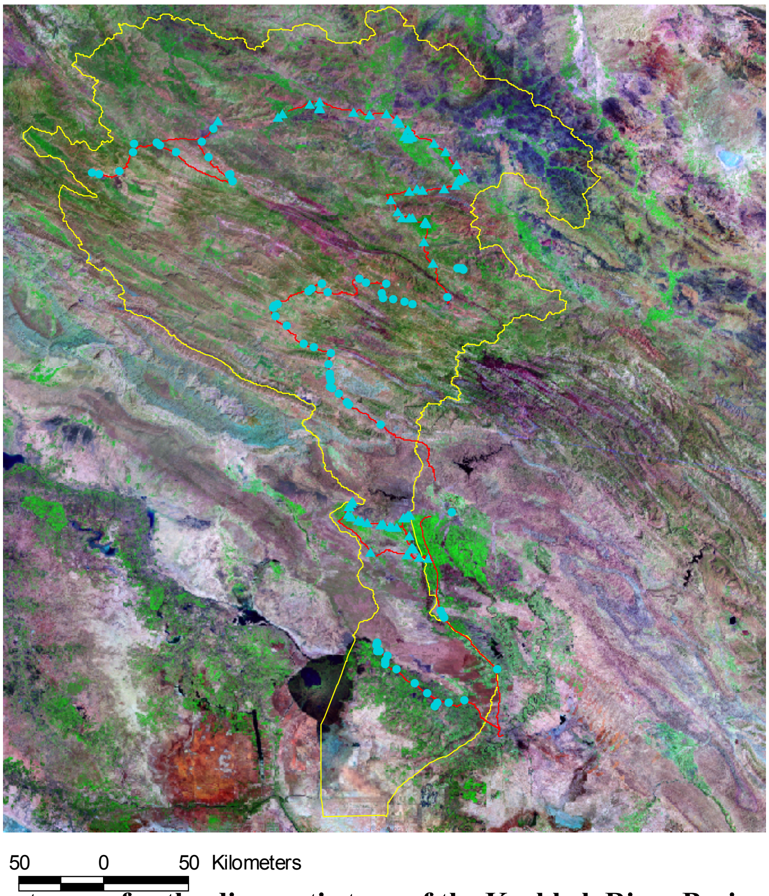


Figure 2. Route map for the diagnostic tour of the Karkheh River Basin

2.4 STAKEHOLDER WORKSHOP AND IDENTIFICATION KEY RESEARCH ISSUES

After the diagnostic tour, a stakeholder workshop was arranged at IWMI-Iran office and the overall impression of the basin was presented. The stakeholders provided useful feedback on the identified problems, researchable issues, priorities and sources of data. The project team identified several areas that they considered to require further research under four main themes of natural resource management, livelihoods, environmental protection and the linkages between them. The issue of geographical focus was also highlighted, including the institutional capacity of the Ministry of Jihad-e-Agriculture (MJA) in the upper Karkheh basin (UKB) and the Khouzistan Water and Power Authority (KWPA) in the lower Karkheh (LKB), as well as the integration of issues across the whole basin.

Key researchable issues in the Karkheh river basin:

1. Overstocking, erosion, grazing resources degradations, low livestock productivity
2. Erosion, sedimentation, watershed management and water storage implications
3. Irrigation development, groundwater mining and implications on downstream water users and uses
4. Waterlogging and salinity management in the lower Karkheh Basin
5. Sustainable use of Hur-ul-Azim wetland (SWAMP)
6. Economic cropping systems and water productivity
7. Education, unemployment, migration and livelihood strategies (diversification)
8. Social issues, local extension and development of livelihood strategies.

Since most of the literature and data in Iran is in Persian, it was decided to conduct 8 synthesis studies (will be completed by April 2006) to provide greater detail on these issues and summarize the adoption and effectiveness of existing research and policy employed to address them. Based on the outcomes of these synthesis studies, further activities will be developed for greater understanding on long-term water poverty and water productivity issues.

The team is also collecting detailed baseline data to characterize the hydrology and farming systems throughout the basin and characterize the distribution of wealth using detailed historical village census data. The basin is relatively data rich compared to many in IWMI's client countries.

3. DESCRIPTION OF THE KARKHEH BASIN

The Karkheh river was part of the flourishing ancient civilizations of Mesopotamia, and irrigation has been practiced for millennia. Karkheh Basin covers a total area of 5.08 million ha and there are 5 sub-basins covering parts of 7 provinces (Figure 2). Nearly two thirds of the basin lies in the mountains (elevations of 1000 and 2500m amsl), and surface and groundwater resources are replenished from winter snow falls in the high Zagros ranges. Agriculture and human settlement is mainly found in the valleys of the upper basin and in the hyper-arid plain, where the river eventually terminates in the Hour-Al-Azim, a very large transboundary wetland shared with Iraq. River water becomes progressively more saline as it flows downstream of the newly constructed Karkheh dam with electrical conductivities reaching well above 3dS/m

The basin has a mean annual runoff of 5.1 km^3 and a mean annual groundwater recharge of some 3.4 km^3.

Although there is extensive oil development in the lower basin, generating national and local wealth, the average per capita income of rural communities is claimed to be only 230 US$ /capita. There has been a significant amount of infrastructure development in roads throughout the basin and an extensive dam development program is underway, with the recent completion of the Karkheh Dam with a designed storage capacity of 7.5 BCM (live storage about 4.7 km^3) and commencement of construction of a second slightly further upstream.

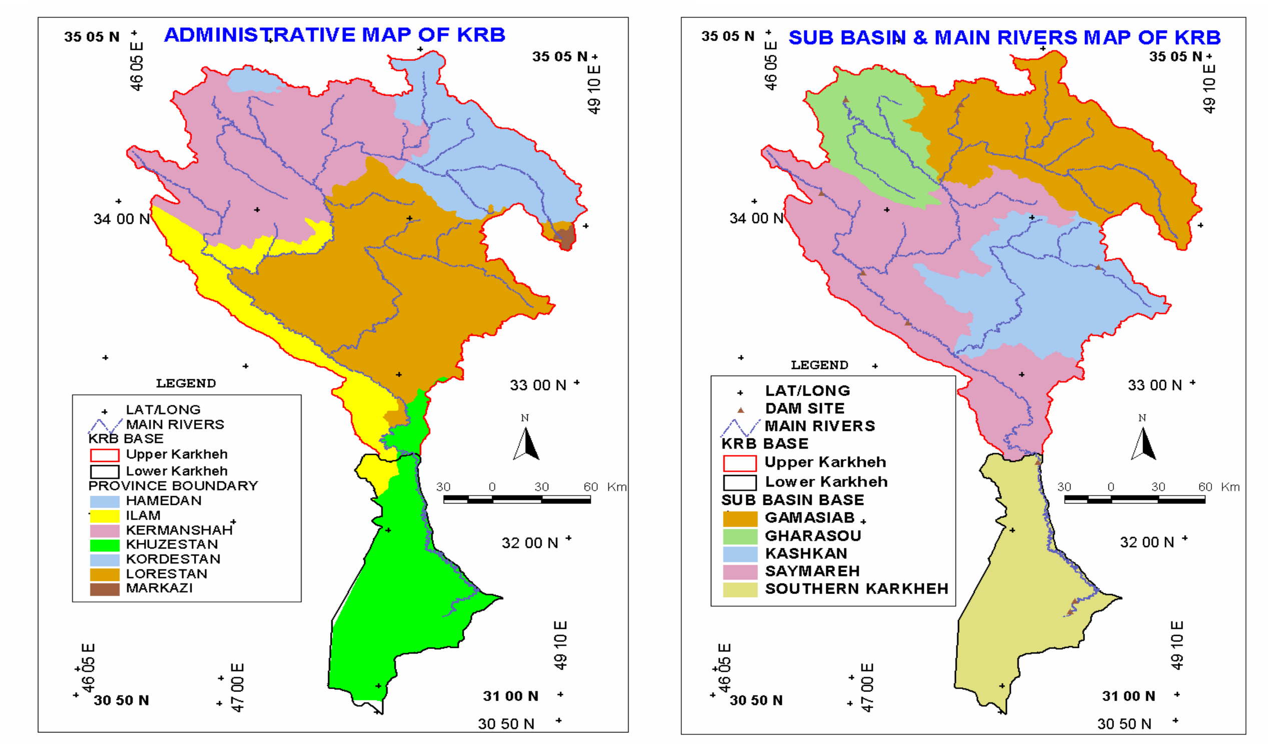


Figure 3. Provincial and sub-watershed map of Karkheh Basin

Farming activities are principally livestock rearing on rangelands and rain-fed agriculture in the upland, complemented by irrigated cropping in the upland and lowland. Irrigation has traditionally been sourced from springs, and more recently by diversion and pumping from the river. In the last 15-20 years, there has been increasing private and state-sponsored groundwater development across the region and major surface irrigation development downstream of the newly commissioned Karkheh Dam. Most of the surface water resources of the basin are now committed for human use. Because of well distributed winter rainfall in the upper and middle reaches, the scenery is surprisingly green from December through to June, although the landscape is parched and brown for the remainder of the year. The dominant crops are winter wheat and barley, which are grown for fodder as well as grain. Yields and water productivity in rainfed areas are low, with wheat, barley and chickpea yielding averages of 920, 950 and 500 kg per ha with corresponding water productivities in the order of 0.3-0.5 kg/m^3. Average irrigated cereal yields are still relatively low at 2300 kg/ha and water productivities typically between 0.5 and 0.6 kg/m^3. Livestock is tightly integrated into all farming systems, with cattle predominating in the lowland and sheep and goats in the upland.

More background detail can be found in the following documents, which provided most of the information given above:

1. Water Productivity at Karkheh Basin, by A, Keshavarz, AREO, 2005, Presentation at ICARDA, Aleppo, Comprehensive Assessment Water Productivity Workshop.
2. Kharkheh Basin Profiles. 2004. Ashrafi S., Qureshi A. and Gichuki F. Challenge Programme on Water and Food, Colombo.

4. OUTPUTS AND METHEODOLOGY FOR 2ND PHASE

4.1 POVERTY ANALYSIS

The water poverty work plan consists of 4 main components – 1) methodology development, 2) poverty mapping, 3) livelihoods analysis/ground-truthing, and 4) linkage with water productivity to produce an understanding of “water poverty” and intervention options.

Methodology development

Our first step is the development of a more meaningful definition of “water poverty” and a better understanding of the possible linkages between water and poverty alleviation which can be used to understand possibilities for intervention targeting within basin specific physical and socio-economic contexts. Existing measures of and assumptions about “water poverty”, based on simple ratios of supply and demand and simple assumptions of causality, are not sufficient for this project, in particular with its aim of providing water options rather than just assessment. Thus our first step is methodological development which can be used both by the Karkheh and other BFP teams, as desired, and can be placed into the broader “water poverty” literature and discussion. Our initial thinking on the direction of this methodological development was presented at the February BFP workshop in Colombo (PowerPoint given to coordinators). It can be summarized as a shift in thinking from “water poverty” to “water and poverty reduction.” Within the BFP context, we expect our efforts to result at a minimum in a working paper, to be published by IWMI or the BFP group, to also be used as the basis of a planned journal article which challenges existing water poverty discussions.

Mark Giordano will coordinate this work with support from Nadia Manning, Alex Clemett, Hugh Turral and Deeptha Wijerathna.

Poverty Mapping

Getting to “water poverty” mapping requires as a first step an exercise in poverty mapping. To the best of our knowledge, no poverty maps of Iran have been produced at scales sufficient for use in the Karkheh BFP. A major effort will be placed on producing such maps of the Karkheh (and possibly all of Iran if marginal costs are not high). ***It should be noted that the production of poverty maps is not a trivial matter and massive resources have been invested in similar projects in other countries.***

The primary issue in the creation of poverty maps is data acquisition. Acquiring secondary data for the production of Karkheh poverty maps has already proven to be a challenge. At present we believe there are two possible options. The first is the use of a series of census products which we have already purchased. The data in the census is, unfortunately, not as directly applicable for the production of poverty maps as one would hope. However, we feel it can be used to produce useful if imperfect maps when coupled with additional data sources and following standard methodologies for linking non-monetary data with other measures of wealth.

A more promising option is a set of Household Surveys conducted annually by the Statistical Center of Iran since at the early 1980s. This data is ideal for the production of poverty maps and would allow use to produce both basin and sub-basin maps of the entire country. In addition, it would allow us to track spatial changes in poverty over time and provide some analysis of the impact of water related interventions in the Karkheh basin over the last 2 decades on poverty.

We have already made steps to access this data and analyze it in partnership with Iranian institutions. In particular, we have formed a partnership with the Economics Department at the University of Tabriz, lead by Dr. Ahmad Assadzaleh. Dr. Assadzadeh has already processed and used the data from 1983, 1988 and 1993 surveys to analyze changes in poverty in Iran as a whole. With his collaboration, we plan to turn his original analyses into a spatial representation and add to it the additional data from the following two 5 year periods, 1998 and 2003 (Assadzadeh and Paul, 2004). While we will focus our analytical efforts on the Karkheh Basin, there will likely be little additional cost to producing poverty maps for all of Iran. Thus we hope to use the effort to provide outputs and impacts for Iran beyond the direct project goals.

The specific methodology we will employ in producing the poverty values, and later analysis, is still under discussion (Kakwani, 1980 & 2000; Satya, 1989 & 1999). At present, our discussion is focused on the Theil index, Atkinson’s index, Gini index. All three of these were used in previous analysis by of the data by Dr. Assadzadeh. Additional measures may also be considered, in particular if value can be gained from consistency across BFPs.

In late May 2006 we plan to hold a meeting in Iran at which we will finalize plans for the poverty analysis. Mark Giordano will coordinate this activity with Dr. Assadzadeh. Robert Zomer with support from Deeptha Wijerathna will lead additional analytical work and GIS training for Iranian partners as needed, however specific planning must await the results of the May meeting.

Livelihoods Analysis/Ground-truthing

Based on the spatial patterns of poverty which emerge in the poverty mapping exercise AND our understanding of the spatial patterns of physical constraints, options and current water use as developed in the Water Productivity work, field surveys may be conducted to generate a better understanding of how people use agricultural water for livelihoods generation. The primary goal of this work would be to develop a more detailed community and possibly household picture of poverty and water linkages and options across the range of existing water use/farming system activities. Initial surveying will naturally occur in conjunction with the water productivity survey. However, an additional survey, based on the results of the water productivity survey and the poverty mapping exercise may also be needed so as to capture the true variation in possibilities for intervention. A decision on such a survey will be made once the initial water productivity survey and poverty mapping exercises have gone through preliminary analysis.

Alex Clemett or a post doctoral scientist will lead this work in collaboration with Mark Giordano, Robert Zomer, other IWMI team members and Iranian partners to be identified.

Mapping Water Poverty The results of activities 2 and 3 will be combined with the hydrologic understanding developed under the Water Productivity work to develop a set of water poverty maps. In this sense, water poverty maps should be understood to represent an understanding of the options for making interventions in the agricultural water sector so as to have the highest likelihood of reducing poverty. Attempts will be made to look at poverty and water relationships across scales both through comparisons of results of the (sub-basin) poverty maps and (community/household) livelihoods work and by extrapolating results from the livelihoods work to larger scales based on our categorizations of farming/water use systems in the basin. The maps and related analysis will also be designed to highlight areas where using water interventions to address poverty may also decrease basin level water productivities. The output from this exercise will in essence be the core product of the BFP-an analysis of the potential for water and land interventions to improve both agricultural and urban livelihoods and produce final project recommendations. This exercise will also attempt to answer the first question posed under Analysis of Water Availability and Access (what is the relationship between access to water and poverty?). However, please note that we do not think examination of this causal relationship, even if it produces results, will produce the most meaningful insights to future action. Instead, we will use the combined poverty and availability (broadly defined) work to identify options for reducing poverty and highlight possible trade-offs between poverty reduction and water productivity.

This activity is covered in more detail until Gantt chart activities 4 and 5 and will be jointly carried out by the water poverty and water productivity teams.

4.2 ANALYSIS OF WATER AVAILABILITY AND ACCESS

Data collection and initial processing

In Karkheh basin, there is a well distributed network of meteorological and stream flow gauging stations (shown in Figure 4). Time series precipitation (1967 to 2001) and stream flow (1955- 2001) data was collected from Iran. Originally data came under Iranian solar calendar and those data convert into Julian calendar by IWMI database team using special program.

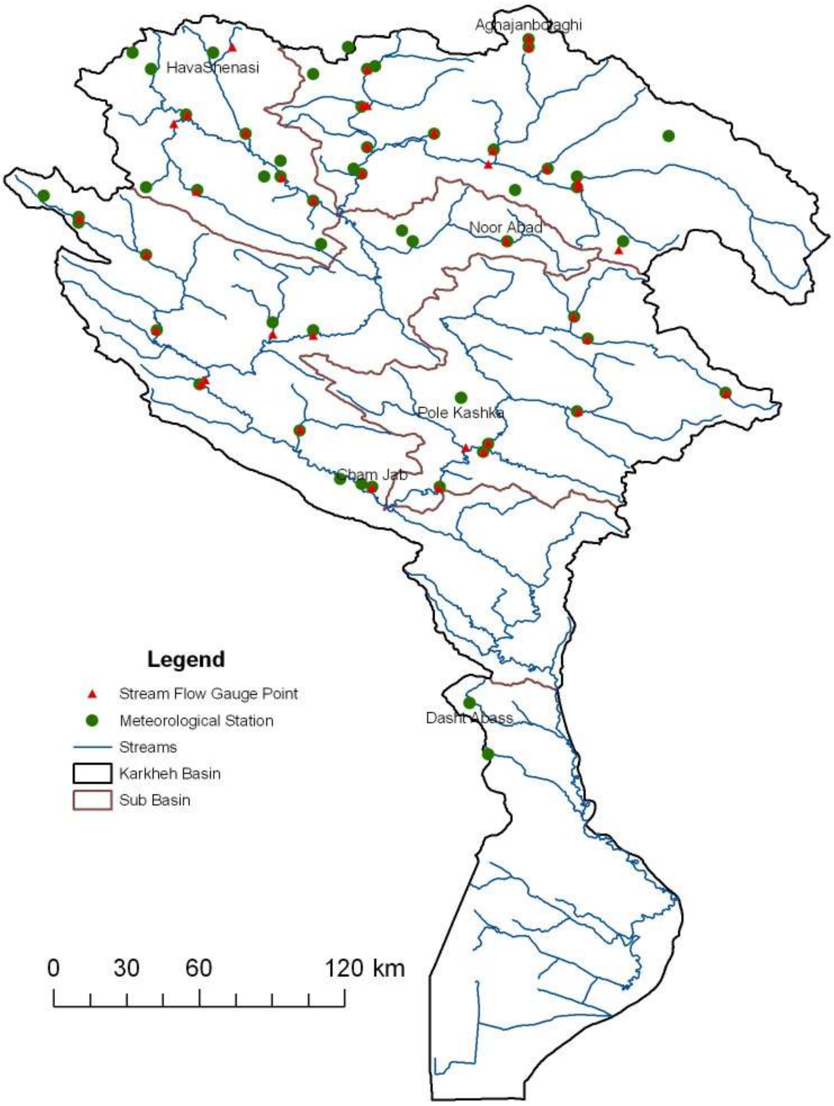


Figure 4. Locations of rain gauge and stream flow gauges in Karkheh basin

(Monthly mean values of stream flow at Aghajanbalaghi, Noor Abad & Cham Jab and meteorological stations at Hava Shenasi, Pole Kashka& Dasht Abass are present in figure 5 & 6)

These data are useful for sub-basin level water accounting. Mean monthly precipitation of 3 stations, representing upper, middle and lower part of the basin, is presented in Figure 5, which clearly shows the spatial and monthly variation of precipitation in Karkheh Basin.

