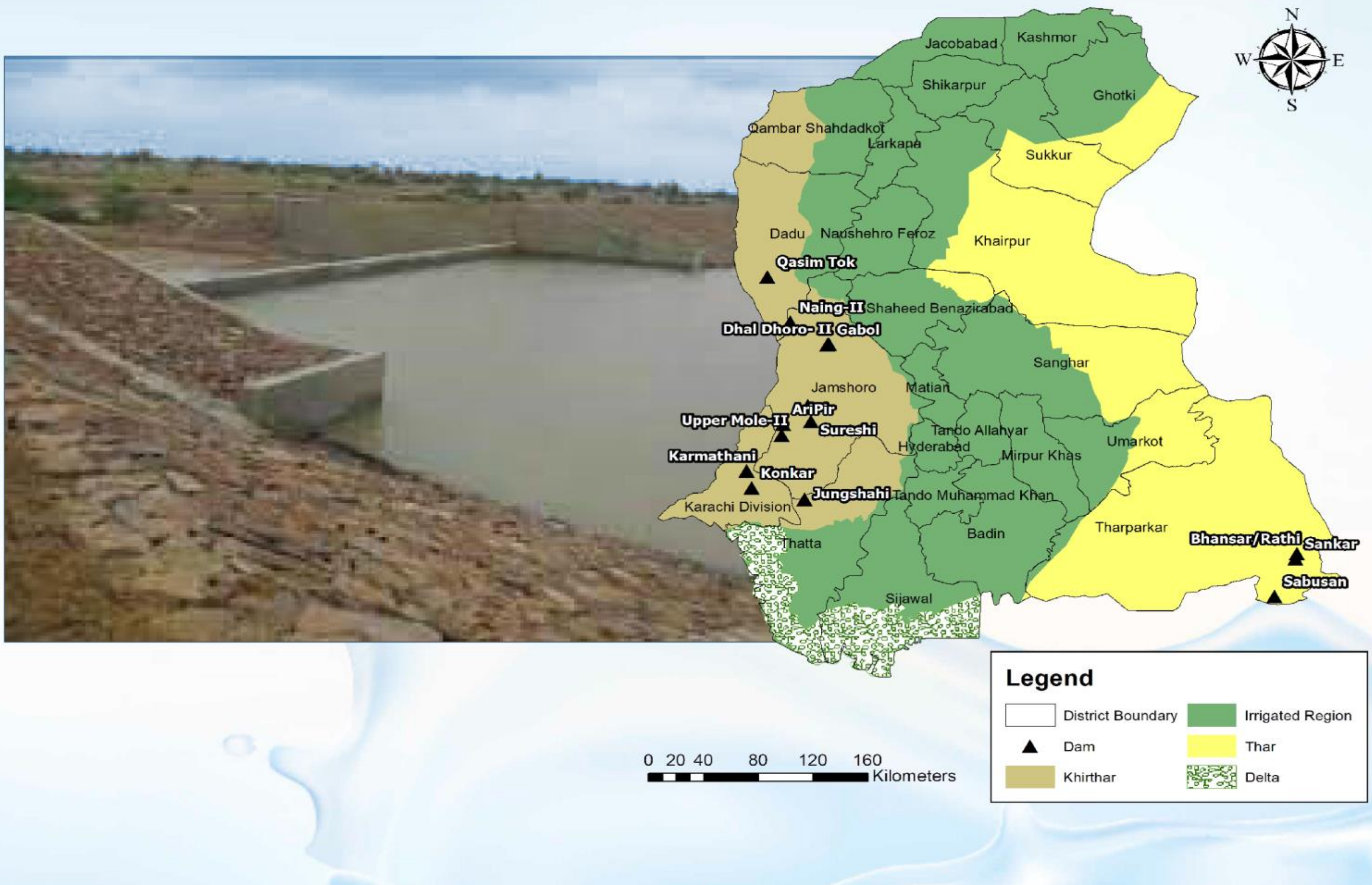
IMPACT ASSESSMENT & PERFORMANCE EVALUATION OF 14 SMALL DAMS IN THE SINDH PROVINCE

Final Report



30 June 2022

Submitted to:

Project Director,
Sindh Resilience Project
Irrigation Component, Karachi

Submitted by:

Project Director,
U.S.-Pakistan Center for Advanced Studies in Water (USPCAS-W)
Mehran University of Engineering & Technology, Jamshoro