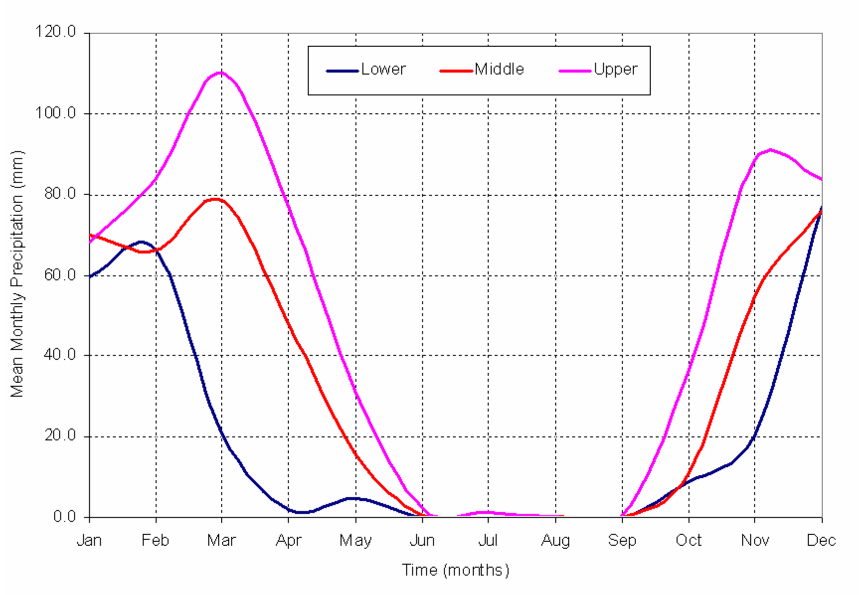


Figure 5. Monthly precipitation for different reaches of Karkheh Basin

(Hava Shenasi = upper; Pole Kashka = middle; Dasht Abass = lower, in figure 4)

Similarly, Figure 6 shows the mean monthly flow for three different locations on the Karkheh River. March-April are the months that highest flow can be seen which is having nearly half a month lag period with comparing rainfall.

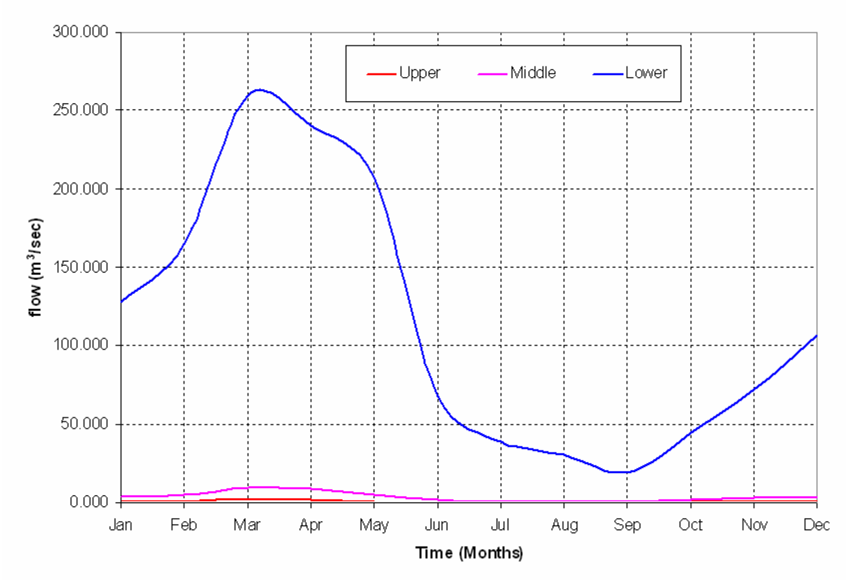


Figure 6. Mean monthly flows for the three sample locations on Karkheh Basin

(Aghajanbalaghi = upper; Noor Abad = middle; Cham Jab = lower, in figure 4)

The IWMI Water accounting framework (Molden, 1997), which distinguishes different water use categories such as process depletion, non-process depletion, non-beneficial depletion, committed- and uncommitted-outflows, will be applied to understand water availability and use in sub-basin and basin as a whole. Time series meteorological and stream flow data is being collected for water sub-basin and basin level water accounting.

Management and allocation options will be considered in more detail using a reach by reach water balance and accounting framework for surface and groundwater. Understanding the hydrology of the basin is the key to understanding current and future water allocation strategies, as security of supply associated with natural hydrological variability is one of the most important factors governing allocation. Modelling of either the hydrology, the water allocation or both, underlie any attempt to understand the potential impacts of interventions designed to improve livelihoods in the rural communities in a basin.

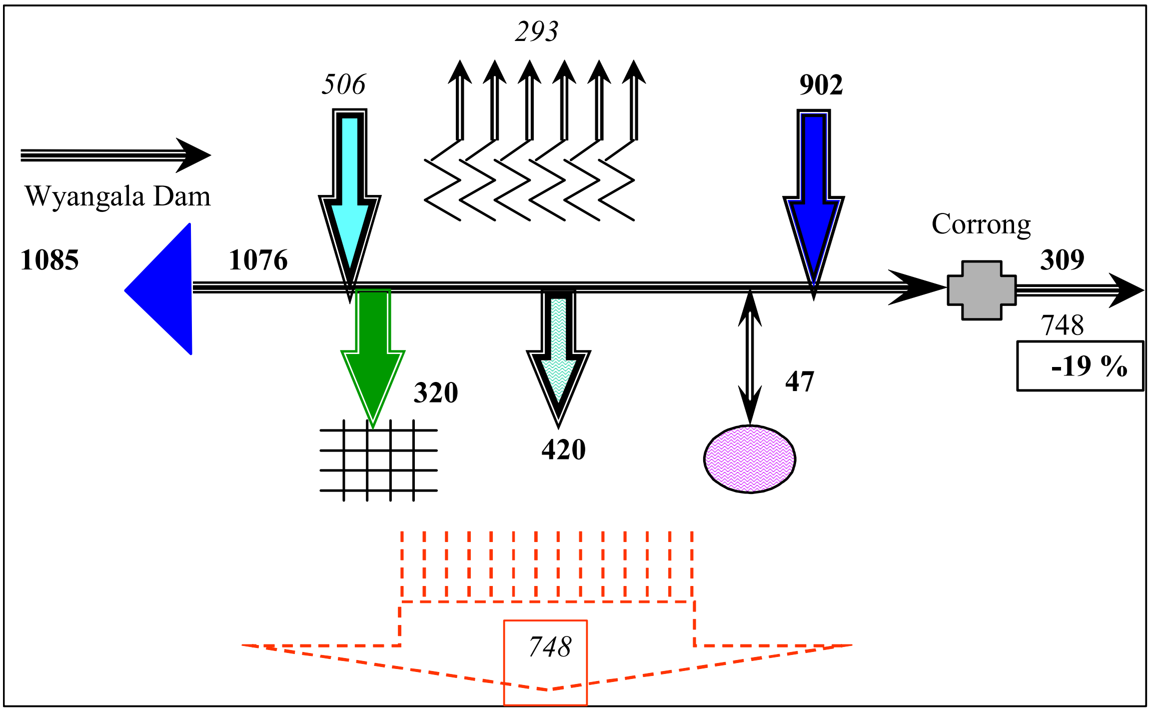
In systems where groundwater use is dominant, the *integrating* model has to be based about groundwater (eg. MODFLOW) and where surface water is dominant, then catchment runoff based models are more appropriate (eg SWAT). Where there is significant ground and surface water interaction, the situation is more complicated and may involve coupling of appropriate models, or use of an integrated model (such as MIKE-SHE). However, in most developing country contexts, complex multi-parameter process models such as MIKE-SHE pose very significant calibration problems. Water allocation models are in principle considerably simpler than hydrologic models, and require most demands and supplies to be input exogenously (eg. WEAP).

An essential precursor to modeling is the understanding of the basin and sub-basin water balances, and their behaviour over the natural range of climatic and hydrologic variability.

In order to provide a basis for modeling, the following steps are suggested:

Water Balance

1. Calculate the annual basin level water balance for an average year using all available data.
2. If the climate is arid, runoff is not usually normally distributed, and is skewed by above average (usually flood) events. The mean overestimates median water availability by a significant amount in such cases and so determination of the median water balance for a basin is also instructive.
3. Water balances also need to be calculated on a monthly basis for the whole basin and for all important sub-basins. The extent to which sub-basins can be defined depends on the availability of medium to long time series data at the outflow point of each basin.
    a. Monthly water balances should be calculated for a 5 year period.
    b. The period chosen should ideally cover above and below average years. If this is not possible, it is better to select a period of dry years than wet ones for the purposes of water allocation.
    c. The balances should include monthly values of all outflows, especially irrigation diversions.



$$Q_{out} = Q_{inflow} + Q_{gauged\ catchment\ inflows} + Q_{ungauged\ catchment\ inflow} - Q_{diverted} - Q_{Evap} +/- Q_{gw} +/- Q_{return\ flow}$$

Figure 7. Example basin river water balance for Lachlan River Australia (not in Molden Finger Diagram form)

Water balances will normally have an **error term** at each downstream node, where the sum of inflows – the sum of outflows is not zero. There can be easily identifiable reasons for this, such as out-of-date or inaccurate rating curves or more complex ones, such as incorrect calculation of net groundwater flows to and from the river. These can sometime be fixed by a range of groundwater simulations and approximations. The error term should be as small as possible and ideally always under 20%.

Hydrologic Variability

Hydrologic variability has a great influence on the reliability of water supplies from rivers, and to a lesser extent on groundwater. As the level of water use in a basin increases, variations in hydrology have increasing impact on the reliability and risk of supply to any individual or bulk user: as allocation increases the supply security of any user decreases unless they have preferential access, in which case, the reliability of remaining users is even further compromised.

Hydrologic variability can be assessed using time series data at annual, monthly and even 10-daily scales.

1. Calculate flow duration curves (FDCs) (Figure 8) for each gauging station, including the outflow of the basin.
   a. FDCs for each month
   b. Annual FDC

c. Plot average water use on the FDC to determine the level of supply security at each node and for the whole basin.
d. Plot environmental flow requirement, if there is any specified, on the FDC.

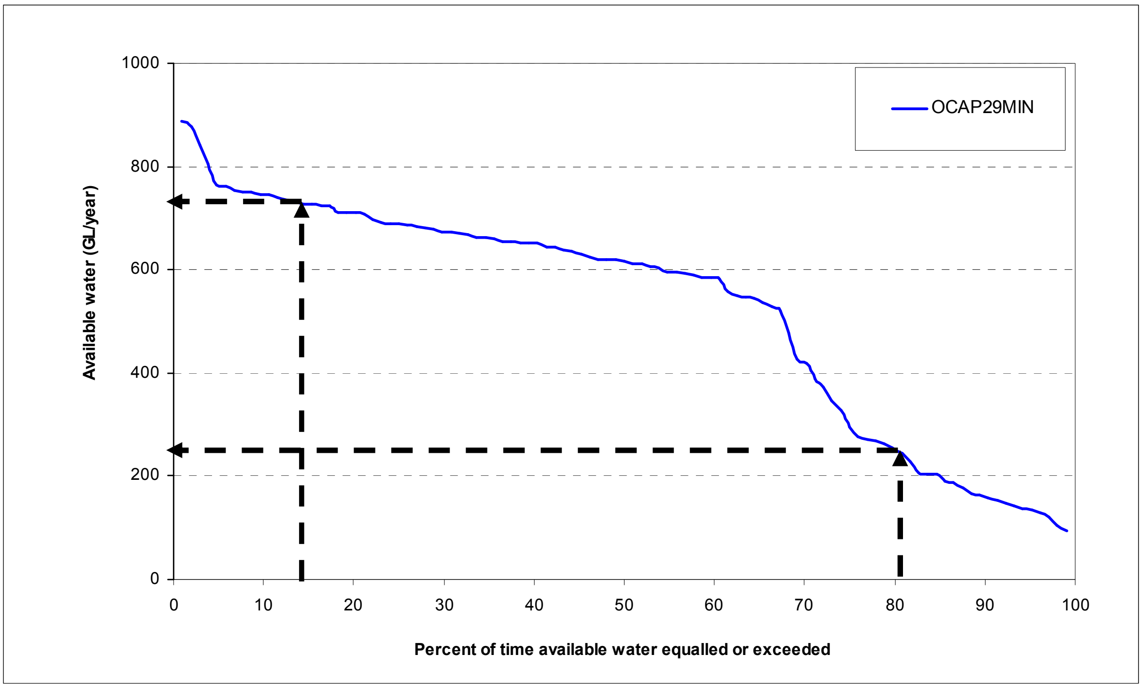


Figure 8. Example flow duration curve for Lachlan River Water Allocation,

2. FDCs can be plotted for natural flow conditions if the hydrological analysis has been undertaken to adjust measured flows to natural flow conditions assuming no regulation and diversion from the river. Otherwise the FDCs will be for actual flow conditions and will reflect storage and diversion, land use change and other factors that impact stream flow over time. It is therefore important to calculate FDCs for a reference period or year, with known characteristics vis-a-vis storage, diversion etc.
3. Simulation outputs in allocation models can be presented in terms of FDC's compared to the bases case scenario, derived from known real-world conditions, as derived in 1 and 2.

If the time series is sufficiently long, we can determine the net **trend** in flows at each gauging station. For example, if groundwater use increases upstream of a measuring point, any adverse effect on stream flow should be visible in the stream flow time series. When large dams are added to the river or irrigation diversions are brought into operation, the flow duration curves downstream of that point will change considerably. Inflow time series and trends may need to be corrected for land use change and for other sources of change, sometime due to climatic changes as illustrated below:

Monthly and annual flows should be plotted and a trend line fitted for each gauging station, as in Figure 9. In this instance we show an example from Australia, as we do not yet have long duration time series (>70 years) of data for stations in the Karkheh.

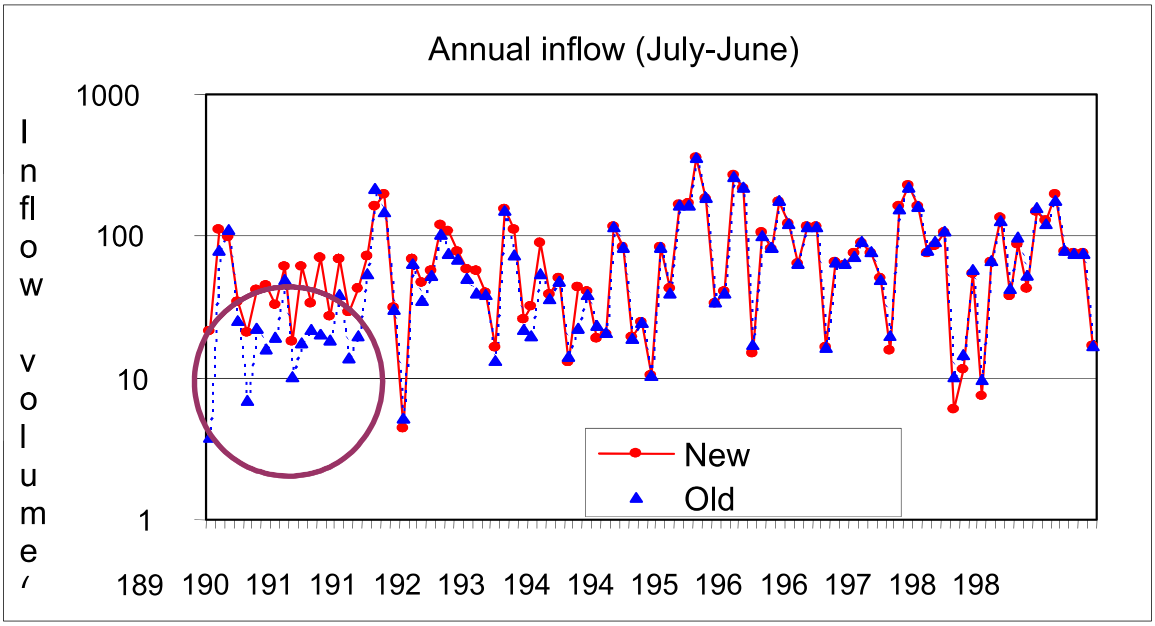


Figure 9. Inflow time series to Wyangala Dam, Lachlan Valley, Australia (1898-2000).

The average rainfall and inflows post 1948 at Wyangala have been higher than in the first half of the century. Inflow availability was therefore recalculated using the Sacramento model, as a synthetic data series (in red), to reflect the higher rainfall in the second half of the 20 Century (Figure 9). A trend line would show a gradual increase, but there is almost a step change between the first and second halves of the century. Different corrections may be required for land use change, and also for regulated rivers, in which case a "natural" flow series needs to be derived.

The synthesis of available information on water availability in Karkheh Basin indicates that the water resources of KRB comprise of both surface water and groundwater. Annually about 3.95 billion cubic meters (BCM) of water is used for irrigating 378,164 ha of agricultural lands (horticulture and field crops). A major part of agricultural water consumption (about 63%) comes from surface water resources. The quality of river (surface) water is generally good, though it varies both seasonally and along the path downstream, reaching up to 3 dS/m near the final outlet. As presented in Tables 1 and 2, average annual rainfall in the basin is 24.9 BCM of water. Out of which, 5.1 BCM is flood and surface water, 3.4 bcm infiltrates to ground water and the rest of 16.4 BCM evaporates directly to atmosphere.

Table 1. Elements of water resources in KRB

Total rain fall	Surface water	Infiltration	Evaporation
24.9 bcm	5.1 bcm	3.4 bcm	16.4 bcm
100 %	20.5 %	13.4 %	65.8 %

It also important to have detailed water balances of each sub-basin and see the water availability from all the sources (such as surface water, groundwater and rainfall). As an example the average stream flow in the Gamasiab Sub-basin is presented in Table 3. The temporal trends are highlighted in Figure 11, showing the average, high and low flow periods. The monthly variations in the river flow for the main rivers of Karkheh Basin are shown in the Figure 8.

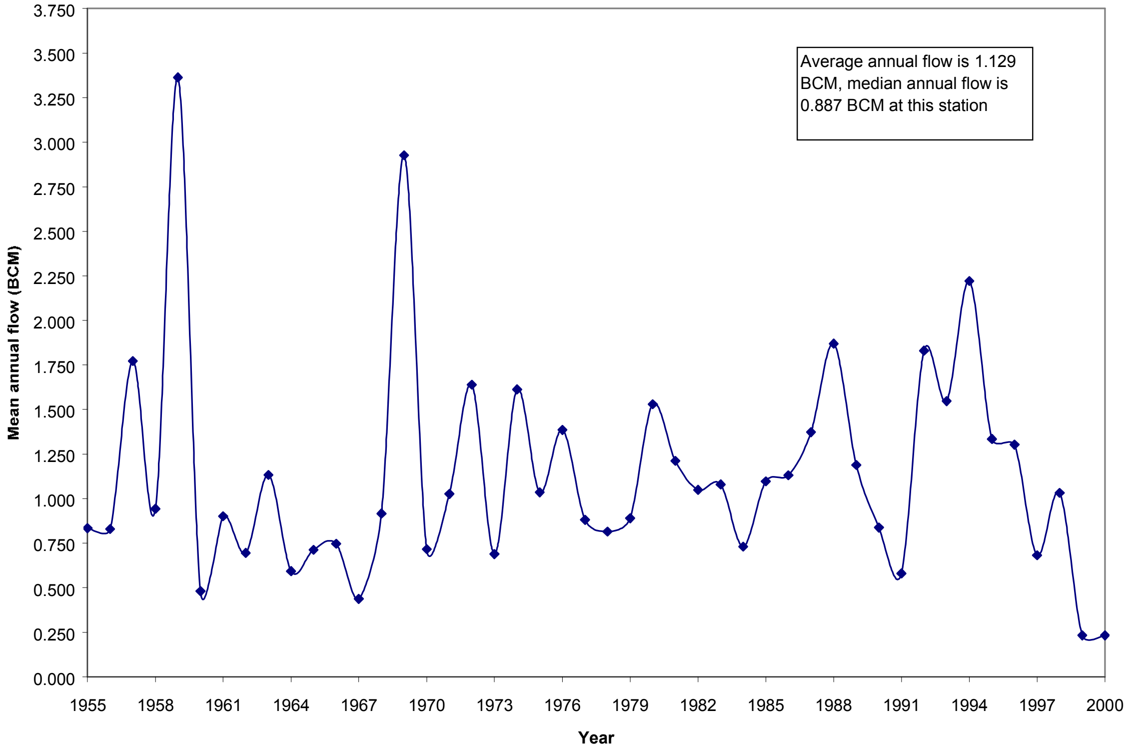


Figure 10. Variations in the mean annual river flow at station Pole Chehr (21-127), Gamasiab River, Gamasiab Sub Basin

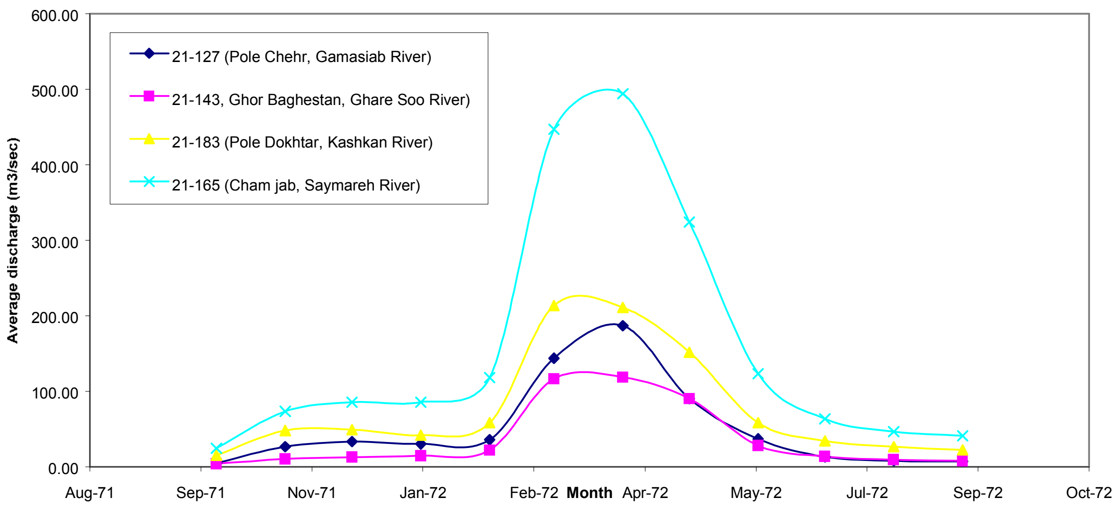


Figure 11. Monthly hydrographs for four main rivers of the Karkheh Basin

Table 2. General information about water resources in KRB

Rainfall	24.9 BCM
Potential renewable water resource	8.5 BCM
Present consumption	3.956 BCM
Consumption from ground water	36.76 %
Consumption from surface water	63.24 %
Average of consumption	10,940 m3/ha
Irrigation efficiency	28 - 36 %

Table 3. Average monthly flow (m^3/sec) at various discharge measuring stations at streams/rivers of Gamasiab Sub Basin

River/stream	Station ID/name												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gamasiab	**21-105 (Sang Sorakh)**	**2.2**	**2.3**	**3.8**	**6.8**	**8.2**	**7.3**	**5.2**	**3.8**	**3.1**	**2.5**	**2.7**	**2.5**
Ab Nahavand	21-107 (Goosheh Sad Vaghas)	3.8	4.4	7.1	8.6	4.4	1.0	0.7	0.6	0.6	1.1	3.1	3.9
Toyserkan	21-109 (Firooz Abad)	2.0	2.3	3.8	5.7	2.5	0.3	0.1	0.1	0.1	0.4	1.3	1.8
Shahab	21-111 (Aghajanabolaghi)	0.6	0.8	1.2	1.4	0.8	0.3	0.2	0.2	0.2	0.4	0.7	0.6
Shahab	21-112 (Bujin)	0.67	0.75	1.13	1.45	0.57	0.26	0.22	0.25	0.16	0.28	0.50	0.51
Khuram Rood	21-113 (Aran)	4.1	6.2	12.6	13.5	7.8	1.9	0.6	0.3	0.2	0.7	2.6	3.5
Gamasiab	**21-115 (Doab)**	**18.5**	**24.3**	**44.7**	**50.0**	**21.9**	**5.18**	**3.24**	**2.57**	**2.44**	**4.1**	**9.7**	**16.8**
Abshar	21-117 (Sahne)	0.4	0.5	0.9	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Maryam	21-123 (kole Choob)	2.3	3.7	7.8	9.2	4.5	0.6	0.2	0.2	0.1	0.3	1.6	2.3
Dinvar	21-125 (Haider Abad)	7.7	13.7	35.2	39.3	23.3	5.0	1.0	0.4	0.4	2.2	4.4	6.2
Gamasiab	**21-127 (Pole Chehr)**	**34.6**	**45.7**	**90.8**	**98.5**	**53.5**	**12.0**	**5.2**	**3.5**	**6.5**	**19.7**	**29.1**	**31.7**

Note: The above table depicts the river reach wise analysis of the average monthly flow at various stations in Gamasiab sub basin. The station discharge at 21-127 (Pole Chehr) is the last point where discharge is measured on Gamasiab River before its entry to the next sub-basin (Saymareh sub-basin)

4.3 ANALYSIS OF WATER PRODUCTIVITY

The principle purpose of measuring Water Productivity is to identify opportunities to improve the net gain from water by either increasing the productivity for a given consumption of water or reduce the consumption without decreasing production. Basically this problem reduces to two opportunities: increase production without concomitant increase in water consumption; or reduce consumption without reducing the net gain from agricultural production.

Concept

The basic concept of water productivity is to understand how beneficially the water is used by different agricultural production systems in a (water scarce) basin. More precisely the term *water productivity* is defined as the physical mass of production or the economic value of production measured against gross inflows, net inflow, depleted water, process depleted water, or available water (Molden, 1997; Molden and Sakthivadival, 1999). The expression is most often given in terms of mass of produce, or monetary value, per unit of water.

Basic measure of water productivity

The goal is to estimate, for a defined area, the expression:

$$WP = \frac{Benefit}{Consumption} \qquad (1)$$

Water supplied and water consumed: The denominator

The main challenge we face in calculating rainfed water productivity lies in determining the denominator – how much water was consumed in order to produce a given output. First we have to account for the spatial variation in rainfall, and secondarily we may need to understand the contributions of residual soil-moisture, shallow groundwater and surface runoff from adjacent areas (run-on). Rockström *et al.* (2003) cite published data that estimates that for semi-arid rainfed environments between 70-85% of rain water can be 'lost' to the system as evaporation, runoff or drainage. Relatively small errors in water partitioning may lead to large discrepancies.

Better estimates of water supply in rainfed systems can be obtained by interpolation of rain gauge data against elevation and over space (Jones et al, 2000). Many authors have found that it is better to do this in two stages: 1) regression of rainfall against elevation followed by 2) spatial interpolation between stations using techniques such as kriging or thin plate splines. Co-kriging with elevation seems not to produce better results than elevation-adjusted splining.

Such data can be rasterised and combined with remote sensed estimates of actual evapotranspiration and of land use. Where met and rainfall stations are sparse, it is possible to use satellite based data (cold cloud cover duration, cloud temperature) to interpolate spatial rainfall patterns. There are three sources of data – Meteosat (now down to 4km), GMS and TRMM (radar) [1].

Measuring actual water use is also not straightforward. In rainfed systems, there are periods of water stress where transpiration is less than potential, and evaporation losses from bare soil can be particularly significant in low density crop stands. It may be possible to improve estimates using coupled rainfall estimates with crop and water simulation models (Droogers and Kite, 2001 used SLURP and SWAP; Diaz *et al.* 2005 used MARKSIM-DSSAT).

The problem remains, however, of estimating T for low density crop stands. If we can measure actual evapo-transpiration (ET_a) directly, we have an unambiguous value for depleted water. In semi-arid and arid conditions, with low cloud cover, it is possible to integrate daily estimates of ET_a over a crop season and sometimes over a whole year. The SEBAL procedure allows ET_a to be calculated using satellite imagery that has a minimum of red, near infra red and thermal bands (Bastiaanssen et al., 1998; Bastiaanssen, 2000; Ahmad et al., 2006). ET_a can only be integrated seasonally or annually at a pixel size of 1 km^2 (100 ha) at the moment (Bastiaanssen et al., 2002) using NOAA AVHRR or MODIS imagery. Spot measurements at finer resolutions (60m pixels) are possible using Aster and Landsat data, which is available with a minimum of 16 day repeat pass measurements.

If we can determine ET_a directly, we do not have to worry about the source of water (rainfall, run-on, shallow groundwater) since all are subsumed into the ET_a value. Where the ratio of ET_a to rainfall is higher than 1.0, we clearly have a situation where there is either groundwater contribution or run-on. However, run-on can occur when ET_a is significantly less than rainfall also.

Where it is not possible to apply the SEBAL procedure, the alternative is to revert to a soil-plant-water model such as SWAP or DSSAT which couple soil water balance with crop growth and water use. It is then possible to estimate actual ET on the basis of water balance and crop limiting soil moisture stress. Models such as SWAP have been "regionalized" for characteristic farm types (Droogers, 2001) and can be used in conjunction with GIS characterization of rainfall and farming system. Higher spatial resolution estimation may be possible for variable soil characteristics (Pracilio *et al,* 2003).

Following the notion of hydronomic zonation (Molden *et al.* 2001), an alternative to exhaustive process simulation modelling is to use environmental correlation of daily climate, soils and terrain from 'known' sites to extrapolate over large areas. Global correlation of climate and soils is available using the method of Jones *et al.,* (2005). SRTM data for all basins is downloadable from the CSI website (URL http://srtm.csi.cgiar.org/).

It is possible to estimate effective rainfall factor if both input rainfall and ET_a are known over a season (ET_a/RF), but this will not show how the residual is partitioned

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[1] See http://daac.gsfc.nasa.gov/precipitation/TRMM_README/TRMM_3A12_readme.shtml,

http://disc.gsfc.nasa.gov/guides/GSFC/guide/arkin_gpcp_gpi_dataset.gd.shtml between runoff and deep percolation. We have to assume that there is no other water supply than rainfall and that ET_a equals effective rainfall.

At field, farm and system scale, the denominator of water use is determined as follows:

$$NetWater_{in} = Rain + SI + GWI + \Delta Soil + runon - runoff - deep\_percolation \qquad (2)$$

where:
SI = surface irrigation supply
GWI = groundwater irrigation supply

Some components may not be significant depending on circumstances. For instance: no irrigation in rainfed farming, no run-on (incoming overland flows) or no capillary rise from high water table. Using both actual ET and net water supply as denominators can help us understand the context and options for management.

The problem of estimating WP becomes more complex for large, heterogeneous areas, containing complex mosaics of land uses and significant flows between them. Discrepancy of meaning between WP of different users can obstruct comparison of different water users within a single area. To simplify this, the method of water accounting may help track different water depletion flow paths (Molden, 1997).

Agricultural production – the numerator

In rainfed farming systems, grain is only one output of value to the farmer – the others are green and dry fodder (straw and stubble). In pastoral systems, the value of green biomass is optimal at a certain stage of growth and it is common to convert green and dry biomass into digestible dry matter to account for this variability. Additionally, the value of product may vary according to its position within the farming system it is used, often in quite complex ways.

In the first instance, we can use secondary agricultural statistics to determine yields for different crops in different areas. These areas will normally be defined by administrative district and some GIS manipulation is required to make them spatially coherent with water use data (see above). IWMI South Africa have developed a good GIS based analysis of secondary production statistics to understand the water productivity of the Olifants Basin, but at the moment, the analysis is limited by the assumption that actual evapotranspiration equals the potential value calculated using the Penman-Monteith equation.

However, it is unlikely that much secondary data will exist on green fodder production and straw/haulm production and utilization. Some primary crop survey or crop cutting in targeted areas may therefore be required.

In the Karkheh river basin, wheat and barley are grown for fodder, which is grazed by sheep and goats. Fodder wheat and barley seem to be found on increasingly steep slopes and thin soils, substituting for degraded pasture. This needs to be differentiated from cereals grown for grain, and one way of doing this might be to use the SRTM 90m DEM to zone slope and aspect over the land use classification.

If secondary statistics are not available, or disagree markedly with research or sample survey data, then more comprehensive ground survey of yields will have to be conducted. Such survey will have to be stratified by farming system and location. We propose to include a research component to develop remote sensing-based techniques to estimate water productivity at a regional scale, using a variety of scales of imagery (Landsat at 28.5 m pixel to MODIS as 1km (thermal) and 500m (visible, near and medium infrared wavebands). Ground-truth, crop histories, classification, biomass development and yield will be required to understand the relationship between net primary productivity and yield and to better assess harvest index as a function of crop condition. Representative areas for survey can be selected from a preliminary analysis of satellite images, and local knowledge.

If we want to understand physical productivity of different farming systems, we need to consider the numerator as shown below:

$$WP_{kg} = \frac{KgDM_{grain} + KgDM_{greenfodder} + KgDM_{dryfodder}}{m^3} \qquad (3)$$

where:

KgDM = equivalent weight of product at a standardized moisture content (say 12% for grain, 86% for green fodder and 10% for straw

m^3 = water supply/use in terms of water delivered or transpired, as appropriate.

Unfortunately, the fodder value of straw and fresh biomass varies with species, variety and time of cutting or grazing. Conventionally, the value of different pastures and fodders is standardized by converting to digestible dry matter, where the digestibility values are often tabulated from experimental work in livestock rearing. It will be very difficult to do anything but assign an average value of digestibility to major fodders in Iran, and the data will have to be obtained from existing experimental data.

If we wish to compare the productivity of different farming systems (including livestock and fisheries), we ideally should be able to determine the marginal productivity of a unit of water in each enterprise, and furthermore, we should be able to quantify the contribution water makes to total factor productivity. The former is very hard to do outside a research station, but it is possible to derive crop production functions that estimate the contribution of water to productivity in physical or monetary terms. Where feasible, production functions should be derived (as in IWMI's work in the Rechna Doab in Pakistan).

A simpler proxy for comparison across scales and enterprises is to look at the **gross margin of production** (**gm** = total value of product – total variable costs) per unit of water used or supplied. Although this still attributes the gross margin value entirely to water, it effectively accounts for the differential benefits and costs of the other inputs. This allows for a first step comparison of water productivity across different uses, including livestock and fisheries, and factors in the primary productivity of vegetation grown as feed with secondary factors of feed conversion efficiency. Of course, determining the gross margin requires a larger amount of field data on input types and costs, and this can only be derived from survey data. The greater the area scale, the more idealized a gross margin becomes for any enterprise, since the variability that explains individual farmer behaviour and management choices is averaged out.

Although there will often be a strong correlation between land productivity and water productivity (see Rechna Doab work, Ahmed et al. forthcoming), it is important to look at the comparable physical and economic measures of land productivity (yield, total income per ha and GM per ha). Many farmers are still more driven by land productivity than water productivity, and again a comparison of the indicators sheds light on farmer's perspectives, and also possibilities for interventions (for instance, where land productivity is high, but water productivity is low and vice versa).

Water productivity in irrigated areas

The determination of WP of irrigated crops is better understood than the WP of rainfed. The steps involved are as follows:

1. Map irrigated areas and crop types within the surface water / groundwater system
   a. Identify conjunctive use areas with the irrigation system
   b. Map high water table areas (secondary data)
   c. Obtain crop yield data through appropriate combinations of secondary (administrative or hydraulic district) data or from primary survey.
   d. Obtain data on straw and green fodder production and utilization from irrigated crops, usually from primary survey.
2. Overlay irrigation networks, and determine where there is flow data for primary, secondary and possibly tertiary canals.
   a. Select units for investigation, where sufficient water supply data exists
   3. Estimate gross inflows
   a. Obtain and spatially interpolate rainfall data. Using secondary data, determine typical values of effective rainfall (that retained in the root zone or as surface storage in the case of rice)
   b. Obtain canal flow data and determine seasonal surface water supply. Where flow data is not generally available at lower levels of the distribution network, it is possible to develop and apply disaggregation techniques to estimate the net local supplies from canal head flows (see Ahmad, 2002)
   c. Survey groundwater pump locations, capacities and average operating hours to determine groundwater supplies.
   d. Where necessary, apply more advance procedures to estimate net groundwater contribution (see PhD thesis by Ahmad, 2002), using remote sensing and soil-plant-water models.
4. Estimate ET_a using SEBAL for each crop season, and disaggregate by cropping system.
5. Determine livestock holdings and fodder use (by survey)
6. Calculate land productivity (LP) in terms of GVP and gross margin.
7. Calculate water productivities (WP), with respect to total supply and ET_a:
   a. Physical production (kg)
   b. Gross value (SGVP)
   c. Gross margin
8. Identify innovative water use practices where WP is low but LP is high and vice versa.
9. Calculate water productivity at larger scales of irrigation system and basin, using the depleted and process fractions of water supply (Molden *et al*, 2001)

10. Determine system and basin average water productivity across all agricultural uses.

In irrigation systems, WP is measured as marginal yield per unit of water depleted by the system, i.e.: average crop product per unit of water consumed. Hussain et al. (submitted) suggest a broader range of possible indicators of productivity to account for value that is not derived from crop production. This paper also cites values derived from direct measurement – possible only in assessing WP of irrigated land.

Table 4. Indicators of productivity and value of water.

	Indicators
(b) Water productivity-based indicators	Average product per unit of water
	Average gross value of product per unit of water
	Average gross margins per unit of water
	Average gross net value of product per unit of water
	Value of marginal productivity of water.
	Note: *Commonly used denominators for calculating water productivity based indicators are amount of water diverteted /supplied, water applied, gross inflow of water (rainfall plus irrigation), and crop evapotranspiration (ET).*

From Hussain et al., submitted.

Challenges in determining rainfed crop and pasture water productivity using remote sensing

Although remote sensing offers us the chance to accurately represent land use and its spatial variation, to determine ET_a and possibly to infill rainfall data, there are a number of challenges to be addressed, as follows:

- Sub-pixel disaggregation of land use (between crops and between cropped and fallow land), when using 1km or 500m pixel (MODIS or AVHRR) data.
- Corresponding sub-pixel disaggregation and attribution of ET_a to each land use, or alternatively to land use defined by higher resolution imagery (Landsat at 28.5m).

The SEBAL procedure needs improved calibration for rainfed, pasture and forest land covers, and new research is probably required to do this, although a detailed literature review my unearth more recent research on this topic. Images for higher relief areas (e.g. the upper and middle Karkheh basin) require topographic correction to account for variations in reflectance due to the surface relief. Procedures have been developed by Tasumi and Allen (2003) to do this with Landsat data, and these can be adapted for use with MODIS data.

The estimate of water input can be complicated by undefinable contributions from high water table (although water table mapping will assist, if available) and not knowing the extent of run-on to rainfed lands from surrounding catchment areas. It is also possible that there will be varying amounts of soil moisture carry-over between seasons, depending on the year, the timing of rainfall: in general, we would expect all soil moisture in the root zone to be depleted every year in the Karkheh, with its strong pattern of winter rainfall and very high rates of potential ET in summer.

In some pastoral systems, such as in the Volta Basin, the value and availability of fodder is partly governed by knowing where livestock are. Animals that are "stall-fed" will consume fodder from non-defined areas.

Key Steps in Karkheh

The main steps of water productivity analysis are present Figure 12.

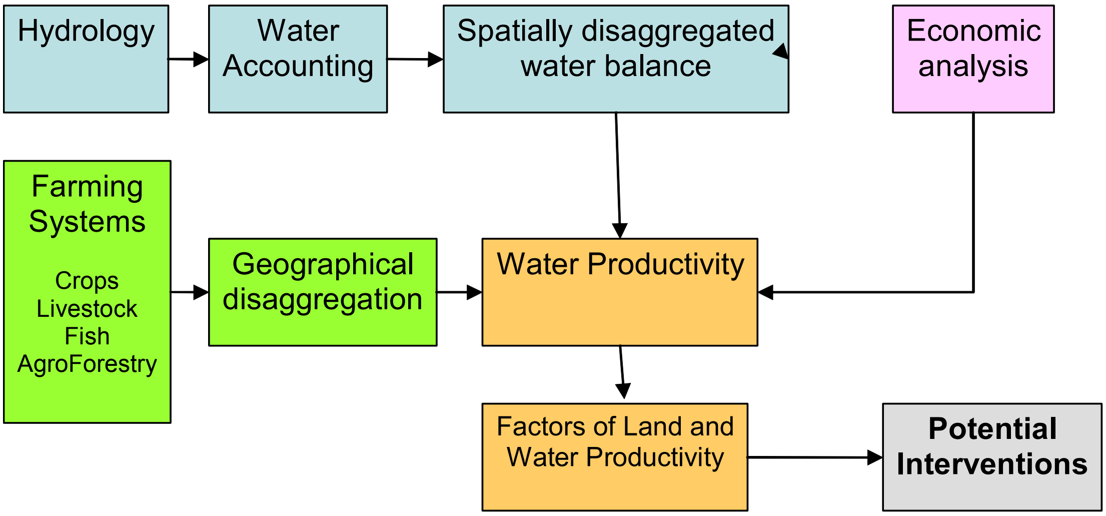


Figure 12. Key steps to perform water productivity analysis in Karkheh Basin

- After hydrological and water balance analysis, the first step in water productivity analysis will be to identify major agricultural production system, such as crop production system, livestock and fisheries. These production systems will be ranked based on their area and associated dependent rural population.
- Assessment of the current level of water productivity for major (agricultural) production systems at basin, sub-basin scale;
- Assessing the variability of productivity in each sub-catchment;
- Estimation of productivity gap in irrigated and rainfed systems in different agro-ecological zones;
- Identification of key impediments to improve land and water productivity for major production systems;
- Potential (actionable) interventions

Methods (in steps)

Hydrological Analysis:

- Water accounting (sub-basin and basin level);

- Water balance analysis (sub-basin and basin level --- to understand field scale processes field scale hydrological studies will be conducted for selected field).