TABLE OF CONTENTS

List of Figures

List of Tables

List of Abbreviations

CC	Climate Change
CN	Curve Number
DEM	Digital Elevation Model
FGD	Focus Group Discussion
HEIS	High Efficiency Irrigation System
KIIs	Key Informant Interviews
LULC	Land Use Land Cover
MFIs	Micro Finance Institutes
MUET	Mehran University of Engineering and Technology
NGO	Non-Governmental Organizations
SIAPEP	Sindh Irrigated Agriculture Productivity Enhancement Project
SRP	Sindh Resilience Project
USPCAS-W	U.S.-Pakistan Center for Advanced Studies Center in Water
WB	World Bank

1 EXECUTIVE SUMMARY

Water scarcity is a severe problem in desert/arid areas of Sindh that are not connected to any canal command area. These areas face acute water shortages due to scanty and uncertain rainfall events. Drought-related disasters frequently cause crop damages and livestock losses and adversely impact the socio-economic well-being of the entire community, especially women and children. Nevertheless, the topography of these regions has enormous potential for water storage through the construction of small dams.

Therefore, as a part of the Sindh Resilience Project (SRP) and under the Irrigation Department component funded by the World Bank (WB), the Government of Sindh commissioned the construction of small dams in prospective regions of Nagarparkar and Kohistan. The primary purposes of these dams were to recharge the groundwater through rainwater harvesting, reduce the drought-related risks and improve the community's socio-economic conditions through improved water availability for domestic use, crop irrigation, and livestock.

This study was assigned to the US.-Pakistan Center for Advanced Studies in Water (USPCASW), Mehran University of Engineering and Technology (MUET), Jamshoro and Carthigo Consultancy (International Consultants) for impact and performance evaluation of the 14 small dams constructed in Sindh province. The overall aim of the study was (i) to assess whether the post-dam construction significantly impacts the socio-economic well-being of the community of the study area and (ii) to determine the sedimentation rate and expected life of the dams.

For assessing the socio-economic impact of dam construction, the data collection framework involved four components: desk review of existing reports and studies, field data collection from the community through beneficiary surveys, focal group discussions (FGDs) and key informant interviews (KIIs). The USPCAS-W team reviewed the available reports and documents related to the SRP project's small dams' initiative, including baseline studies, feasibility reports, other assessment reports, etc.

Separate tools were designed for beneficiary surveys, FGDs, and KIIs and finalized through consultation and testing. The beneficiary surveys involved interviewing the selected representatives of the local community and other relevant stakeholders, consisting of 387 respondents from 24 out of 74 villages. The FGDs were held with the beneficiary communities using pre-designed semi-structured questionnaires. A total of 25 FGDs were conducted for all 14 dams, including 11 with females and 14 with males. The data were triangulated to ensure its reliability and validity.

The KIIs were held with representatives of the Revenue Department, Pakistan Agriculture Research Council, Irrigation Department, SRP, Academia and NGOs operating in the project area and notables.

The second objective of this study entirely focused on determining the sedimentation status and life of each dam. The sediment-related features required for this study include sediment inflow, deposition, and degradation processes. Sedimentation processes in a reservoir are pretty complex because of the wide variation in many influencing factors such as (1) hydrological fluctuations in water and sediment inflow, (2) sediment particle size variation, (3) reservoir operation fluctuations, and (4) physical controls or size and shape of the reservoir. Because of this complexity, empirical relationships developed from surveys of existing reservoirs have been used to define sediment depositional patterns. The data were generated using the methodology given in the report for sediment inflow, sediment yield rate, reservoir resurvey, sediment rate, reservoir sediment deposition, trap efficiency, density of deposited sediment, reservoir depletion rate, and expected life of the dams.

The socio-economic situation analysis reveals that **approximately 100,650 people residing in 74 villages** including scattered settlements directly benefit from the construction of these 14 dams. Additionally, there were indirect beneficiary communities such as short-term migrants, especially livestock holders. Thus, the overall outcome of the study shows that 100% of respondents were satisfied at Dhal Dhoro, Gabol, Naing-II, Qasim Tok, and Aripir; and more than 80% at Tikho-II (85%), Upper Mole-II (93%), Jungshahi (80%), Sankar (95%), and Bhansar Rathi (93%). However, at Sureshi Dam, though all respondents were satisfied with the development initiative, around 60% of the respondents favored a large-sized dam.