Productivity Analysis:

Water productivity analysis will be conducted at field, farm and sub-basin/basin scale using primary, secondary and survey data and following indicators will be estimated for Karkheh Basin:

- (Total factor) Productivity analysis (development of production function for major/selected agricultural production systems).
- Water Productivity
  - Global/basin level water productivity
  - Relative water productivity

Similar exercise was conducted by IWMI's researchers in the Rechna Doab, Pakistan (Ahmad et al., 2004; Ahmed et al., 2006). Under this study, we have tabulated and analyzed field and farm level data in terms of physical and economic outputs per unit of water supplied, depleted and transpired. We have also turned this into gross margin per unit of water and also compared similar indicators of land productivity (yield). Using survey information, we have also derived production functions. We have also looked at administrative district level statistics to generate water productivities in at larger scales in Rechna Doab.

Tools Used

Range of tools will be used for this assessment including:

- Simple spreadsheet analysis using available agricultural census and hydrological data;
- Field scale and basin scale hydrological/water balance models;
- Statistical modeling / development of crop production function, based on survey and secondary data.
- Geo-information techniques (i.e. GIS, Remote Sensing, geo-statistics) to map crop/irrigated area mapping, evapotranspiration estimation, interpolation of point datasets etc.

Data Required

- All variables required for water accounting and water balance analysis;
- Agriculture statistics (on cropped area, yield, production, different farm inputs, livestock, prices…etc)
- Potential yield
- Spatial data
  - Land use maps
  - crop classification maps;
  - maps showing the extent of irrigated & rainfed;
  - DEM;
  - Soil maps;
  - Administrative boundaries;
  - River/canal network

Outputs

- Methods and tools developed for basin scale water-productivity (and water poverty) analysis will be available for use in other basins in-side and out-side of Iran
- Research reports & papers
- Maps

Upscaling/Application
This project aims to provide useful information to understand & improve water productivity in similar agro-ecological zones such as CWANA (Central West Asia and North Africa) regions.

4.4 INSTITUTIONAL ANALYSIS

Institutional analysis will take place in two phases, the second depending on the outcome of the first and insights generated from the poverty and water availability/productivity work. In the first phase, an Iranian PhD student, under supervision of the BFP team, will produce a report on the development trajectory of the Karkheh. The report will follow the general lines of work by Francois Molle for the Comprehensive Assessment in developing basin trajectories. (e.g**.** *Historical Transformations of the Lower Jordan River Basin: Changes in Water Use and Projections (1950 – 2025).* Courcier, R., J.P. Venot and François Molle). This work will analyze to the extent possible the evolution of key policies and institutional factors in the basin that have impacted both water demand and supply across the basin. In the second phase, the results will be reexamined in with outputs from other aspects of the project to provide additional insights into the relationships between institutional factors, poverty, water use and options for future interventions. The approach to be taken will be eclectic and involve literature surveys, data analysis and interviews with key informants.

4.5 INTERVENTION ANALYSIS

Matching technologies and management to the needs of the poor

Farmer choices
Farmers will invest in a technology that serves their need to improve their family food security and nutrition and/or profit from sales of some proportion of their produce. It is possible, though rare, for farmers to sell all their produce and buy in the food they need to consume. More commonly they will buy other foods to balance nutrition using sales of staple products.

The factors governing farmer choices have been investigated in great detail in the literature, and focus on the management of risk in relation to the costs of production (capital, recurrent costs and labour) and the returns from production (yield, quality and value). The risk element is primarily mediated by climate – the availability of rainfall or water for crop growth in relation to its evaporative demand. Within this primary constraint to agriculture, farmers must juggle the resources they have with the probability of success in recouping those resources, preferably with some net profit. The greater the risk in achieving this goal, the less farmers are prepared to invest in realizing it. It is often the farmer's perception of risk that is paramount, rather than risk itself. Farmers understand robust systems through many (hundreds) of years of accumulated experience dealing with multiple situations. This tends to risk averse strategies that apply in all situations. Better information (if believed) can result in the adoption of less risk averse strategies when risk is less than anticipated – so for example improved rainfall forecasting would be very useful to a farmer in optimizing a risk strategy.

Therefore technologies that reduce risk but do not imply significantly increased costs will always be preferred. Generally the higher value the output, the higher will be the investment costs to produce it, as typified by horticulture, which requires more capital equipment; higher recurrent costs in inputs such as fertilizer and agrochemicals and; greater amounts of labour compared to field crops, such as wheat or rice. The nature of the market adds a further element of risk that farmers internalize in their decisions, including: price stability and level; communications to markets and with buyers; and the availability of storage to see them through price troughs and glut periods. Farmers can target out of season markets to obtain high prices, but this incurs increased levels of risk, due to competition and greater price volatility and the need for precision and high level management to meet the target season window. Even where markets are favourable, farmers may not have access to finance for capital and recurrent costs, or they have to balance the cost of that finance with the risks in production and marketing.

The quantity, quality, timing and frequency of water supply all have an impact on the choice of crops a farmer can make and without reliable water supply high levels of investment are rarely viable. The farmer has to deal with two types of risk associated with water supply – 1) within season reliability and availability and 2) inter-annual variability in rainfall and water supply as a result of natural variations in rainfall and hydrology.

In general, farmers will prefer technologies that reduce costs and reduce risk compared to those that increase them, even if they have potential for greater returns.

Generically speaking, there are three broad situations of interest in the developing world with respect to poverty alleviation, in which more detailed technology choices are nested.

1. Rainfed areas, where both rainfall and evapotranspiration are high;
2. Semi arid and seasonally arid conditions, where rainfall is nominally sufficient to produce a crop in one season, but the variability of rainfall is high and evaporative demand is always high;
3. Arid conditions, where rainfall is much less than potential evaportanspiration and additional sources of water are required for crop production.

Rainfed areas

Where rainfall is high in relation to evaporative demand, farmers will mostly be concerned with minimizing water logging through effective management of rootzone soil moisture, minimisation of water logging and where necessary enhancing runoff. Where both rainfall and evapotranspiration are high, it is possible for both temporary water logging and water stress to occur at different stages within the season. It is for this reason that irrigation is often developed in rice systems in the wet tropics, to:

1. remediate temporary water stress at critical times, such as germination and emergence, late vegetative stages, flowering and grain-fill in rice production.
2. provide water for second and third rice crops outside the rainy season
3. provide water for non-rice crops outside the rainy season.

Where rainfall is adequate seasonally, but annual ET is high, soil moisture conservation, rainwater concentration and harvesting and supplemental irrigation or obvious avenues to reduce risk and improve productivity. Likewise, adoption of shorter season and drought tolerant varieties may also benefit the farmer.

Semi arid and seasonally arid areas
Under these conditions, there is the option of full irrigation from a variety of available resources and often this will be full irrigation in the dry season complemented by supplementary irrigation at key growth stages in the rainy season. The alternative is to harvest water more locally through a variety of methods to enhance available soil moisture for the crop, or through storage and application (as supplemental irrigation) in periods of stress or critical shortage. Irrigation will address dry season water shortage, and rainwater harvesting will address within season water deficit. Where sufficient water can be stored in small reservoirs (farm or system tanks) or in groundwater, it may be possible to water an out of season crop using local water harvesting technologies. One general drawback of these technologies is that their cumulative capital cost per ha may exceed that of formal irrigation, although the benefits may be spread more equitably. The risks associated with water harvesting hare higher than with irrigation (especially dam-based irrigation) and farmers adapt their choices accordingly.

Arid areas
There are instances of rainwater harvesting technologies being used successfully in arid conditions (where evaporative demand might be 2-5 times that of rainfall). However, many of these systems have fallen into disuse in countries like Tunisia, and in the Middle East with the construction of more reliable irrigation systems. Large scale flood water spreading is another successful technology practiced from Wadis (ephemeral streams) in arid countries such as Pakistan and continue to be practiced in very hostile conditions, growing crops using soil moisture retained by one or two large flood events (filling up to 2m of soil moisture storage). Rainwater harvesting systems are highly vulnerable to drought years, the more so the higher the frequency of very low to zero rainfall years.

However, the risk associated with rainwater harvesting in arid conditions is high, so future potential is not as great as in higher but variable rainfall areas, and full irrigation has been the preferred solution, even with the risk of salinisation. Irrigation, even from groundwater, may not be resistant to drought. The storage capacity and the management policy associated with it are key factors in the drought resilience of irrigated agriculture. In the Indian sub-continent, most storage is annual only, whereas in Australia, there is nominally about three years of storage to support the Murray Darling Basin's irrigation systems. Nevertheless in prolonged drought spells irrigation systems can and do fail, and crop insurance and other non-structural measures are required for impacted areas. The greater the storage security, the greater the likely negative impacts on river flows and wetland ecosystems associated with them.

Technologies

A farmer has a broad range of options in farming, and some are substitutable or interchangeable. As noted, some crop choices (horticulture) imply increased levels of capital and recurrent costs, tighter market niches and greater risk.

1. Crops
    a. Type (field crop, horticulture, oilseed, fibre)

   b. Variety (season length, planting dates, yield potential, drought resistance, rooting depth.
2. Ancilliary technology
   a. Crop storage
   b. Crop drying and processing facilities (threshing etc.)
   c. Protected cropping (tunnels, cloches, greenhouses)
3. Management practices
   a. Tillage and land preparation (conservation tillage, irrigation application methods, drainage)
   b. Recycling and re-use (surface and groundwater)
   c. Input use, timing and effectiveness (mainly N, P and K fertilizer and animal or petroleum based traction)
   d. Seed rates and crop establishment.
   e. Timing, duration, quantity and quality of irrigation
   f. Weed control (minimizing non-beneficial transpiration)
4. Water supply
   a. Irrigation (run of river, or from storage (dams)): run of river systems experience greater flow variability and seasonal and short term variation that can impact farmers in their choice of crops and
   b. Irrigation from groundwater (flexibility and continuous availability achieved at cost of capital needed for well development, and recurrent energy costs to lift water; salinity and other water quality hazards): if farmers paying the true cost of supply, groundwater use implies the need for higher value crops or more intensive high output production systems.
   c. Supplemental irrigation from groundwater or from short term or limited capacity (on farm) storages. The main drawback of supplemental irrigation is cost, especially in the case of groundwater development and on-farm/small dam construction. Where the investment has been made, and water is continuously available, it is normal for full irrigation to be practiced, rather than supplemental watering.
5. Water harvesting
   a. Enhancing and capturing runoff
      i. To soil moisture, through generating increased runoff and directing and concentrating it to smaller cropped areas.
      ii. To storages (gw, cisterns, small dams)
   b. Capturing more rainfall in situ to increase soil moisture storage

There are two strands of action that can help address poverty through agricultural development using water: 1) what farmers do to best use the resources available on farm and 2) provision of better resources to the farmer, through enhanced capture and distribution of resources and better management of the means of doing so. There are many interactions between social and physical setting, the choice and scale of technology and the social interactions with the technology itself and the systems and bureaucracies that provide it.

Interventions

The principal choice in augmenting water supplies is whether to irrigate or not, and then how best to satisfy farmers' needs using an appropriate system of water distribution and management. Because irrigation involves the transport of water and is subject to the limitations of gravity, capital costs are significant and if pumping is required to lift water to farmer's fields, then operational costs can be significant too. A major criticism of canal irrigation in the past has been that benefits are restricted to only those who can physically gain access due to the limitations of the resource (at source), the costs of development and distribution and the limitations of topography.

An alternative approach is to spread benefits more widely by harvesting rainfall over a much larger area, giving better local supplies to a larger number of farmers, through recharging groundwater or soil moisture or through on farm storage. Such technologies can enhance the water availability within one season, and occasionally store sufficient water to enable a second season crop. They are still vulnerable to inter-annual variability in rainfall and only irrigation with significant surface or groundwater storage can mitigate drought years, and even then both can fail.

In situations where cropping is intensified, it becomes possible to employ landless labour (as in northern India following the development of irrigation in Punjab and Haryana, creating employment opportunities for migrant labour from the eastern Ganges provinces). Any from of intensification can create employment possibilities, but this is more likely to happen where 1) land holdings are intermediate (ie large scale mechanization is not a cost effective option) 2) irrigation is available and/or 3) higher value crops are grown.

Since a list of interventions cannot be exhaustive (and this would be self-defeating in terms identifying new ones), we attempt to provide a way of assessing interventions broadly, and to present what is currently available. Factors such as farms size obviously have a key role in allowing greater options and are linked with higher capital availability and commercial farming. In Tables 5 to 7, we try to summarise the available options in terms of the three broad climatic categories outlined above:

Table 5. High rainfall zones with high evapotranspiration

Intervention	*Relative cost/ha*	*Suitability*		
		Self-sufficient producer	*Market oriented small holder*	*Commercial Farmer*
Flood control	Very high			
Supplemental surface irrigation	High		x	
Out of season surface irrigation	High	x	x	x
Drainage	Surface drainage - medium	x	x	x
Groundwater development for irrigation	Low with shallow water table depth	xx	xx	xx
Treadle pumps	*Low*	*xx*	*X*	
Mechanised pumps	*Medium to high*	*Through pump markets*	*X*	*xx*
Adjust cropping patterns and dates	Low	xx	x	
Intensify input use	Low	(x) access to credit crucial	xx access to credit crucial	xx
Crop diversification (out of rice)	Low, but may imply better field drainage or land mgmt.		xx	
Protected cropping	High		x	xx
Low cost mechanization – sowing/harvesting	"Low"		x Rental	xx
On-farm storage	High			xx dependent on land availability

Table 6. Semi and seasonally arid zones

Intervention	*Relative cost/ha*	*Suitability*		
		Self-sufficient producer	*Market oriented small holder*	*Commercial Farmer*
Surface irrigation dvpt	High	xx	x	X
Groundwater irrigation	Very high	xx	xx	Xx
Treadle pumps	Low: only where water table shallow	Within irrigation systems and deltas	Within irrigation systems and deltas	
Mechanised pumps	High	Pump markets	x	Xx
Runoff harvesting	Medium	x		
Soil moisture capture & storage	Low	xx	xx	xxx
Small dams	Medium - High	x	x	Xx
Supplementary irrigation	High	(x)	(x)	xx gw
Drought resistant vars	Low	x	(normal yield potential lower)	
Higher yielding varieties	Low	Governed by other input use	xx	xxx
Short season varieties	Low	xx	x	xx
Crop diversification	Medium	Governed by water availability	Governed by water availability	x
On farm storage and recycling	Medium	x	xx	xx
Higher input use	Low	Credit and payment probs	xx	xx
Mechanisation	High	(x)	xx	xxx
RCTs	Medium	(x)	xx	xxx
Harvesting	Medium high		x	xxx
Farm layout (levelling)	Medium to high	x	xx	xxx
Soil Management	Low-medium	Salinity control	Salinity amendments	x
Micro irrigation	High		x	xx
Deficit irrigation	Low, but risky	x	xx	x if improves quality

Table 7. Arid zones – some form of irrigation is mandatory.

Intervention	*Relative cost/ha*	*Suitability*		
		Self-sufficient producer	*Market oriented small holder*	*Commercial Farmer*
Surface irrigation	High: plus externalities	xxx	xx	X
Drainage	Medium	xx	xx	xx
Groundwater dvpt (mechanised)	High, except within surface irrigation systems	x gw markets	xx	xxx
Wetland development	Potentially high on env.	xx	x	
Flood water spreading	High	xxx 'last resort'		
Small dams	Medium - High	x	x	xx
Supplementary irrigation	High	(x)	(x)	xx gw
Drought resistant vars	Low	x	(normal yield potential lower)	
Higher yielding varieties	Low	Governed by other input use	xx	xxx
Short season varieties	Low	xx	x	xx
Crop diversification	Medium	Limited options without irrigation	Governed by water availability	x
On farm storage and recycling	Medium	x	xx	xx
Higher input use	Low	Credit and payment probs	xx	xx
Mechanisation	High	(x)	xx	xxx
RCTs	Medium	(x)	xx	xxx
Harvesting	Medium high		x	xxx
Farm layout (levelling)	Medium to high	X	xx	xxx
Soil Management	Low-medium	Salinity control	Salinity amendments	X
Micro irrigation	High	?bucket and drip kits?	x	Xx
Enhanced livestock rearing	Variable	xxx	xx	??
Dual purpose crops (fodder and grain)	Variable	xxx	x	

4.6 KNOWLEDGE BASE DEVELOPMENT

Karkheh BFP will contribute working papers, methodological documents (for example the ones on water productivity by Cook, Turral and Gichuki and on Water Poverty by Giordano et al.). These contributions will also be submitted to the workspace on the BFP website. The 5-10 synthesis reports from Iranian colleagues will likewise be published, as will the results of the investigative studies, being set in train now.

The team view journal publication as a high priority for the results of survey work, and the special investigations in water productivity and its links to poverty.

All inventories of data and literature that will be made available through the CP (e.g. source references; grey literature; presentations; internal task reports), as far as is possible through IDIS and the IWMI-DSP (for map and remote sensing products). The Karkheh BFP expects considerable support from the IDIS team in cleaning and entering collected data into IDIS for retrieval. Happily much of this may simply involve conversion from one data-base format to another, since the data being assembled by the local project team is being entered into ACCESS where possible

A formal stakeholder plan is not yet in place and will evolve in conjunction with the second stakeholder workshop scheduled for May 2006. The team will attempt assemble a good cross section of local, regional and central stakeholders from farming, local government, regional development agencies, such as KWPA and its specialist units and AREO, and the 2 CP funded projects managed by ICARDA. The project is still building is stakeholder base as more and new contacts are made, most recently being good collaborators for social science survey and analysis in Iran.

5. PROJECT MANAGEMENT

5.1 IMPLEMENTATION PLAN

For the successful implementation of this holistic and very time-bound project, we have brought together a well-balanced interdisciplinary team, including soil and water experts, socio-economists, agronomists, RS & GIS experts, simulation modelers, poverty experts and communication advisors. From NARES, all leading land and water research organizations of Iran involved in KRB are part of this project in different capacities. While these agencies will be helping IWMI to execute this project with data and other technical support, it will be equally beneficial for them to build their capacity for basin level analysis. After this project, these agencies can continue their efforts for the development of KRB and other basins in the country using these approaches.

Livelihoods, poverty and gender sensitive research is relatively new in Iran. Most of the available information on these aspects is based on the national statistical data collected by different public agencies. In this project, special attention will be given to do productivity, poverty and livelihood surveys by involving poorer households of the community in order to get first hand knowledge of their problems and living standards. The livelihood surveys will enable to identify resources-poor households whereas gender analysis will clarify gender differentiation in decision making and sharing responsibilities. The outcome of these analyses will help in understanding the root cause of poverty, social imbalances and livelihood strategies adopted by the farming communities especially in rain-fed and saline areas. This will be a unique research activity in Iran. The involvement of main local organizations in this process will help in generating valuable impact and ensure continuity of this work even after the termination of BFP.

AREO is the umbrella organization of all agricultural research institutes in Iran. They are in a best position to play coordination role for the local NARES involved in BFP. Their involvement in BFP also ensure the adoption of BFP results for developing government policies for the management of land and water resources management in the KRB. Five major organizations under AREO are directly involved in the project:

- Soil Conservation and Water Management Institute (SCWMRI), Tehran
- Iranian Agricultural Engineering Research Institute (IAERI), Karaj
- National Salinity Research Center (NSRC), Yazdh
- Seed and Plant Improvement Institute (SPII), Karaj
- Forest, Rangeland and Watershed Management Organziation (FRWO), Tehran

All these organizations have a strong national network with presence in all major cities. These organizations also have significant resources to help BFP as partners.

Tabriz University and Tehran University are also partner in this project for different activities. In addition to these formal partnerships, BFP has also hired the services of about 10 local consultants/experts in different field of land, water and environmental management to facilitate BFP implementation in KRB.