Groundwater recharge was reported across all dams. The majority of respondents shared that the water table has risen after the construction of dams. According to the notable KIIs and FGD participants at various dams, the average water table level has risen in between 25 to 50 feet. The data shows that due to an increase in the water table, the **cultivation of agricultural land is increasing**, and new crops such as onion, wheat, chili, cotton, and tomato are emerging. Traditionally, these areas have grown millet, sorghum, guar, sesame, mung, moth, and caster bean. Overall data shows the area under cultivation has increased by 15% at all dams.

The economic activity in agriculture, livestock, and agro-labor is gaining momentum after groundwater availability increases. Most respondents across all dams shared **an increase in their incomes by 34% with standard deviation of ± 18.63 after the construction of the dams.** The variation in agriculture income depends on the type of crop(s) being cultivated.

Livestock constitutes one of the significant sources of income and contributes to the food security of the people living in these areas. Respondents across all dams shared the positive impact of increased water availability on livestock. The improved water quality positively impacted livestock health, milk production, and the capacity to keep more livestock for longer. Thus, the dam intervention has increased water security, food security, and the community's bargaining power while selling animals.

In these areas, migration is a usual phenomenon. However, after the construction of dams, migration trends are changing. The respondents living in the vicinity of most of the dams categorically stated that the **migration-in has increased and the migration-out has decreased**.

Women and children are generally vulnerable to any disaster in the resource-poor and arid regions of the province. Nevertheless, results reveal that the small dams are positively impacting the overall socio-economic well-being of the communities and **helping cope with the adversities of women and children in particular.** Women spent hours fetching water for domestic uses, which has significantly reduced due to water availability near their homes. Moreover, nutrition and food insecurity have been the main issues in these regions, adversely affecting the health of women and children. With the construction of these dams, and in a short time after that, the improvement in food security is visible as people are growing high-value crops for domestic consumption and the market. Besides, **increased milk production significantly impacts children's health as it contributes to nutritional security**. In addition, the rise in income will potentially help the community to enroll their children in schools, as a long-term impact of the small dams.

Sediment deposition in the studied area has shown encouraging results. The sediment layer thickness was 2-6 inches at Dhal Dhoro, Gabol, Naing II, Qasim Tok, Ari Pir, Sureshi, Upper Mole, Konkar, Karamtiani, Sabusan, Sankar, and Bhansar Rathi. However, Tikho II and Jungshahi were most silted, where the sediment deposit was found around 3 feet.

Further, it is observed that Dhal Dhoro, Gabol, Ari Pir, Qasim Tok, Konkar, Karamtiani, and Bhansar Rathi have lost less than 3 percent of their storage capacity. Whereas, Gabol, Naing II, Sureshi, Upper Mole II, Sabusan, and Sankar have lost 3 to 6 percent of storage capacity. The maximum capacity that has been lost was observed at Jungshahi and Tikho II, which is about 10 to 16%.

The life of these Dams, thus calculated, is more than 25 years in most cases. However, few dams like Jungshahi and Tikho II may have fewer than 15 years of life. It is suggested that a mechanism for desilting the reservoir may also be developed to help increase the life of these dams. Furthermore, it is proposed that, wherever possible, another dam may be constructed upstream of the present dams. This action would help trap some of the sediments and thus increase the life of both the dams.

2 INTRODUCTION

The Sindh Resilience Project (SRP), funded by the World Bank (WB), comprises of three components i) Strengthening Disaster and Climate Risk Management, ii) Improving Infrastructure and Systems for Resilience, and iii) Contingent Emergency Response. The project's objectives are to mitigate flood and drought risks in selected areas and strengthen capacity of government of Sindh to manage natural disasters. The project is aimed to reduce vulnerability and risk within Sindh through a combination of physical works, strengthening fiscal resilience, and institutional development activities. The project is meant to provide benefits to the entire population of Sindh in general due to the increased capacity at the Provincial Disaster Management Authority Sindh, Sindh Irrigation Department, and the Finance Department to manage and respond to adverse natural disasters

The construction of Small Recharge Dams is one of the sub component of SRP project to address drought and flash flooding risks in the arid zones of Sindh province. This sub component supports the construction of small rainwater harvesting recharge dams, less than 10 meters in height, in the Kohistan and Nangarparkar regions. These small dams primarily contribute to the recharging of underground aquifers and providing water to communities during dry periods. Additionally, these dams are meant to protect communities against seasonal hill torrents and flash floods originating in the Kirthar Range.