5.2 RESEARCH TEAM, ALLOCATION OF TASKS AND COORDINATION

The detailed roles and responsibilities of different individuals and organizations are:

#	Person	Speciality	Organisation	Tasks
IWMI Team				
1	Dr. Mobin-ud-Din Ahmad	Remote Sensing Specialist and Agro-hydrologist	IWMI, Colombo	Project Leader, Productivity, Water accounting & balance, SEBAL remote sensing.
2	Dr. Hugh Turral	Water resources management, irrigation	IWMI, Colombo	Methodological development: Water balance, and water accounting, modeling framework; rainfed water and pastoral water productivity; Hourolazim Swamp study.
3	Dr. Asad Sarwar Qureshi	Groundwater, SPW modeling	IWMI Iran	Coordination and liaison with Iranian and non-Iranian Scientists. GW survey and modelling, SWAP modeling for rainfed and irrigated

				areas, water productivity
4	Dr. Mark Giordano	Oversight of water poverty work	IWMI Colombo	Coordination of poverty work studies
5	Dr. Robert Zomer	Senior Landscape Ecologist	IWMI, Colombo	Poverty Mapping
6	Ms. Clemett, Alexandra	Researcher- Livelihoods/Water Quality/Waste Water	IWMI, Colombo	Livelihood analysis
NARES				
7	Dr. Abbass Keshaverz	Watershed hydrologist	AREO	Coordination of local research groups, Liaison with Ministry of Jihad, secondary socio-economic data.
8	Dr.Argai/ Dr. Ashrafi	Rainfed Agriculture	Basin	Synthesis of trial work, determination of rainfed water productivity.
9	Mr. Mirghasmi	GIS and agriculture, agro-ecological zoning	SCWMRI, AREO	GIS support, mapping of water productivity and "water poverty" indicators.
10	Dr. J. Porehemat	Soil-water Hydrolo.	SCWMRI	Soil water erosion studies
11	Dr. S.M. Cheraghi	Salinity expert	NSRC	Salinity studies in the lower Karkheh basin
12	Dr. Ahmad Assadzadeh	Economics and Sociology	Tabriz University	Water poverty – definitions, survey, mapping
13	Dr.Nadir heydari	Hydrologist	IAERI	Water productivity studies
PhD students				
14	Ilyas Masih	Hydrologist	PhD student	Water accounting studies
15	S. Marjanizadeh	Environmentalist	PhD student	Trajectory study, PODIUM

5.3 WORK PLAN AND BUDGET

Directions to fill the Template :

1) Please fill the cells highlighted in **GREEN** and **BLUE** only.

2) Please refer the Intranet to get the names and codes of existing projects.

3) Please refer the comments given in each expenditure line. It provides a brief description of expenses to be classified under each line.

4) Amounts are in US $ Thousands

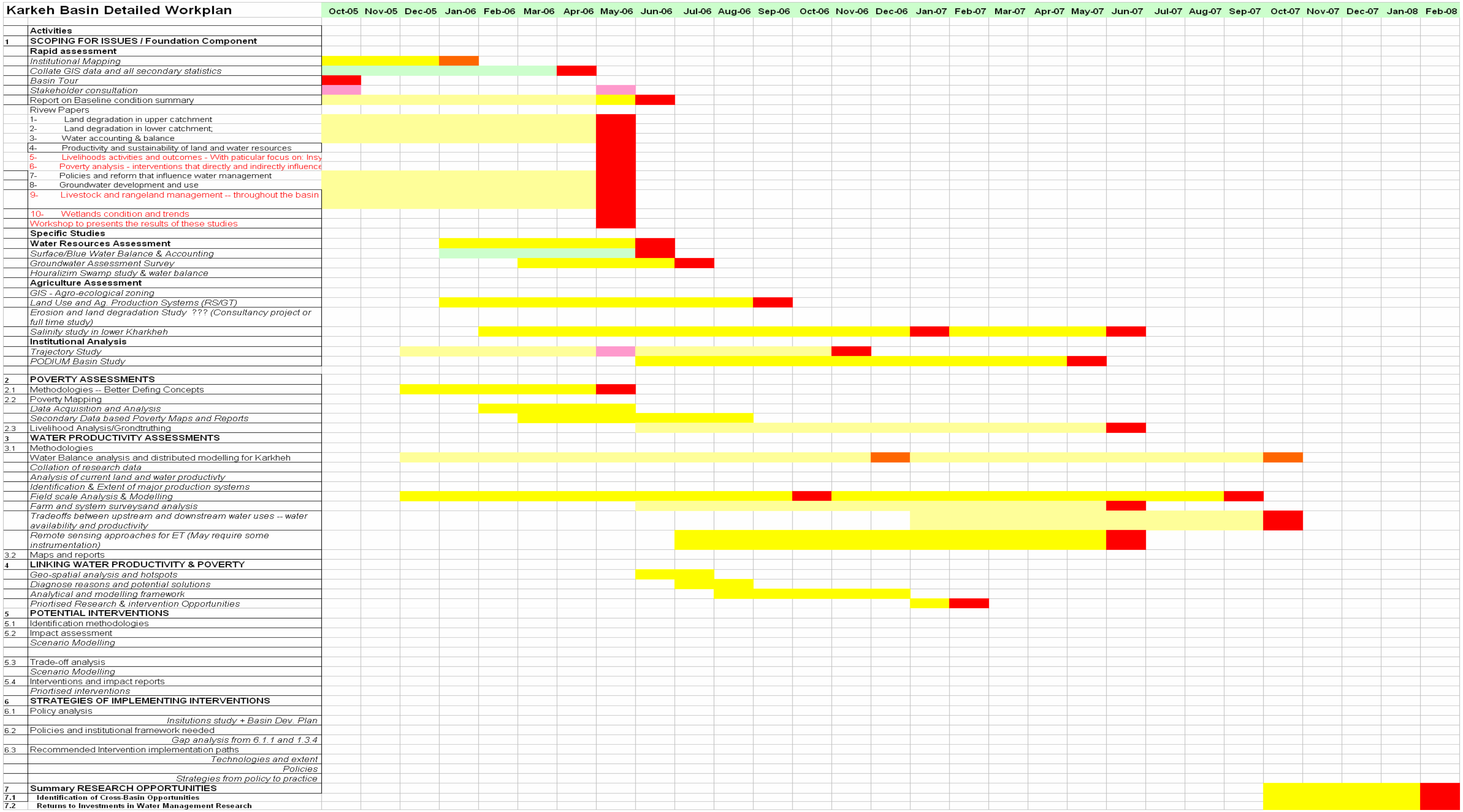
IWMI Multi-year Budget Template (Commencing from 2005)

Name of Project	Karkheh -- Basin Focal Project
Theme	Basin Water Management
Project Leader	Mobin-ud-Din Ahmad
Regional Office	Global Research Division
Existing Project Code	3p1505GHTA00157CPMUL03
Total Budget (US$)	700,000

Officially Project started on 1 Sept 2005
Old Project Code: 3p1505GHTA 00100000 MUL03

Project Ending on 28 Feb 2008

	Grand Totals			2005			2006			2007			2008			2009		
	Total	RF	URF	Total	RF	URF	Total	RF	URF	Total	RF	URF	Total	RF	URF	Total	RF	URF
	[in US Dollar thousands]			[in US Dollar thousands]			[in US Dollar thousands]			[in US Dollar thousands]			[in US Dollar thousands]			[in US Dollar thousands]		
Personnel Costs																		
Researchers	346,838	346,838	0	5,738	5,738	0	162,250	162,250	0	151,250	151,250	0	27,600	27,600	0	0	0	0
Research Officers & Support staff	56,625	56,625	0	0	0	0	26,625	26,625	0	30,000	30,000	0	0	0	0	0	0	0
Non - research National Staff Salaries/Benefits	19,497	19,497	0	497	497	0	9,000	9,000	0	10,000	10,000	0	0	0	0	0	0	0
Consultants	25,000	25,000	0	0	0	0	25,000	25,000	0	0	0	0	0	0	0	0	0	0
	447,959	447,959	0	6,234	6,234	0	222,875	222,875	0	191,250	191,250	0	27,600	27,600	0	0	0	0
Operational Costs	75,824	75,824	0	7,224	7,224	0	38,500	38,500	0	27,000	27,000	0	3,100	3,100	0	0	0	0
Institutional Development Costs	53,758	53,758	0	1,958	1,958	0	24,400	24,400	0	27,400	27,400	0	0	0	0	0	0	0
Cost of Collaborative Activities	40,000	40,000	0	0	0	0	32,500	32,500	0	7,500	7,500	0	0	0	0	0	0	0
Others	30,081	30,081	0	0	0	0	15,931	15,931	0	10,000	10,000	0	4,150	4,150	0	0	0	0
Indirect Costs	52,378	52,378	0	1,346	1,346	0	26,138	26,138	0	21,825	21,825	0	3,070	3,070	0	0	0	0
	700,000	700,000	0	16,762	16,762	0	360,344	360,344	0	284,975	284,975	0	37,920	37,920	0	0	0	0



Karkeh Basin Detailed Workplan
Oct-05 Nov-05 Dec-05 Jan-06 Feb-06 Mar-06 Apr-06 May-06 Jun-06 Jul-06 Aug-06 Sep-06 Oct-06 Nov-06 Dec-06 Jan-07 Feb-07 Mar-07 Apr-07 May-07 Jun-07 Jul-07 Aug-07 Sep-07 Oct-07 Nov-07 Dec-07 Jan-08 Feb-08
Activities
1 SCOPING FOR ISSUES / Foundation Component
Rapid assessment
Institutional Mapping
Collate GIS data and all secondary statistics
Basin Tour
Stakeholder consultation
Report on Baseline condition summary
Rivew Papers
1- Land degradation in upper catchment
2- Land degradation in lower catchment;
3- Water accounting & balance
4- Productivity and sustainability of land and water resources
5- Livelihoods activities and outcomes - With paticular focus on: Insy
6- Poverty analysis - interventions that directly and indirectly influence
7- Policies and reform that influence water management
8- Groundwater development and use
9- Livestock and rangeland management -- throughout the basin
10- Wetlands condition and trends
Workshop to presents the results of these studies
Specific Studies
Water Resources Assessment
Surface/Blue Water Balance & Accounting
Groundwater Assessment Survey
Houralizim Swamp study & water balance
Agriculture Assessment
GIS - Agro-ecological zoning
Land Use and Ag. Production Systems (RS/GT)
Erosion and land degradation Study ??? (Consultancy project or full time study)
Salinity study in lower Kharkheh
Institutional Analysis
Trajectory Study
PODIUM Basin Study
2 POVERTY ASSESSMENTS
2.1 Methodologies -- Better Defing Concepts
2.2 Poverty Mapping
Data Acquisition and Analysis
Secondary Data based Poverty Maps and Reports
2.3 Livelihood Analysis/Grondtruthing
3 WATER PRODUCTIVITY ASSESSMENTS
3.1 Methodologies
Water Balance analysis and distributed modelling for Karkheh
Collation of research data
Analysis of current land and water productivty
Identification & Extent of major production systems
Field scale Analysis & Modelling
Farm and system surveysand analysis
Tradeoffs between upstream and downstream water uses -- water availability and productivity
Remote sensing approaches for ET (May require some instrumentation)
3.2 Maps and reports
4 LINKING WATER PRODUCTIVITY & POVERTY
Geo-spatial analysis and hotspots
Diagnose reasons and potential solutions
Analytical and modelling framework
Priortised Research & intervention Opportunities
5 POTENTIAL INTERVENTIONS
5.1 Identification methodologies
5.2 Impact assessment
Scenario Modelling
5.3 Trade-off analysis
Scenario Modelling
5.4 Interventions and impact reports
Priortised interventions
6 STRATEGIES OF IMPLEMENTING INTERVENTIONS
6.1 Policy analysis
Insitutions study + Basin Dev. Plan
6.2 Policies and institutional framework needed
Gap analysis from 6.1.1 and 1.3.4
6.3 Recommended Intervention implementation paths
Technologies and extent
Policies
Strategies from policy to practice
7 Summary RESEARCH OPPORTUNITIES
7.1 Identification of Cross-Basin Opportunities
7.2 Returns to Investments in Water Management Research

5.4 Intellectual Assets Audit

There is huge amount of data and information which needs to be collected from different agencies in Iran for the successful implementation of BFP. This includes both restricted and unrestricted data. BFP has made considerable efforts to get access to these data information resources.

- Prominent of these are Iranian Space Agency who is custodian of all RS and satellite data needed for basin level analyses of water productivity and land use. Detailed discussions with this agency have been held and an agreement is being drafted for large scale cooperation with this agency. As this data is of strategic importance, it needs more time to finalize the deal. However, it is expected that within next 1-2 months an agreement will be reached to have access to this data and develop cooperation with this agency for BFP activities in Iran. One the agreement is signed, BFP will have free or low cast access to all these resources. (Agreement will be submitted after finalization).
- For poverty analysis, already an agreement was signed with the Statistical Organization of Iran to get household and other crop survey data. IWMI has purchased full data set for Karkheh from this organization.
- For stream flow and other hydrological data, an agreement is being discussed with the Ministry of Energy. *Considering the importance and sensitive nature of this data, MoE is seeking permission from high level authorities before releasing this data for our use*. The un-restricted data has already been released for IWMI. More data will be made available within next 1-2 months (agreement will be submitted after finalization).
- For detailed salinity mapping of the lower Karkheh basin, an agreement has been singed with the National Salinity Research Center at Yazdh. This agreement is based on shared responsibilities or resources as well as outputs. Agreement will be made available soon.
- For other BFP activities, similar type of informal agreements have been made for sharing public goods and information available free of cast.

5.5 Monitoring and Evaluation

The project coordination and management will be as follows:

1. A Steering Committee (SC) is in the finalization stage for the implementation of BFP in KRB. The SC will be comprised of representatives of major partner institutes and IWMI projects managers. The selection of partners for SC has been made on the basis of stakeholder meetings held during and after the basin tour. To ensure local government support, a member of AREO has been included in the SC. The SC will meet annually to evaluate the achievements of previous year and plan activates of the next season. Other decisions regarding the project will be taken collectively in that meeting. An electronic network among the SC members will be managed by the project managers to ensure continuous consultation over the project issues.

2. A project technical committee has also been formulated to take day to day management decisions. This committee include researchers from all collaborating institutes. This committee is proposed to meet physically at least two times a year. However, the members of committee are encouraged to keep regular on-line contacts. Activities and research results will be discussed in this

meeting and draft plans will be developed to be considered by the steering committee. The first informal meeting of this committee was held in October and second is planned for May 2006 together with the one day workshop organized for the synthesized studies.

3. IWMI Iran programs coordinator in Tehran will coordinate between scientist from outside Iran and national scientists and project staff.

Four project milestones are identified:

1. **Project Commencement** meeting of all partner institutions at the basin (held in October 2005.
2. **Project establishment Workshop** to be held in the middle of first year to review the plans and planned activities of all partner institutes. This workshop is planned on May 24, 2006 in Karaj. About 60 local scientists from different field will be invited in this workshop. IWMI team will also participate in this workshop. Ten synthesis studies will be presented in this workshop. In addition, technical meeting will be held to discuss the status of different activities being carried out in collaboration with local partners.
3. **Midterm Project Workshop** to be held in the early 2007. In this workshop, results achieved by that time will be discussed to refine planning for the second year.
4. **Final Project Workshop** at the end of the project when all results and reports are prepared for discussion the results and developing recommendations for policy and other.

Monitoring and evaluation will also include:

1. Progress reports will be published annually
2. Annual SC meeting and Technical Committee meetings will ensure timely plans and oversee and supervise the activities and progress

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APPENDIX A: BASIN DIAGNOSTIC TOUR REPORT

General Impressions of the Basin

Karkheh River Basin is facing acute water shortages in the upper and middle reaches, which in turn affects the land productivity and livelihoods of the people in these areas. In the highlands water availability is also a constraint and households must depend on rain-fed agriculture and livestock grazing. As a result they appear to be amongst the poorest households in the basin.

As most of these lands are heavily depended on the amount and frequency of rainfall, most of farmers sow their wheat crops in the winter (the main rainy season in these areas) and migrate to near by cities and towns in search of off-farm jobs to earn their living. If the rains are sufficient, they can harvest small amounts of crops on their return in spring otherwise half matured crops are mainly used for grazing sheep and goats. Therefore inhabitants of these areas rely more on livestock for their livelihoods than agriculture.

In the lower KRB (especially below Karkheh dam), water availability is improving due to installation of large scale irrigation and drainage network. However, full scale delivery of irrigation water from Karkheh dam is still about 8-10 years down the road as the pace of construction of the distribution network is very low and in certain cases required funds are not available.

The limited surface water availability in the KRB has prompted farmers to use more and more groundwater to meet crop water requirements. In the middle reach, groundwater is mainly used to irrigate orchards and field crops. As a result, the area under maize and rice is increasing. In the lower reaches, groundwater is also pumped to irrigate field crops especially in summer when there is very little water in rivers, canals and natural streams.

The general documentation about KRB indicates that there is little groundwater use for agriculture. However, during the diagnostic tour, we found a reasonable number of pumps exploiting groundwater for agriculture purposes. Usually these pumps are of very high capacity and run with 80-100 hp electric motors and 20-30 hp diesel engines. A major reason for this increasing groundwater exploitation is easy and cheap access to energy resources. This increasing access to groundwater is replete with serious consequences as water tables in most of the areas are falling rapidly (1-2 m annually). In most areas, they have already fallen to 80-100 meters. As a result, farmers are facing water quality and sediment problems in these areas. Due to lowering of water table, bore damage problems create sedimentation problems in the pumped water.

Local experts believe that groundwater accounts for less than 10 percent of the total water resources in the KRB and is therefore not important for overall calculations of the water balance. However, our observations are that groundwater abstraction is much larger and increasing and therefore should be studied in detail to evaluate its overall impact on the long-term water balance of the basin. It was also generally observed that farmers having access to groundwater are better off than those who are deprived of this resource.

Currently there are no restrictions on groundwater abstraction. It is said that you need permit before installing a tubewell but these laws are commonly ignored. Similarly no groundwater rights are defined. In irrigated areas, no hard and fast rules are applied for irrigating crops. Generally the land productivity is good and water is usually taken as granted and major focus is on increasing crop yields rather than improving productivity of water.

Another issue which has been and will continue to be a major challenge in the management of KRB is soil erosion. In the upper reaches, grazing of livestock is the major contributor to the livelihoods of the people. As a result, overstocking and over-grazing are common phenomenon, which is causing soil degradation problems. Soil erosion is occurs on both agricultural lands as well as mountains. Sedimentation in the river is a major issue for the long-term sustainability and efficacy of the Karkheh dam. Khuzistan Water and Power Authority (KWPA), who are responsible for all water development projects in the KRB are putting many plans in place for the control of sedimentation. This includes one sediment control dam upstream of Karkheh dam. Studies are being undertaken in collaboration with DHI to find simple, quick and cost effective ways of controlling sediment flow into the Karkheh dam. However, due to complexity of the issue, it is not clear if a sustainable solution can be found. The complexity of the problem suggests that there is no single solution and efforts need to be focused on all aspects of river basin management. This necessarily includes soil conservation measures at different sections of the basin, changes in land use, controlling over-grazing, land forms, addressing socio-economic issues and creation of off-farm income generation activities to reduce peoples' dependence on livestock. In the Lorestan province (middle reaches), the government is already implementing a plan to encourage farmers to replace sheep and goats with cattle farming in order to control soil erosion caused by over-grazing. However, the results of these incentives are still awaited.

The KRB is faced with a major problem of allocating river water for maintaining environmental quality and sustainability especially swamp. Currently wetlands are under pressure and are mainly used for subsistence. Fishing, buffalo production and harvesting of natural products are common in the surrounding area of Horal Azim swamp. Considering its size, more productive ways of using swamp could be explored. KWPA is trying to address this issue but needs help to further their efforts.

We were particularly impressed by the network of excellent roads and other infrastructure, communications, electricity and telephone facilities. In most of the places, we also found very well trained, knowledgeable and committed staff with good communication and logistic facilities. What appears to be lacking, however, is coordination between different levels of government and governmental organizations. It appears that managers of every reach are taking independent decisions without considering implications on other reaches. During the meetings with officials from different departments, lack of coordination and cooperation within different organizations emerged as a major issue. Therefore there is a need to formulate a commission with representatives from different provinces and experts from different fields to pursue strategic thinking about the future development and sustainable management of the basin to improve its productivity and to align it more closely with the national economic goals.

In the upper Karkheh livelihoods appear to be most constrained by land availability with average land holdings in the villages visited being around 2-3 ha. This is barely sufficient for a family and older children have to migrate to nearby cities for work. This is likely to have a social impact in the future especially as lands are gradually divided between sons and daughters. Unemployment in the young generation is also leading to drug addiction.

Orchards are being promoted by the government but few households have commercial orchards in the areas we visited. There may be more in more northern areas. The reasons for this were lack of land, low prices for fruits and poor storage facilities. People were more satisfied with nuts but the time taken for trees to mature prevents people with only small land holdings to change to orchards. Similar constraints appear to exist in the middle part of the basin though we did relatively fewer interviews here.