Under this assignment of impact assessment and performance evaluation of 14 small dams was carried out. An approximate 100,650 direct beneficiaries reside in 74 villages and scattered settlements of the Kirthar range hills and the Nagarparkar region of Tharparkar desert. Currently this population is exposed to drought and food insecurity, will benefit from the construction of small dams for rainwater harvesting and recharging of groundwater aquifers. In addition, these dams also are meant to protect communities inhabiting the Kohistan area from flash flooding in the hills of the Kirthar Range. Further, about half of all project beneficiaries are estimated to be female, based on demographic information available for these areas.

2.1 SCOPE AND OBJECTIVES OF THE STUDY

The Government of Sindh through Sindh Irrigation Department under Sindh Resilience Project (Irrigation Component) awarded a study to conduct "Impact assessment and performance evaluation of 14 small dams in Sindh province" constructed in Kohistan and Nagarparkar regions to the U.S.-Pakistan Center for Advanced Studies in Water (USPCAS-W), Mehran University of Engineering and Technology and Carthago Consultancy as international consulting firm.

The overall aim of the study is to assess the post dam construction impacts in the areas with the following specific objectives:

1) To assess the socio-economic impacts of the "Recharge Dams" on the communities in the study areas.
2) To study the sedimentation and expected life of dams.

The study was scoped to undertake following tasks:

Task-1: Socio-Economic Impacts of Recharge Dams

Groundwater recharge by small dams needs to be beneficial to the local community, and it has to improve the livelihood of the people. It will result in changes in the quantity and quality of water, which in turn will have an impact on the people living in the nearby areas. Studies show that after the construction of small recharge dams, and improved livelihood in the nearby areas has been observed.

The yield and quality of crops produced have been improved significantly, as more water is available for agriculture after groundwater recharge. Due to the rise of the water table after the dam construction, and economical groundwater source is available for various purposes. Changes in cropping patterns, raising livestock, increased yield, and revenues have been observed after the construction of small dams worldwide. A review of research on socio-economic aspects of recharge dams suggests that water harvested increases income of the communities, mainly due to sustained subsistence agriculture. Women could save time as the water is made available near their homes.

The specific activities of under the Task-1 are as follows:

- Collection of data related to agriculture yield, different cropping patterns and increase in cultivable command area.

- Impact on project area population due to in-migration.
- Impact on household income assess through the beneficiary interviews.
- To assess the socio-economic and environmental impacts by field survey, local community interviews and questionnaire in the beneficiary areas.
- Quantification of the socio-economic improvement of the target beneficiary communities of each project as a result of increased agriculture area, yield, livestock and other direct and indirect benefits to their lives and livelihoods.
- Propose interventions to maximize the impacts to target beneficiaries and recommendations for future projects.

Task-2: Calculation of Sedimentation and expected life of dams

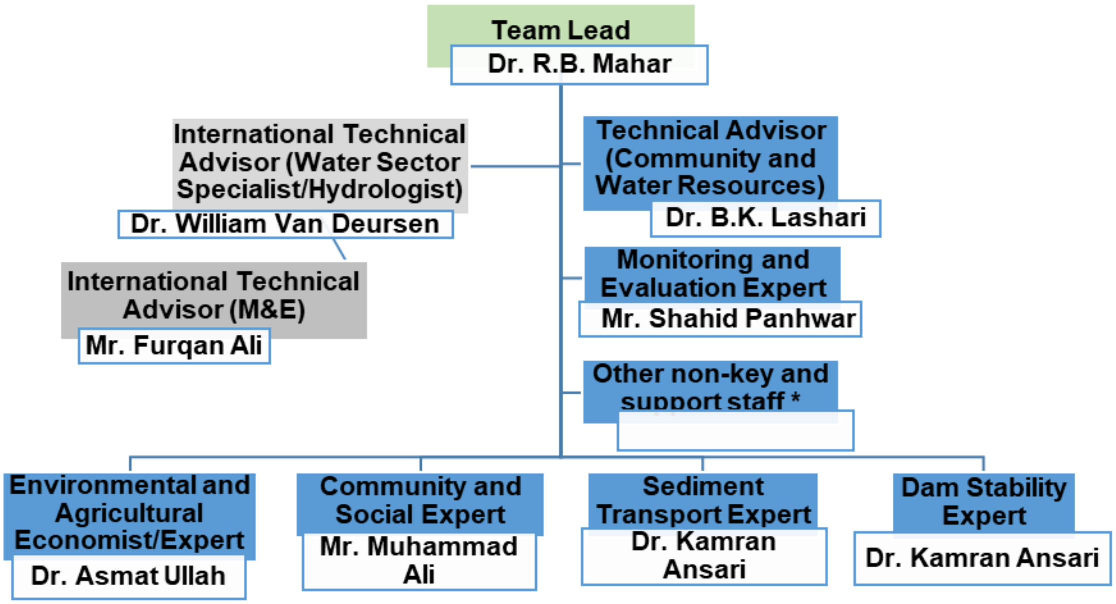
Reservoir sedimentation presents a major challenge to the sustainability of small dams in general. Due to degraded land cover and terrain of the catchments, the sediment inflow to the reservoirs of the small dams in dry, semi-arid zones are high and their expected operational project lives are relatively short. Unchecked sediment deposition also results in siltation of storage and intake blockage.