People appeared to be quite healthy (no obvious cases of severe malnutrition were observed for example) but questions were not really focused on this issue. It appears that people have a reasonably balanced diet of meat, milk, grains and some vegetables. In the northern part variety may be better as there appeared to be more fruit and nut orchards but this is not confirmed. The good quality water distributed to the households probably also contributes to good health and nutrition as cases of diarrhoeal disease may be low. Certainly poor health was not something that people complained about. There concerns were more about receiving piped gas and home phones.

In the lower part of the Karkheh it seemed that land was not such a constraint but access to irrigation water is. Many lands were rain-fed or left fallow. Due to this livestock rearing is also an important strategy for many households with almost all owning some livestock including cows, sheep, goats and chickens, and some owning as many as 3000 sheep and goats. They are generally grazed on crop residue and fed wheat or barley straw or barley. Milk was often consumed in the household and the main income was from selling sheep when cash was required. The south has also suffered considerably from the war. There are many deserted villages but people are returning and are being given some government assistance.

It appears to be difficult to obtain agricultural inputs despite the fact that they are supposed to be provided at a 50% subsidy by the government. Fuel for cooking is also a constraint with some households using bottled gas, those in the upper Karkheh using wood and the use of manure throughout the basin. The use of manure for fuel may be an issue for nutrient cycling.

Labor division between men and women depends on the area but in general both men and women do agricultural work with men mainly doing mechanized tasks and working on wheat and barley fields, while women grow vegetables and tend livestock.

Education levels were low with children leaving school at 12 or younger to work in fields or with livestock. Family size is also large at around 8-16 persons per household but this appears to be coming down with young adults saying that they only want 2-5 children.

Most of the villages visited have access to electricity, telephone, roads, television even satellite TV, piped water for drinking and in some cases sanitation facilities. The houses in the villages were large and of reasonable quality with bricks and plastered walls. Our general impression is that the people are not as poor as usually reported in available documents. Land holdings are relatively large and agriculture is heavily mechanized. Most of the farmers have access to tractors, planters and harvesting machines. Those who could not afford to buy can rent from their neighboring farmers at reasonable cost. Production levels are reasonably high. The situation in rain-fed areas is not as good as in irrigated areas. Therefore for poverty and livelihoods studies, general indicators will not apply. Therefore other better indicators such as size of land holding, larger physical assets (cars, tractors, trucks, number and type of livestock) might be more appropriate. Cash income could also be a good indicator for poverty analysis. Although it has not been said, it seems likely that families receive remittances from family members working in other cities and nearby towns.

The upper region of south Karkheh sub-basin has variety of land features such as newly developed irrigated lands, barren lands, rain-fed areas and patches of irrigated area from groundwater. One of the salient features is the Karkheh dam, constructed for flood control, irrigation development and power generation. The agriculture in the newly developed canal irrigation schemes is boosting up. The canals are lined and very well constructed.

The salt effected lands and the wetlands are the main features of the lower part of the South Karkheh Sub-Basin. The discussion with staff from the salinity research center in the region and with the farmers indicates that the soil salinity is highly variable in the region ranging from 2 dS/m to 180 dS/m. The major causes of salinity are high water tables (1-3 meters below land surface) and high evaporation rates. The construction of Karkheh dam helped in minimizing flood damage but it has induced more salinity. Before the construction of dam, seasonal floods were the biggest source of water for leaching salts and keeping soils healthy. Now this is not possible, salinity in the soils is increasing many fold. Groundwater quality in the area is very poor and can not be used for agriculture. Farmers are growing wheat and barley using river water or flood water but yields are low (1-1.5 tons/ha). For the moment, no reclamation measures are adopted by farmers. Recently National Salinity Research Center of Yazdh has started some initial work for the management of salinity in this area. However, more concerted efforts are needed to do work on various aspects of research, development and policy interventions to improve productivity of salt effected lands for eradicating poverty in this area.

Detailed Impressions by River Reach

- ***The Upper Reach***

The upper reach survey was started with the visit of Natural Resources Management Center of the Karmanshah. In this center, a detailed meeting was held with the experts on agronomy, livestock, sociology, irrigation management and rangeland and watershed management. The average annual rainfall in this area is about 480 mm.

Most of this rainfall occurs in the winter season i.e. December to April. Average land holding is about 4 ha. The main cropping system is rain-fed with some irrigation farming. Irrigation is mainly done through natural streams and groundwater. Irrigation development is slow as this is not the priority region for the development of irrigation infrastructure. The wells are bored at depth 50-100 meters whereas water table is around 20-25 m.

Wheat is the dominant crop, especially in rain-fed conditions. Other crops are barley, chickpea, pulses, maize, alfalfa and vegetables. Orchards are also main features of the area with marked dominance of olives. The orchards include apple, nuts, peer, olive, citrus, palm granite, fig and grapes. The fruit is exported to the other provinces as well and farmers who can bring their fruits (matured early season) earn high profits. As agriculture in this area is susceptible to weather conditions especially rainfall, animal husbandry is considered more reliable for livelihood. With the increasing water shortage of water, orchards are considered as luxury. Farmers are becoming less and less interested in orchards due to lack of water and processing industry. Crop insurance schemes have just started but could not get momentum yet.

Livestock and crop husbandry are essential part of the livelihood. Mostly all family members work for producing crops and animal rearing. Nomads were always present in this area and settlement they started agriculture and animal husbandry. Now with the decreasing trends in agriculture, nomads have left the area and settled in the adjacent rural areas. Goat and sheep are the dominant livestock depending upon the rangelands and crop residues. Animals are usually sold in spring-summer raising their incomes during this period.

Wheat yield in rain-fed and irrigation conditions 900-1300 kg/ha and 3500 Kg/ha. The barley yield is mostly similar to wheat. Chickpea is grown in rain-fed conditions and the average yield is around 500-600 Kg/ha. Maize and sugar beat depend on irrigation and their average yield is 6-10 t/ha and 35 t/ha, respectively. The crop yields in this area are low as compared to overall average yields for the KRB. This is mainly attributed to small land holdings, higher cultivation costs, lack of technology and technical knowledge. Details of water productivity values recorded during the field survey are given in Table 1.

On sloppy rain-fed lands, farmers cultivate wheat going up to maximum height which tractor can cover. Mainly in these areas only crop is grown. In flat valleys, some groundwater development is going on and farmers are able to take two crops mainly wheat and maize. For irrigation, mainly flooding method is used. However, some farmers are also using sprinkler and pipe systems. Yields are generally low due to lesser soil depth and soil fertility. Farms are not well mechanized and the limitations in irrigation development restricts introduction of profitable cropping patterns in this area. Unlined irrigation channels are poorly maintained causing considerable conveyance losses and low field scale irrigation efficiencies.

A view of the rain-fed farming on hillside slopes in the upper catchments of KRB.

Martaza, a 27 years old farmer of the slopy lands believes that his livelihood depends upon the farming and labor work in the city. His family size is 11, of which 6 are males and 5 females. He owns 12 ha of sloppy and undulating land. The source of water is only rainfall, which is concentrated only in winter season. Therefore he can only grow wheat and chickpea. He can not access to groundwater because of drilling difficulties in his land. Therefore he only cultivates land in winter and has to migrate to city during summer for earning his livelihood through labor work. Family income is low due to lower agricultural produce and low wages earned due to uneducated/unskilled family members. The crop yields are highly influenced by rainfall variability. The wheat and chickpea yield is averaged around 650 Kg/ha and 500 Kg/ha, respectively. Crop water productivity is very low and is about 0.2 Kg/m^3*. For improved production he looks for the help in terms of provision of better seeds and enough fertilizers at lower cost. Better access to the farming machinery at household and village level is also in his wish list for improved productivity. However, he was satisfied because his family has access to drinking water supplied by the government thorough groundwater pump and piped system.*

Murtaza explaining agriculture on his land.

The net income from irrigated lands is about 110 $/ha in irrigated conditions and is about 85 $/ha in rain-fed conditions.

The irrigation volume applied to wheat, where surface and groundwater is available, is around 8,000-10,000 m3/ha. In areas where water availability is low, irrigation amounts vary between 3000-4000 m3/ha for wheat. Ministry of Power is responsible for construction of dams (Ghuashan dam is under construction) and main canals. Secondary and tertiary canals are constructed by soil and water management department.

About 90% of the population work in agriculture in the upper catchments and are hard working. Their agriculture and income is very sensitive to precipitation. There is a policy for crop insurance but it has only been in operation for 2-3 years and does not cover all their costs. There are also a number of problems with it to date. They feel that even if the government gave $1000s for agricultural subsidies it would not change things. There is a strong need to educate farmers about the innovative water saving methods and selection of proper crops for the amount of water and/or rainfall available in this area. For example, wheat is usually grown for self-sufficiency which is being promoted by the government but most of the farmers think that it may be better to grow cash crops and import wheat.

The household survey of two villages suggest that previously people in this area collected wood from the forest for fuel but now the government provides them with oil. They have water from a spring which they bring to their house via a hose pipe. They never had water shortages for domestic purposes unless there is an electricity failure or pump broke down. However due to the lack of water for economic activities and the low farm income, many people from the village have gone to work in factories or joined the army.

The nomads living in one of these villages spend 6 months here and 6 months in another area. They pay the farmers to let them graze their livestock on the crop residue at a cost of about 15 Euro for 2 ha (10 $/ha). This village has 300 ha of land of which 150 is owned by 5 brothers and the remaining 150 is divided so that households have an average of 2 ha each.

The second village was on the upper slopes and seemed relatively poor. All families (10) have water delivered to their homes which is pumped from a stream. These families came here about 50 years ago with their livestock and settled here for the grazing. However, the grazing land has deteriorated and they have turned to rain-fed agriculture, but they are not satisfied with this livelihood activity. Most households have around 10 sheep each. They cultivate barley and wheat but there is not enough rain so productivity is low. They also live far from the markets and the government does not help them with inputs, so things are hard. They feel that other villages have better lifestyles because they have good access to irrigation water and their economic returns are sizeable.

Many of the younger generation move to the city to work. The average family sizes among the 4 women interviewed were 11.

Eslamabad Research Station

This research center works on the improvement of cereal crops (wheat, barley and chickpea). The main focus is testing high yielding crop varieties for local conditions under various agronomic and irrigation regimes (basin, border, sprinkler, drip irrigation). The focus is mainly on maximizing land productivity and not water productivity. No real measurements of irrigation water applied to different crops are made. Groundwater is the major source of irrigation at the station. The well depth is 110 m and water table is around 40 m below the ground surface. At the station submersible pump powered through electricity is being used. It was told that water table is declining at the rate of 1-1.5 m per year. The reported wheat yields (12 tons/ha) were unbelievably high. However, the potential for wheat yield in the farmer fields was reported as 7-8 tons/ha. The reasons for this large difference in the experimental farm yields and farmer fields were not clear. However, it could be due to better access to inputs and irrigation water at the experimental fields as compared to farmer fields. This station is also providing high yielding crop varieties to farmers.

Sprinkler system at the Eslamabad Research Station

Another area visited in the upper reach was the Sahna, east of Karmanshah. This area consists of about 200 ha of rangeland and 300 ha of good crop land. This area has no apparent water shortage due to good access to surface supplies and groundwater. About 200 ha are irrigated with about 15% fully dependent on groundwater. About 30% are fully irrigated through surface supplies and the rest 55% is on conjunctive use of surface water and groundwater. Large capacity (40-50 l/s) tubewells were seen operating on many farms. The groundwater in this area is about 7-8 m deep. This area can be clearly distinguished from the other upper reach areas due to good standing maize crop. Due to good access to water supplies, farmers are taking two crops. The soils of this area are considered as the most productive lands in the KRB.

In water access areas, rice is also grown although in limited quantities. Livestock usually graze wheat crop residue. Rice crop residue is not used for grazing and is usually burnt or sold for use in processing of composite manure. Rice husks are usually used as livestock feed.

The third stop in this area was of Qal-e-Muzafari. The lands in this area were originally irrigated with water of Ghamasiab river. However, due to decreasing surface water supplies, farmers have started using more and more groundwater. The groundwater in this area is about 40 m deep whereas the wells are drilled up to 120 m. The pump discharge is usually around 30 l/s and it serves about 30 ha. The drilling costs of these pumps can be as high as 40,000 to 50,000 US $. Pumping costs are up to 400 US $ per month. This cost has gone up from 130 US $ over a period of 10 years. The local farmers reported continuous decline in well depth and discharge due to reduced recharge as a result of decreased rainfall over the last few years. In order to control the situation, government has restricted the drilling of new wells and regularly monitors the levels of pumping for compliance.

Groundwater pumping using high power electricity pump

Wheat is planted in October and receives 5 irrigations in springs and harvested in July/ August. Average wheat yields are 5-6 tons/ha while farmers in neighboring areas gets as much as 9 tons/ha using the same level of inputs and management. These figures are unbelievably high however the farm manager insisted that they are true.

Maize is usually planted in May and harvested in October and receives 8 irrigations. Yields can be as high as 19 tons/ha but most farmers get 13-14 tons/ha.

Socio-economic and livelihood issues

The major socio-economic issue in the upper reach is unemployment. Almost 2-3 members of each family have gone to other towns (mainly Tehran) in search of jobs. One of the respondents said that around 60% young men are addicted to opium due to high level of unemployment. Generally agricultural labor is divided equally between men and women with both groups doing the same jobs and also being hired for agricultural labor by people with larger land holdings who come and pick them up in the morning and take them to their fields for work.

Waste water (not toilet waste) from homesteads runs through the village and appears not to be made use of. Whilst vegetable production in the homestead is unlikely to be feasible due to the large numbers of goats and sheep, it may be possible to divert this water around trees, for shade, fodder and fruit production for homestead consumption.

Manure also appears not to be used for fertilizer by most people but is dumped and burnt. Could this be a useful input or is the effort (labor) too high due to distance from homesteads to fields and the ease of application of chemical fertilizers? Given the complaints in other villages about the delay in receiving inputs it may be a viable option at least in some villages. It may also reduce the problem of downstream nutrient pollution which may not be a problem now but could arise in the future. It could also reduce dependence on government provision of inputs but since these are currently provided with a 50 % subsidy it is unlikely that they will start to use manure unless this changes.

The unemployment issue is so high that almost 90% of the young boys go to Tehran to find work. Due to increasing unemployment, young boys can not get married because they are too poor to afford it. This is creating many other social problems. Many people showed their anger about the government for not doing enough to provide them jobs. They were asking for some more industry in the rural areas and education for the girls and boys.

Farmers complain that they do not get their due share of subsidized fertilizer or pesticides from the government cooperative stores. Therefore they are forced to buy these inputs from the black market. Government stores also provide some edible oil and rice to every family in the village every 2 months.

There is a competition of water between upstream and downstream users. People at the downstream were concerned that the upstream people take more water than their allocated share. As a result, orchards in the lower parts are decreasing everyday. About 30 years ago there were good orchards and sugarcane in this area. However due to decreased water availability from the irrigation system, they have to dig wells to get enough water to irrigate their crops. This also has limited accessibility due to high cost and the fact that inspectors are regularly monitoring the size of wells. In the past the population was also lower so they could rely on rain-fed agriculture and even leave some lands fallow but this is no longer possible.

Land and water related issues

In the upper reaches, amount and timing of precipitation, shallow soil depths, topographic limitations and unavailability of irrigation water are the major constraints to the agricultural productivity. In rain-fed areas, the major issues related to land are erosion and low fertility of lands. The lower level of irrigation developments and lower efficiencies of irrigation water needs are also contributing factors. The farmers are susceptible to rainfall (very high and low rainfall causes damage) and there is low predictability. Lack of fruit storage and processing industries are causing poverty as farmers could not get due profit on their produce and most of their produce is just destroyed in their homes. Mechanization is also low in these areas.

Separate and more focused studies are needed to evaluate the extent of soil erosion both from agricultural lands and mountains and their impact on overall sedimentation problems in the KRB. Thorough investigations should be carried out for the *in situ* control of soil erosion. Other management options such as controlling livestock numbers and management of rangelands need also to be explored. However, before doing so, we need to study in detail the impact of such interventions on the livelihoods of the people. This becomes even more important considering the fact that almost every household rely substantially on livestock and animal husbandry for their livelihood than agriculture.

Farmers believe that they lack knowledge about optimal use of farm inputs, irrigation management, and selection of suitable cropping patterns for their lands. They also want more facilitation for improving farm mechanization (farm machinery, drip and sprinkler systems etc). They strongly believe that building their capacity in these areas will greatly help in improving land and water productivity, reduce poverty and reverse the trend of migration from rural areas to urban areas in search of jobs.

In the upper catchments, fully and partial irrigated systems cover about 250,000 ha. In these areas, crop yields are relatively high i.e. for wheat it is 2.5 t/ha as compared to rain-fed yields of 0.8 t/ha. The upper catchments are the most suitable rain-fed zones of the country, with long-term annual precipitations of 350-500mm. However, due to non-uniform distribution of precipitations and rainfall fluctuations between seasons as well as the variations in agro climatic conditions and lack of appropriate agro management measures the productivity is way below potential. Water productivity (WP) ranges from 0.3-0.5 $kg.m^{-3}$, these productivity levels achieve an income of less than $50 per ha. Under these circumstances, the scope of improving land productivity in terms of mass of produce seems limited. However, by adopting better water management practices, productivity of available water resources can be greatly improved both at farm and basin levels. The scope of improving gross margins through reducing input costs, especially reducing high tillage costs and optimizing fertilizer use is also very high.

The increasing use of groundwater in upper eastern parts of KRB has revolutionized the land development and farmers have started enjoying its benefits. However, looking at different conditions of the groundwater table (especially in Gamasiab sub-basin; in some parts it is very deep and in other parts it is shallow), one has to be careful in allowing uncontrolled use of groundwater in the long run. Therefore there is an immediate need to study the extent of groundwater use (as it is mostly controversial) and its possible impact on the overall water balance of the basin. For the moment, groundwater is mainly ignored in the planning of water resources and in the basin management options. The economics of groundwater use for agriculture also needs to be studied because in most of the areas farmers complained about declining groundwater tables and increasing pumping costs. Continuous growing of crops (less valuable) with groundwater will further reduce the on-farm incomes besides have negative impacts on the environment.

Therefore it would be good to develop a pilot hydrological/water balance study in the Gamasiab sub-basin to better understand complex interactions between surface water and groundwater and its impact on socio-economic and environmental conditions of the people living in this area.

- ***The Middle Reach***

The middle reach of the KRB is basically a continuation of the upper reach with some difference in cropping patterns and interventions adopted for the management of soil erosion and water management. The Lorestan province is mainly falls under the middle reach of the KRB. Total population of the Lorestan province is about 1.6 million. Out of which 52% live in urban areas and 48% in rural areas. About $1/3^{rd}$of KRB is in Lorestan province. About 100,000 ha of irrigated and 400,000 ha of rain-fed area of KRB is in Lorestan province. About $2/3^{rd}$ of the total population of the Lorestan province lives in KRB. The 70% of the total income of the people living in Lorestan comes from agriculture whereas the rest 30% comes from the livestock. The average annual rainfall is 520 mm.

The number of agricultural plains in the Lorestan province is much less as compared to Karmanshah. Wheat, Barley and chickpea are major crops for the rain-fed areas whereas wheat, rice, maize, sugar beet and alfalfa are more common in irrigated areas. This part produces lots of water for the KRB but can not use it for irrigation due to hilly terrains. Only on terrace lands, river or stream water is pumped to irrigate field crops and orchards along the river banks. In irrigated areas such as Kohdesht, some groundwater pumping is also going on. However, due to negative balance of groundwater, pumping is discouraged. The irrigation is usually done through basin or border methods however government is encouraging farmers to use pressurized irrigation methods.

The quality of agricultural lands is not very good. Soil erosion, rangeland degradation and over-exploitation of groundwater are major problems in this reach of the KRB. Most of the rangelands produce only 200-300 Kg/ha of the biomass and therefore falls under the low productive rangelands. Livestock is mainly sheep and goats because it is difficult to keep heavy animals on these highly sloppy lands. However, for the conservation of rangelands, government is encouraging farmers to shift from sheep and goat to cows to increase milk production and save rangelands. Due to this shift, rangelands have started improving.

Another major change in the middle reach is the shift from field crops to orchards. The common orchards in this area are of apples, walnuts, peaches and olives. The reasons for this change are that on steep slopes, orchards are preferred than field crops and they help in controlling soil erosion. Some farmers are making this shift because of low productivity of field crops. Along the river banks, cultivation of rice and maize is also increasing due to access to water resources.