The specific activities of under the Task-2 were as follows:

- Submit survey plan and evaluation methodology at the inception stage.
- Investigate and quantify the sediment flux, size classification and deposition rates.
- Study the impact of sediment deposition on the live storage volume of the dams and evaluate the impacts of sediment on the sustainability of the reservoirs.
- Propose suitable interventions in the cases where alarming levels of sedimentation may significantly reduce operational life and usefulness of the dams.

2.2 TEAM FOR CONDUCTION THE STUDY

Being a national water center USPCASW was assigned to carry out this study by a group of national and international experts. The team of experts and their area of expertise is given as follows:



Other Support Staff

1) Accountant

2) Logistics

3) GIS Analyst

3 METHODOLOGY

The study has been conducted to evaluate the socio-economic impacts of 14 small dams constructed in Kohistan and Nagarparkar regions of Sindh Province. The study has focused on the benefits gained by the local communities in terms of their socio-economic well-being through improved water availability and accessibility for different uses including domestic, irrigation and livestock. The results from this study highlight the performance of these dams in terms of improved livelihood of the concerned communities. The essential missing links and the critical areas for improvements have also been identified. The study has solicited the feedback of beneficiary communities, SRP project staff and other stakeholders through survey, focus group discussions and key informant interviews. Besides, the study has also quantified the potential sediment load transported from the catchment of the streams up to the dam sites to assess the productive lives of the dams. The task-wise methodology adopted by the study included the following stages.

3.1 TASK-1: SOCIO-ECONOMIC IMPACTS OF RECHARGE DAMS

3.1.1 Desk Review

The USPCAS-W team reviewed the available reports and documents including baseline studies, feasibility reports, and other assessment reports etc. related to the small dams' initiative of the SRP project. The main aim of the desk review was to understand the context of the impact assessment assignment and document the work already done by SRP and avoid any duplication of effort. The SRP project office indeed facilitated in collecting all such material for review.

3.1.2 Sampling Strategy and Framework

A proportionate stratified sampling approach was applied for socio-economic data collection, considering the target group of the local community. The proposed sample size of the beneficiary households was drawn using an appropriate statistical and scientific method based on the target population for primary data collection regarding the impacts of the dams on their livelihoods.

A two-stage sampling design was employed using two main stages to select households around each dam that included:

1) **First stage:** selection of targeted villages.
2) **Second stage:** the identification of the targeted community members to be interviewed for the survey.

Depending upon the total population, a statistically representative sampling method was adopted to calculate the sample size considering a 95% level of confidence and 5% margin of error using multi-stage cluster sampling approach. It helped to maximize the internal and external validity of the survey data collected through interviewing individual community members. In total, 387 community survey interviews were conducted at all 14 small dams.

3.1.3 Field Data Collection

Tool Design: Separate tools were designed for beneficiary survey, focus group discussions, and key informant interviews. The tools were finalized in consultation with SRP team.

Survey Team Training: A separate survey team was formulated who carried out quantitative survey and assisted project team in collecting qualitative data through FGDs. The survey team was selected from among the active masters' students of USPCAS-W preferably having understanding of the subject matter, well versed with Sindhi language, and due number of female members.

When the survey tool was approved by SRP team, the tool was translated into Sindhi language with aim to avoid chances of ambiguity as the survey team might use different terminologies while translating from English to Sindhi during data collection. Since some terms, used in the survey questionnaire, are better understood and known in local language than in English so the translation of survey tool ensured uniformity and clarity in asking the survey questions.

Subsequent to selection of survey team, a three-day customized training was organized at USPCAS-W. All the survey teams were trained centrally to ensure uniformity. This training exercise built the team spirit and familiarity among each other. During the training, the participants were also provided background information regarding the area, local culture and how the various questions were to be worded in their local settings. The training was divided into three parts, first part was lecture based in house training, second part was pre-testing of the survey tool in the field and third part was comprised of the debriefing session which involved adjustments in the questionnaire. The training was attended by SRP representatives and their input was incorporated in finalizing the survey tool.