Rice cultivation along the river banks in the middle reaches of the KRB (Lorestan Province)

The major issues of this area are high rate of hillside erosion and low productivity of rain-fed crops. About 10 years ago, the Ministry of Water initiated a program to cope with these constraints and improve productivity and livelihood situation in the area. The major interventions introduced by the government and local communities include:

- Distribution of good quality seed and improved varieties of wheat in the area.

- Improving access to chemical fertilizer.
- Introducing seed drills for transplanting wheat.
- Spring water harvesting through construction of ponds and other structures.
- Erosion control measures such as terracing, delay action dams and turkinest.

The local research organizations are involved in carrying out research on water harvesting, soil conservation measures, river training, watershed planning, climate, hydrology and groundwater recharge mechanisms. They have carried out research on 45 watersheds and have completed their characterization and extent assessment and are investigating the effects of different watershed management interventions.

Wheat sowing using seeddrill in Lorestan province

These initiatives are moderately successful and getting popularity among the farming community. The farmers have adopted these water harvesting techniques at available spring sites and have constructed ponds financed by loan from the government and also by solely using own investment. The number of ponds has increased to 40 in 9 years and the number of trees has increased considerably in the area, e.g., nuts trees have increased from 5 to 20,000 over the period of 9 years. However, they need more financial and technical support from the government to make a real difference.

The touring team visited one such pond (Mr. Shikari). He has constructed a pond for spring water harvesting. The finances came from his own pocket, although he could have used bank loan and start returning it in installment after 5 year. The pond was build using concrete material. The pond is 5 meter long, 3.7 meter wide and 1.7 meter deep and can store about 30 m^3 of water. The water stored in this pond is mainly used for supplementary irrigation to walnut trees. By this spring water he irrigates 2 ha of peach and walnuts trees using drip irrigation method. The expected annual sale of fruits is about 500 $/ha in a year.

For scaling up these and other best practices, the government provides soft loans. These loans had a grace period of 5 years and were to be repaid after 5 years with a

4% interest rate. For scaling out these interventions, several other watersheds are also being helped.

Flood water flowing into a pond for groundwater recharge

The construction of check dams to collect silt, recharge groundwater and to prevent flooding of the downstream town started some 9 years ago. The recharging of groundwater is very essential in this area as many people on the plain rely on irrigation from deep tube wells. Due to drought conditions over the last 5-6 years, groundwater tables have already started declining. The model of the system is that it trains the water from the stream that originates in the mountains into a small reservoir, this water is then released slowly along two channels which flows into a series of bunded areas and then onto fields. The unused water at the end of the systems is returned to the stream further down, thereby avoiding flooding of the town. The project finished 7 years ago and they are monitoring the results. Since the completion of this check dam project, groundwater levels have improved due to increased recharging, crop yields have increased and there have been no floods.

Spring water flowing into the newly constructed pond for irrigation of orchards

Like the upper reaches, they also grow maize and wheat on the irrigated lands, and wheat, barley, chickpea and lentils on the rain-fed lands. The wheat yield from rain-fed land is around 1 ton /ha as compared to 3 tons/ha for irrigated land.

They feed the crop residue to the animals. Five households in the visited village also own tractors and are paid to work on other peoples' fields. Unemployment is also big issue here (in certain cases even worse). Most families also have at least one person working in the town. The people in this village are well educated, having Bachelor and Master degrees and 5 are doctors/PhD and 6 are engineers. However many of them are jobless despite their education.

Most houses have piped water for drinking. However, some houses also have open wells to provide drinking water for themselves and for their livestock. The people of this village also stressed that they are facing shortage of water and other agricultural inputs. Though they are supposed to receive subsidized inputs they often have to buy them on the black market.

Koh Dasht irrigation area in Kashkan sub-basin

Koh dasht valley is one of the large agricultural areas in Lorestan Province located in the Kashkan Sub-Basin of Karkheh River Basin. The wheat is cultivated in rain-fed areas and maize-wheat rotation is dominant in irrigated pockets. The sources of water for crop production are rainfall, groundwater and seasonal floods. There are about 700 pumping stations in the valley. The bore depth of wells is about 150 meter. Groundwater table is very deep at about 100 meters and is declining. Overexploitation of groundwater is one of the major threats to sustainable crop production from irrigated lands. In order to improve efficiency of irrigation, government is promoting sprinkler irrigation in the region and about 30 % of irrigated area is already under sprinkler irrigation. The well drilling is now prohibited in the area to avoid acceleration of already declining water tables-the current rate of draw down is estimated about 1.5 meter per year. For recharging groundwater delay action dams and bankets are constructed at suitable places. There is need to strengthen these efforts and search for other possible options for sustaining groundwater resources. These should be focused on artificial recharge measures, on-farm irrigation efficiency, cropping pattern, use of floodwater, groundwater regulation etc.

In the Kashkan catchment, afforestation is being encouraged by the government mainly for greening of river valleys. Since indigenous oak trees grow very slow, they have introduced pine trees which are irrigated in the nursery for two years and then brought into the fields. In the Kashkan sub-basin, also number of management measures is being adopted for erosion control and improve productivity. These include:

- Conservation agriculture
- Encouraging orchards
- Grazing management (controlled grazing in various parts of the catchment).
- Spring protection
- Water harvesting, storage and supplemental irrigation development in rain-fed areas.

These interventions started 13 years ago and ran for 4 years. The adoption rate by farmers is faster than what government and other agencies can afford. Therefore there is a strong need for more resource mobilization to facilitate interesting farmers to improve their productivity and livelihoods.

- ***The Lower Reach***

Upper reach of the south Karkheh basin

The upper region of the lower Karkheh basin has variety of land features such as newly developed irrigated lands, barren lands, rain-fed areas and patches of irrigated areas mainly from groundwater. One of the salient features is the Karkheh dam, constructed for flood control, irrigation development and power generation.

The agriculture in the newly developed canal irrigation schemes is boosting up. The canals are lined and very well constructed. Due to elevation differences in the area, water from Karkheh river is pumped into irrigation canals. For other high elevation areas, water is first taken to that area through closed pipes and then pumped into open channels for delivery up to farmer fields. In some parts, irrigation network is still under construction and according to an estimate it will take another 5-10 years for completion. Canal water is allocated on weekly rotation basis and charged according to the type of crop grown. The productivity of the lands is increasing with time as lands are being cultivated under irrigated conditions.

The groundwater in this area is of relatively good quality and is being used in conjunction with the canal water. Wheat and maize are the main crops in this area. Alfalfa and vegetables are next in importance. Due to the increasing availability of water in this area, the annual cropping intensities have gone up to about 120 %. The field sizes are very large ranging from one to four hectares. Farmers are still applying irrigation through basin/border irrigation methods. Most of fields are not very well leveled which is causing patches of low and higher infiltration within the same fields. This in turn affects the overall productivity and poor water use efficiencies. The groundwater pumps are running day and night with few hours break. Groundwater supplies still make up 50% of the water available at the farm gate. The lower on-farm irrigation efficiency is one of the major issue in these newly developed irrigation schemes.

Before the introduction of this irrigation network, the situation was bad in this area and mostly people were relying on groundwater irrigation. After the installation of irrigation network, they have better access to surface water. The water charges for wheat, maize and cucumber crops are about 40, 45 and 110 US $ per ha, respectively.

The discharge capacity of the most of the tubewells working in this area ranges between 30-40 l/s. This discharge is not good enough to irrigate large fields through basin irrigation. Therefore to increase the flow rate and stream pressure, the groundwater is first pumped into a **storage pond** located at a relatively higher elevation. After filling this pond, water is released into small field channels for irrigation. These ponds are also used for fish production.

A lined canal receiving water through pumping from Karkheh river

Groundwater is being pumped for filling the pond before releasing water for irrigation.

The access to productive land and water resources is major constraint in the upper part of the lower Karkheh basin. The rainfall is very low i.e. 50-150 mm per year. The lands are barren and groundwater is costly to pump in most parts. Groundwater pumps are usually installed at 90 m depth near the bank of seasonal stream. The year round availability of water had made it possible to grow two crops. The yield of wheat and cucumber were reported as 4 tons/ha and 15 tons/ha, respectively. This indicates that water management interventions are critical to improve livelihoods of village communities through improved access to productive land and water resources.

Before the construction of dam and irrigation network in this area, many families moved to other areas in search of off-farm jobs to earn their living. However, many of them have started coming back to cultivate their lands. Usually farmers in this area cultivate wheat themselves and then rent out their lands to nomads for the cultivation of vegetables. This is mainly done because cultivation of vegetables is a hard job and requires lots of labor. Those families who have less family members prefer to rent their lands for vegetable cultivation and move to other jobs during this period. Family sizes are usually around 10 but some families are up to 16. This generation is changing though and would prefer to have smaller families of 4-5 children.

Like other parts of the basin, electricity and piped water in the houses are common in this area. The drinking water supply usually comes through communal well installed outside of the each village. One person who lives close to the well is responsible for switching the pump on for a few hours twice a day. There is also a communal telephone in most of the villages, though they have promised home connections. Most of the young peoples work on their farms as there is no other activities for job creation.

Every household has some livestock mainly sheep and cows. Milk produced is usually just sufficient for home consumption and not much to sell. They get around 10 kg per day from each cow and sell around 5 kg for 1500 Iranian Rials (0.20 $) per kg. They feed the cows with grass and crop residue but do not buy any special fodder (however we observed stores of wheat straw so either they buy this or do actually have land.

Women are usually involved in vegetable cultivation. Tubewell water is usually used for irrigation as the water has not yet reached in many parts of this area. The yield is around 500-600 kg/ha for which they receive around 600 Euro per crop twice a year (i.e. annual income of 1200 Euro from cucumber).

Lower reach of the south Karkheh basin

Salt affected lands and wetlands are the main features of the lower part of the South Karkheh basin. The discussion with the people from salinity research center in the region and with the farmers indicates that the soil salinity is highly variable in the region ranging from 2 dS/m to 180 dS/m. The major causes of salinity are high water tables (1-3 meters below land surface) and high evaporation rates (3600 mm per year). The floods are the major threats to livelihoods (high floods) as well as provide opportunity to cultivate these saline lands (low floods). Before the construction of Karkheh dam, seasonal floods were the biggest source of salt leaching in the area. However, after the construction of dam, this natural leaching phenomenon has stopped and salinity is increasing in the adjacent lands. Now the areas where irrigation infrastructure has reached, situation is becoming much better because people have access to good quality surface water. As a result, prices of agricultural lands have increased 20 fold. Farmers are now more motivated to invest in their production systems. No big initiatives are taken for the recalmation of saline lands in this area. Salinity control measures usually adopted by farmers include one heavy irrigation at the time of planting to leach down the salts up to 25-30 cm for the germination of seeds. In some areas, construction of drainage systems is also planned. National Salinity Research Center of Yazdh has recently started working in this area to study the extent and types of salinity and to develop reclamation measures.

The groundwater is highly saline and therefore not pumped for irrigation. The farmers can sow wheat crop on irrigation water pumped through rivers or on floodwater. The average wheat yield is about 1.5 t/ha and salinity is major reason for low productivity.

There is great need to work on the various aspects of research, development and policy interventions to improve productivity of salt effected lands, improve food security and eradicate poverty in the area. The following areas should be immediately focused:

1. Mapping the extent and variability of salt effected lands
2. Studying options for water management to reduce salinity build up in the long run
3. Improve the drainage network
4. Develop and promote salt tolerant cultivars of wheat
5. Study the scope of other salt tolerant crops and grasses and do efforts to promote the suitable options
6. Provide alternate sources of livelihoods in the area

Salinity in the lower south Karkheh basin

Before the development of irrigation network and dam, there was a lot of migration to the cities from this area but now people have decided to stay here and work on their agricultural farms to make their living.

This area was also severely affected during the Iraq-Iran war, and almost every one migrated from this area. But after the war the government helped them to rebuild the village on the other side of the road.

The unemployment rate in this area is also very high because productivity is still low even though they have plenty of land because the drainage channels have not been completed yet. They have built primary and secondary canals but not field canals. When this is complete the unemployment rate will go down.

Visit to the Horal Azim Swamp

Visiting the swamp area gave picturesque of environmental condition of the area and socio-economic characteristics of the region. The swamp area covers about 300,000 ha. Most of the areas before the swamp are waterlogged. Rice is the main crop grown in the area and other source of livelihoods are livestock, fisheries, weaving/mat making. There are not many job opportunities in the area but most people do not usually migrate away for work because they have very close family ties and if they are to migrate then whole family would move. If they do go off to work they come back every month. In one village almost all the families migrated to the city for work.

Though families appear to have few income generating activities they still have satellite TV and A/C. This could imply 2 things – firstly that the son's income is quite high and very important in the livelihood strategy of the household and secondly that electrical assets might not be a good indicator for the poverty analysis. Poverty has to be seen in relative terms and new indicators need to be developed which can explain the situation better.

Most families have livestock including sheep and calves. They rent fields for crop residue or buy barley for fodder for milk sheep. The cost is around \$10 per ha for crop residue and \$10 for a 50kg bag of barley, of which they need around 4 bags per sheep per year. They pump water from the Karkheh for irrigation and take their livestock to the river to drink.

People near the swamp have different opinion about Karkheh dam. They feel that Karkheh tributary near the Swamp was a big river but now it is just a small stream. They also feel that the biodiversity in the swamp has declined and that hardly any of the birds that used to come here do anymore. They believe that it was better to have annual floods and a continuous water supply than this infrastructure. Now at irrigation time there are lots of pumps extracting the river water but before the dam there was plenty of water. A local farmer of the Maraz village explained the life style and difficulties of nomads and other people living in this area.

Horal Azim Swamp at the tail of Karkheh basin

Waterlogged areas near the Swamp

A view of wetlands in lower part of South Karkheh Sub-Basin

The story of a farmer-Maraz Village

The person we interviewed was very knowledgeable and educated. He had a job in a sugarcane factory in the city.

There are 25 families in the village and they are mostly involved in agriculture but a few have livestock. Some families have around 10 sheep while others have more than 300, and some have 30 cows. Each family has around 10-20 ha of land none of which is rainfed as the rainfall is too low, instead they pump water from the Karkheh river. The cost of pumping is very high at round 5000-6000 Euro to install a pump and 2000 Euro per year operating costs. As a result some families can not afford this and have to stop pumping for a while or have to take a loan.

Land in this area is also saline and is therefore not very productive so people mainly grow wheat and barley. He explained that as the land was not cultivated during the war the lands became increasingly saline but now that they are cultivated and irrigated with river water, and evaporation is less, the salinity is not so high.

This family had land before the war but they lost all their papers and the government allocated the land to other people. They now have to rent land at around USD 22 per ha. They also spend around 30% of the income from the land on irrigation water and the government license to irrigate. They tired to cultivate cucumber and melon for 4 years and the yield was good but it cost too much to transport them to the city and as too many people were growing them the returns were not good.

The family also has livestock and rent fields for crop residue. Farmers also leave land fallow and when they do this they can graze the livestock on the weeds. The barley that they grow is used for fodder. The best yield they have is 5 tons/ha for wheat.

Since most families in the village are poor the children have to work in the fields and do not go to school. He was very lucky to get a diploma. Most families also lost everything during the war and the government have done very little to help them recover. Some of the families migrate to the city or to the oil fields to work.

He believes that if they were given an irrigation and drainage network things would be much better and he would probably even give up his job and work in agriculture. Some people have leveled their land and are producing a good crop growing barley for 2 years and wheat the third year.

APPENDIX B: DATA SOURCES AND NEEDS

Karkheh Basin is potentially rich in data, as the Iranian public agencies have collected and managed most of the information in a professional and disciplined way (Table 1). A key task will be to identify the available secondary data, obtain and then collate it with the help of in-country partners. Most of the data need to translate from Persian to English and also requires conversion from Iranian solar calendar to Julian calendar. Ultimately the data will be archived in IDIS/IWMI-DSP and made available to all stakeholders as a unified data set. However, there will be plenty of work to do to get to this point.

#	Topic	Organisation
1	GIS	1. Forest, Rangeland and Watershed Organization (FRWO) (AREO) 2. KWPA (Ministry Energy) 3. Tarbiet Moderes University
2	Secondary socio-economic data; Detailed national household survey data (40 years)	1. Ministry of Jihad-e-Agriculture 2. Karkheh River Basin Data Book (in Farsi) 3. University and AREO studies – identify 4. Ministry of Energy
3	Institutional landscape	Study by IWMI Iran
4	Local agricultural and livelihood characterization. Set of agricultural interventions and research findings.	Ministry of Jihad-e- Agriculture AREO Research Units Karmanshah Agricultural Organization Lorestan Agricultural Organization Khozestan Agricultural Organization o Dryland Agriculture Research Institute o Safiabad Agriculture Research Institute CP 8 Project on Water Productivity CP 24 Resilience Project IWMI Salinity study (IWMI + ICARDA +National Salinity Research Center (NSRC)
5	General water resources, flow monitoring, water quality, water use, groundwater monitoring, sediment transport and deposition, dam operations. Irrigation data.	KPWA (Parviz Talebzadeh) AREO Ministry of Jihad-e-Agriculture Consultancy reports. Ministry of Energy
6	Remote sensing – land cover classification and advance remote sensing analysis (eg application of SEBAL to determine evapotranspiration)	Tarbiet Moderes University FRWO Soil and Water Institute (Dr. Momini)

APPENDIX C: CVS OF RESEARCH TEAM MEMBERS

1. Hugh Turral

Name	: Turral
First Name	: Hugh
Year of Birth	: 1957
Nationality	: Australian and British
Key Area of Research in BFP	Basin level water management issues; Water Productivity and water poverty analysis

KEY QUALIFICATIONS

Hugh Turral has 24 years experience as a water resources / irrigation engineer and irrigation agronomist. He has spent about 15 years living in developing countries, mostly on long-term assignments. After 1990, he worked as a researcher on topics including: water resources policy; water allocation and modelling; irrigation system operation and modelling; and farm water management. Since 1998, he has developed a strong interest in the application of remote sensing to water management. Hugh has worked long term in Australia, UK, Indonesia, Pakistan, Nepal and Vietnam, with shorter-term activities in India, Philippines, Thailand, Botswana and China. Hugh has worked, or consulted, for the UK Overseas Development Administration (now DFID), the European Union, the World Bank, the Asian Development Bank and FAO. He has developed decision support and information systems for the management of large irrigation systems and been involved the development and use of models for water resources management, allocation and environmental flows through consulting and postgraduate supervision at Melbourne University. In 1994-95, he spent 18 months with the Overseas Development Institute in London, working on various aspects of water policy in developed and developing countries.

Hugh Turral is theme leader for IWMI's Theme 1 'Basin Water Management'. Theme 1 is one of four themes at IWMI and is concerned with the management of water for agriculture and food production at a basin scale. It has three sub-themes: (1) water productivity in agriculture, fisheries and agro-forestry; (2) sustainability of water use (3) economics, institutions and policies that support basin level water management for agriculture.

He also manages a number projects, including: 1) Global Irrigated Area Mapping, an investigation of suitable techniques to map actual irrigated area and cropping intensity using remote sensing. This work is funded as part of the IWMI's Comprehensive Assessment. The work involves a number of international collaborators and is intended to lead to a full scale global mapping exercise to provide a clearer statement on the extent of irrigation activity over the globe. A major output of the programme is the development and dissemination of new multi-temporal techniques of image analysis. 2) Operations support for Pehur High Level Canal (PHLC), North West Frontier Province, Pakistan. PHLC is the first downstream locally automated canal in Pakistan and feeds into the old Upper Swat Canal. IWMI is undertaking modelling, performance investigation, the development of a management information system and refinement of an operational manual for the Department of Irrigation. 3) Assessing the potential of groundwater for irrigation in the Fergana Valley, Syr Darya Basin, Central Asia. Groundwater has been reserved for urban and domestic supply through the existing licensing regime in Uzbekistan. Vertical drainage to control water tables using pumped wells has fallen into disuse in many places, but private development of groundwater for irrigation is starting. There are great potential benefits from better conjunctive management of surface and groundwater in the Fergana Valley. IWMI is working with local partners (The Hydrogeology

Institute, BVO Syrdarya, and TIIM) to understand the surface groundwater interactions using modelling and the extensive data available in local organisations. This will be coupled with a socio-ecological groundwater survey to establish how much provate development has taken place and also the extent of abandonment of vertical drainage.

EDUCATION

1980	B.Sc. (Honours), Agriculture, University of Reading, UK.
1982	M.Sc., Soil & Water Engineering, National College of Agricultural Engineering, Silsoe, UK.
1994	Ph.D, Civil and Environmental Engineering, University of Melbourne, Australia.

PROFESSIONAL EXPERIENCE

2003 - present	Principal Researcher and Theme Leader for "Agricultural Water Management", IWMI, Colombo.
2001 - 2003	Senior Researcher, International Water Management Institute, a CGIAR Research Centre with headquarters in Colombo.
2000	Short course: Introduction to IDL Programming, RSI. Held at Dept. of Geomatics. University of New South Wales, Sydney, Australia.
1999 (2 months)	Irrigation Engineer, Snowy Mountains Engineering Corporation, Cooma, Australia. Asian Development Bank Technical Assistance Project 3050, Second Red River Water Resources Sector Loan, Hanoi, Vietnam.
1998	Short course on Synthetic Aperture Radar, science and applications, Department of Geomatics, University of New South Wales, Sydney, Australia.
1995 - 2001	Research Fellow in Irrigation and Water Resources Management, International Development Technologies Centre, Department of Civil and Environmental Engineering, University of Melbourne, Australia.
1994 - 1995	Research Fellow, Water Resources Network, Overseas Development Institute, London, UK.
1990 - 1993	Ph.D student, Department of Civil and Environmental Engineering, University of Melbourne, Australia.
1987 - 1990	Irrigation agronomist and water management engineer, Hunting Technical Services Limited (UK), on secondment to Groundwater Development Consultants Limited in Indonesia 1987-1989)
1987	Independent Consultant – Farming Systems Analyst and Research Planner. Baluchistan Agriculture Extension and Adaptive Research Project, World Bank, Pakistan.
1984 - 1987	Irrigation Agronomist and Water Management Engineer, Technical Cooperation Officer, Overseas Development Administration (UK), for the Baluchistan Small Scale Irrigation Schemes Development Project.
1982 - 1984	Irrigation Engineer, Overseas Development Administration (UK), placement on the Kosi Zone Hill Area Development Project, Nepal.
1981	Investigator (Wind Energy Programme), Intermediate Technology Industrial Services Limited, Rugby, UK, in Botswana.
1978 - 1980	Engineering Technician, Water, Wind Energy and Stoves Programmes, Applied Research Section, Intermediate Technology Development Group, Reading, UK.

PUBLICATIONS (SELECTED)

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Khanna M. and Malano HM, Fenton JD, and Turral H. 2003. Design and management guidelines for contour basin irrigation layouts in Southeast Australia. Agricultural Water Management

2. Mobin-ud-Din Ahmad

Name	: M.D. Ahmad
First Name	: Mobin-ud-Din
Year of Birth	: 1970
Nationality	: Pakistan
Key Area of Research in BFP	Project Management; Water Accounting; Water Productivity; Remote Sensing & Modelling Application

KEY QUALIFICATIONS

I am an agricultural and water resources engineer and have over 10 years of experience in the planning, design and implementation of research projects related to sustainable land and water management for agriculture. I have worked in multidisciplinary international research teams in France, Iran, Pakistan, Sri Lanka, South Africa, Thailand and the Netherlands to develop robust methods for integrated land and water resources management to increase the agricultural productivity from field to basin scale. I have demonstrated my skills in the use of physically based transient models such as Soil-Water-Plant-Atmosphere (SWAP) to understand the impact of different irrigation and agronomic practices in irrigated fields on moisture dynamics in the unsaturated zone, groundwater recharge and evapotranspiration. For basin scale analysis, I have used satellites imagery to map actual evapotranspiration & soil moisture mapping (using Surface Energy Balance Algorithm for Land: *SEBAL*), net groundwater use estimation, irrigation and salinity mapping, land use classification (cropping pattern & cropping intensity), and agricultural water use performance.

In December 2002, I completed PhD studies at International Institute for Geo-information Science and Earth Observation (ITC) – Wageningen University, the Netherlands. I was appointed as international researcher at the Global Research Division of International Water Management Institute (IWMI); a CGIAR-supported research institute headquartered in Colombo, Sri Lanka. At IWMI, I am involved in the performance investigation for Pehur High Level Canal (Pakistan), OPEC groundwater study, integrated modeling & scaling-up water productivity projects in India and Pakistan and Basin Focal Project in Iran. Currently, I am leading the Scaling-up Water productivity project in Pakistan and Basin Focal Project in Iran.

PROFESSIONAL EDUCATION

1999-2002	Doctorate in Water Resources and Environmental Engineering, International Institute for Geo-information Science and Earth Observation (ITC) and Wageningen University, The Netherlands
1993-1994	Master in Irrigation Engineering and Management, School of Civil Engineering, Asian Institute of Technology (AIT), Bangkok, Thailand
1987-1991	Bachelor in Agricultural Engineering, University of Agriculture, Faisalabad, Pakistan

PROFESSIONAL EXPERIENCE

Jan. 2005 – to date	International Researcher – Hydrologist and Remote Sensing Specialist – International Water Management Institute (IWMI), Global Research Division, Colombo, Sri Lanka
Feb. 2003 – Dec. 2004	Post Doctoral Scientist, International Water Management Institute (IWMI), Global Research Division, Colombo, Sri Lanka

Feb. 1999-Dec. 2002	Doctoral Researcher, Department of Water Resources and Environmental Studies, International Institute for Geo-information Science and Earth Observation (ITC), The Netherlands
Nov. 1994-Jan. 2003	National Researcher – Water Resources Engineer, International Irrigation Management Institute (IIMI), Lahore, Pakistan

PUBLICATIONS (SELECTED)

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3. Mark Giordano

Name	Giordano
First Name	Mark
Year of Birth	1966
Nationality	US
Key Area of Research in BFP	Poverty & Livelihood analysis; Economic Analysis

KEY QUALIFICATIONS

Mark Giordano is an economist and geographer with broad experience in agricultural policy, economic development, and water resources management. Before joining the International Water Management Institute in November 2002, Mark spent nearly 10 years as an economist at the U.S. Department of Agriculture's Economic Research Service, where he specialized in analysis of Asian agricultural policy and trade modelling, and 3 years at Oregon State University conducting research on transboundary and common property resource issues. While at Oregon State University he also taught a number of undergraduate and graduate courses on world geography, resource geography and development. Mark is now a Senior Researcher and Head-Institutions and Policy at IWMI. He manages and works on range of projects focused on such diverse topics as the economics and geography of groundwater use and depletion in sub-Saharan Africa and Asia, institutional aspects of river basin management in China, the political economy of land degradation and conservation in Laos, and transboundary issues in the management of Africa's Volta and Limpopo basins. Mark is also heavily involved in the mentoring, management and development of a multicultural staff. His international experience includes past residency in Austria, Botswana, Cambodia, China, Taiwan, and Zimbabwe. Mark currently lives in Colombo, Sri Lanka.

EDUCATION

1987	Institute for European Studies, Vienna, Austria
1988	B.A., Economics, Whitman College, Walla Walla, WA, USA
1991	M.Sc. Agricultural Economics, University of Minnesota, St. Paul, MN, USA
1994	Hopkins-Nanjing Center for Chinese and American Studies, Nanjing, China
2002	Ph.D. Resource Geography, Oregon State University, Corvallis, OR, USA

KEY PROFESSIONAL EXPERIENCE

2002-2004	Senior Researcher, International Water Management Institute, Colombo, Sri Lanka
1999-2002	Regional Geography Instructor, Oregon State University
1991-1999	Economist, U.S. Dept. of Agriculture-Economic Research Service, Washington, D.C., Zimbabwe, Botswana and Cambodia

PUBLICATIONS (SELECTED)

Giordano, Mark. 2005. Agricultural Groundwater Use in Sub-Saharan Africa: What do We Know, Where Should We Go? Water Policy 7, 613-626.

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4. Asad Sarwar Qureshi

Name	: Asad Sarwar Qureshi
First Name	: Asad
Date of Birth	: March 10, 1965
Nationality	: Pakistani
Key Area of Research in BFP	Soil Salinity; Groundwater Management; Water productivity

Key Qualifications

Asad Sarwar has 15 years of experience as a water resources manager / irrigation / drainage engineer. He has been involved in the planning, design and implementation of projects related to the management of surface and groundwater resources to increase crop productivity and maintain environmental sustainability. He has long been associated with the action research aimed at developing irrigation management and water conservation strategies for the water short areas and evaluating agronomic and engineering solutions to mitigate incipient waterlogging and soil salinity problems and reclaiming saline-sodic soils. In recent years, Dr. Asad Sarwar has developed a strong interest in integrated water resources management, particularly in the application of computer simulation models in both saturated and unsaturated zones to evaluate long-term effects of different irrigation and groundwater management strategies on crops and environment. He has worked in the Netherlands, France, India, Pakistan, Nepal, China, Afghanistan. Presently, he is coordinating IWMI's work on sustainable groundwater management for Pakistan, Central Asia and Middle East region. This work is focused on technical, social and legal aspects of groundwater management in South-Asia and China. He has commitments to work on Groundwater Contribution to Agriculture through Comprehensive Assessment. He is also coordinating Pakistan Water Partnership (Pakistan chapter of Global Water Partnership) and SASTAC activities in Pakistan. Dr. Asad has also participated in the preparation of Needs Assessment on Soil and Water in Afghanistan under USAID led Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA).

Asad Sarwar started his career at IWMI in 1988 as a water resources engineer. Since then he has served IWMI in different multi-disciplinary research projects. In 2001, Dr. Asad was appointed as Acting Director for the IWMI's Regional Office for Pakistan, Central Asia and Middle East based in Lahore Pakistan. Since then he is focusing on regional water resources management issues including countries like India, China, Afghanistan and Iran.

Education

1987	B.Sc. Agricultural Engineering, University of Agriculture, Faisalabad, Pakistan.
1993	M.Sc. Soil & Water Engineering (with Distinction), Wageningen University, the Netherlands.
2000	Ph.D. Water Resources and Environmental Engineering, Wageningen University, the Netherlands.

PROFESSIONAL EXPERIENCE

2004-todate	Researcher (I) and Director, IWMI-Iran office
2001-2003	Acting Director, IWMI Regional Office for Pakistan, Central Asia and Middle East, Lahore, Pakistan.

1999-2001 Senior Irrigation Engineer, International Water Management Institute, Lahore, Pakistan.

1997-1999 Research Engineer (soil physics), International Water Management Institute, Lahore, Pakistan.

1993-1997 Drainage Engineer, Netherlands Research Assistance Project (NRAP), a collaborative research project with the International Waterlogging and Salinity Research Institute (IWASRI), Lahore, Pakistan.

1991-1993 M.Sc. student at Wageningen University, the Netherlands.

1988-1991 Field Research Engineer, International Water Management Institute, Lahore, Pakistan.

1987-1988 Research Officer, Water Management Research and Training Institute, University of Agriculture, Faisalabad, Pakistan.

PUBLICATIONS (SELECTED)

Sarwar, A. and C.J. Perry, 2002. Increasing water productivity through deficit irrigation: Evidence from the Indus plains of Pakistan. Irrig. and Drain. 51: 87-92.

Sarwar A., 2002. On-Farm Water Mangement Issues in Irrigated and Rainfed Areas of Afghanistan. A contribution for the Needs Assessment on Soil and Water in Afghanistan. USAID sponsored study under Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRRA) coordinated by International Center for Agricultural Research in Arid Areas (ICARDA).

Sarwar, A. and Ilyas Masih, 2002. Sustaining Groundwater Irrigation in the Indus Plains of Pakistan. First South Asia Water Forum (SAWAF), Kathmandu, February 26-28, 2001.

Asghar, M.N., M. Ashraf, M.M. Saeed, and Asad Sarwar, 2002. Root zone salinity control options for agricultural areas irrigated with skimmed groundwater. International symposium on sustainable agro-environmental systems: New trends and applications, cairo, Egypt, October 26-29, 2002.

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Prathapar, S.A. and Asad Sarwar,1999. Mechanically reclaiming abandoned saline soils: A numerical evaluation. IWMI Research Report No. 30. International Water Management Institute (IWMI), Colombo, Sri Lanka.

5. Abbas Keshavars

First Name	:	**Abbas**
Last Name	:	**Keshavarz**
Date of Birth	:	22/12/1946
Place of Birth	:	Karaj- IRAN
Marital Status	:	Married , 3 children

Education

Degrees	Name of Institution	Major Field	Years
B.Sc.	Agricultural Faculty- Tehran Univ.	Irrigation Eng.	1966-1970
M.Sc.	Agricultural Faculty- Tehran Univ.	Irrigation Eng.	1975-1979

M.Sc. Thesis Title : Evaluation of Pressurized Irrigation Systems in Iran- 1979

PROFESSIONAL EXPERIENCE

Year	Name of Institute	Duty
Oct. 1970-May 1972	Azerbaijan Water & Power Authority	I/c Irrigation Units of Ardabil, Sarab & Khalkhal Cities
June 1972- Oct. 1975	Agricultural Cooperative Co. Azirbaijan & Khuzistan Provinces	Irrigation Officer
Oct. 1975-Sep. 1977	Agricultural Cooperative Co. – Tehran Province	Agricultural Officer
Sep. 1977-Feb. 1981	Agricultural Cooperative Co.- Organization Tehran	Technical & Irrigation Expert
Feb. 1981- Aug. 1983	Agricultural Production Cooperative – Tehran	Director General of the Evaluation & Planning Office
Aug. 1983- June. 1985	Member of High Commission Rural Services Deputy Minister's Office	Irrigation Specialist
June. 1985- Sep. 1988	Ministry of Agriculture	Director General of Agricultural Planning
Sep. 1988- Apr. 1989	Agricultural Research, Education & Extension Organization (AREEO)	Specialist for Agricultural Development & Coordination
Dec. 1988- Sep. 1995	Agricultural Research, Education & Extension Organization (AREEO)	Director of Iranian Agricultural Engineering Research Institute (IAERI)
Apr. 1989 - July 1997	Agricultural Research, Education & Extension Organization (AREEO)	Deputy, Technical Services
Jan. 1995- Aug. 1997	Agricultural Research, Education & Extension Organization (AREEO)	Deputy Director of AREEO
Aug. 1997- March 2001	Agricultural Research, Education & Extension Organization (AREEO)	Deputy Minister of Agriculture & Head of AREEO
Apr. 2001- June 2001.	Ministry of Agriculture Jihad	Consultant to the Minister
June.2001 to present	Agricultural Research, Education Organization (AREO)	Director General of Agricultural Engineering Research Institute

Additional Experience: (1) Teaching at Tehran University of an advanced course on "design of micro-irrigation systems" from 1989 to 2003, (2) Supervision of 4 MSc students at Tehran

University (1993-2000), and (3) Member of 3 international scientific societies/international organizations, and of 9 national scientific societies, dealing with research, development and policy in agriculture and water issues.

PUBLICATIONS (SELECTED)

Keshavarz, A. 1994. Determination of mathematical model for the cost estimate of operation and maintenance of three common tractors. Research Report Number 23, IAERI, Tehran, Iran.

Keshavarz, A and Kourosh Sadeghzadeh, 2000. Management of water use: estimation of future demands, dry year crisis, present status, future visions and strategies for optimization of water use. National Report. Ministry of Agriculture. Tehran, Iran.

Keshavarz, A. 1989. Technical and scientific criteria for the development of pressurized irrigation systems development in Iran. First Technical Conference on Production and Application of Pressurized Irrigation Systems, Tehran-Iran. 1989.

Keshavarz, A. 1994. Pollution of water resources - Pollution and sustainable agricultural development. The First Iranian Congress on Irrigation, Water Management, Land Use Strategy and Planning in Agriculture, September 17-19, 1994. Tehran, Iran.

Keshavarz, A. 1996. Investigation of farmer managed surface irrigation procedures in Iran. In Proceeding of the Second National Congress of Soil and Water February 1996, Tehran, Iran.

Keshavarz, A. 1999. Model of Water Use in Agriculture. Journal of Scientific and Research Papers, Agricultural Engineering Research, Fourth Year, N.14, Summer 1999.

Keshavarz, A. 1998. Irrigation Scheduling for the Shavour Areas located in the Khuzestan Province of Iran. Aiming for Sustainable Development in Irrigated Agriculture in Arid Land Areas. J. Japan Soc. Hydrol &Water Resour. Vol. 11, No. 4, 1998

Keshavarz, A. 1998. Desertification and Salinity Problem in Iran - Sustainable Development in Irrigated Agriculture in Arid Land Areas. Journal of Arid Land Studies Vol. 8,No. 2, 1998.

Taeb M and Keshavarz A, 1998. Country Status Report, Iran. National Agricultural Research Systems in the Asia-Pacific Region: A Perspective. Asia Pacific Association of Agricultural Research Institutions (APAARI), South Korea.

Keshavarz A, 2000, The Strategy for National Development of Agriculture in the Year 2010. Ministry of Agriculture, Islamic Republic of Iran.

6. Nader Heydari

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EDUCATION

D. Eng.2001
AIT, Bangkok, Thailand
Field of study: Integrated Water Resources Management.
Dissertation: Influences of Water Quality (Salinity and Sodicity) on Infiltration and Advance Rate under Surge and Continuous Flow Irrigation.
Course work G. P. A. 3.94/4.00
M. Eng.1993
Tehran University, Karaj, Iran
Field of study: Irrigation and Drainage Engineering
Thesis: Determination of Leaching Efficiency Coefficient of Saline-Sodic Soils using Numerical Method
G.P.A 3.94/4.00
B. Sc. 1988
Irrigation Engineering
Tehran University, Karaj, Iran

PUBLICATIONS (SELECTED)

Heydari, N., Das Gupta, A., Loof, R. (2001), " Salinity and sodicity influences on infiltration during surge flow irrigation". Irr. Sci, 20(4): 165-173.

Heydari, N. and Das Gupta, A. (2001), "Soil salinization and sodification under surge flow irrigation with brackish waters". Paper presented at Sustained Management of Irrigated Land for Salinity and Toxic Element Control, IUSS (Int'1 union of soil science) Sub-commission A Symposium and Bouyoucous Conf., June 25-27, 2001, Riverside, California, USA.

Heydari, N. and Das Gupta, A. (2001), "A review of drainage-watertable management models", Proceedings of the 7th National Convention on Civil Engineering Conf., Chulalongkorn Univ.,Thailand.

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Heydari, N. (1998), "Recent trends in management of irrigation systems". Proceedings of Int. Agr. Eng. Conf., AIT, Thailand.

Heydari, N. and Pazira, E. (1996), "Determination of leaching efficiency coefficient using numerical method". Proceedings of Int. Agr. Eng. Conf., Puna, India.

7. J. Porehemat

Birth-day: Sept 1957
Assistant Prof. in Hydrology and Water Resources
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EDUCATION

M.Sc. Thesis: Evaluation of hydrological balance componenets in karstic high lands, 1993, Shiraz University, Shiraz, Iran.

Ph.D. Thesis: Distributed snowmelt runoff modeling based on remote sensing data and GIS, 2002, Science and Resaerch Branch of Islamic Azad University, Tehran, Iran.

PUBLICATIONS (SELECTED)

Porhemmat, J. and Sedghi H., 2001, An estimation of probable maximum floods in large mountainouse basins(a case of Karun basin in Iran), International Conference on Flood Estimation Proceedings, Mar.6-8, 2002, Bern, Switzerland.

Porhemmat J. and B. Saghafian, 2000, Application of remote sensing data to drive snow cover area time series, The First Conference on the Methods of Collation to Water critisis Proceedings, Mar. 2002, Zabol, Iran.

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Porhemmat J., B. Saghafian, 2003, Evaluation of interpolation and extrapolation models to determining spatial distribution of daily and annual precipitation in mountainouse basins, Sixth International Symposium on Consruction Engineering Proceedings, May 2003, Esfahan, Iran.

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Porhemmat J. and B. Saghafian, 2003, Evaluation of spatial resolution of satellite data on snow cover estimates, Abstract of International Symposium on Snow and Avalanches Proceedings, June 2-6, (2003), Davos, Switzerland.

Porhemmat J., B. Saghafian and H. Sedghi, 2004, An algorithm to mapping snow cover, An International Symposium on Natural Resources held by Iran ana Russia in Shahre-Kord, Sept. 2004, Shahre-Kord, Iran.

Porhemmat J. and M. Ganji, 2004, Evaluation of actual evaporation and it's role on water balance componenets, First National Conference on Water managements, Oct 19-18 (2004), Tehran, Iran.

Porhemmat J., B. Saghafian and H. Sedghi, 2005, Application of SRM (Snowmelt Ronoff Model) model in snomelt simulation using NOAA AVHRR Images in ungaged basins (Case study: Khersan sub-basin, Karoon), Iran Water Resources Research Journal, Vol 1, No. 1.

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