The data collected from the field was analyzed and triangulated. Village profile and socio-economic data were collected through a pre-designed semi-structured questionnaire (Annex-1&2). The questionnaire was tested in the field. Based on the recommendations of the representative of SRP and the feedback from the field, the questionnaire was revised and finalized. Besides primary data from the field, the study also collected secondary data related to the impacts of the selected dams. The study also tried to ensure women's participation through FGDs and their feedback has been documented about the benefits of the dams on their lives while considering the local cultural dynamics. Besides key informants from different stakeholders were also interviewed to validate the data collected through field survey. Separate question guide for FGDs, and key informant interviews were developed and are annexed to this report as Annex-3, and Annex-4.

It was found during the field survey that some villages included in the list of specific dams were not benefitting from the dams so those villages were replaced with the ones benefitting from the construction of dams. Meanwhile, it was agreed that focus of the survey should be to reach out to those villages/households which are situated near to dams and not necessarily stuck with the list of villages provided in the SRP reports. Hence, the survey has been completed accordingly and the detail of surveyed villages is given in Annex-1.

Focus Group Discussions: FGDs focused on knowing the socio-economic impacts of dams and included about groundwater recharge, cropping pattern change, new crops introduced, change in yield of the crop, inward migration, improvement in population and health of livestock, protection from floods, improvement in a drought situation, change in use of energy (solar pumping), drinking water situation, rise in income from agriculture, livestock and business, and change in status of health and schooling.

In total, 25 FGDs were conducted for all 14 dams. This included 11 FGDs with females and 14 with males. No FGD could be conducted at Qasim Tok dam whereas, female FGD at Sankar and Bhansar dam could also not be done due to cultural constraints.

The dam wise breakup of the FGDs conducted in the field is given in Table 1.

Table 1: Number of FGDs Conducted at each Dam

Name of Dam	No. of FGDs	Male/ Female	Date	Place	No. of Participants
Dhal Doro	2	Male	28.06.22	Village Khaidin Gabol	8
		Female	28.06.22	Village G M Gabol	15
Gabol	2	Male	28.06.22	Village Juman Gabol	6
		Female	28.06.22	Village Juman Gabol	12
Naing-II	2	Male	27.06.22	Village Qadir Bux Nohani	12
		Female	27.06.22	Village Qadir Bux Nohani	10
Qasim Tok	0	--	--	--	--
Aripir	2	Male	11.07.22	Village Saifal Faqeer	14
		Female	11.07.22	Village Photo Khaskheli	12
Sureshi	2	Male	07.07.22	Village Nabi Bux Barejo	10
		Female	07.07.22	Village Suleman Barejo	12
Tikho-II	2	Male	07.07.22	Village Safar Barejo	10
		Female	07.07.22	Village Safar Barejo	8
Upper Mole-II	2	Male	11.07.22	Village Moton Khan Hamlani	6
		Female	11.07.22	Village Teroo Khaskheli	6
Junghshahi	2	Male	09.07.22	Village Mal Mari	6
		Female	09.07.22	Village Mal Mari	8
Konkar	2	Male	06.04.22	Chanesar Jokhio	8
		Female	06.04.22	Konkar Stop	7
Karamtiani	2	Male	09.07.22	Village Haji Jokhio	12
		Female	06.04.22	Malang Goth	6
Sabusan	2	Male	13.04.22	Sabusan Village	8
		Female	13.04.22	Wadhan Jo Wandio	6
Sankar	1	Male	14.04.22	Sankar Village	8
Bhansar Rathi	2	Male	13.04.22	Rathi Villag	6
		Male	13.04.22	Pabasro Village	6

Key Informants interviews: The KIIs were conducted through a semi-structured questionnaire attached as Annex-4. The list of targeted key informants from different organizations was finalized in consultation with the SRP team, which included informant interviews with representatives of the Revenue Department, Pakistan Agriculture Research Council, Irrigation Department, SRP, Academia, and NGOs operating in the project area and notables.

3.1.4 Data Analysis

Data entry and cleaning was done at the completion of data collection. All the survey questionnaires were reviewed, cleaned, and coded before the data entry. Once the data entry was completed, 10% of questionnaires were rechecked to analyze the quality and reliability of data entry. Data cleaning was done on excel by applying filters which helped correct the mistakes of the data entry and finalized the data for analysis. Descriptive statistics i.e., frequencies and cross-tabulations were performed and the results are presented in graphs and tables.

3.1.5 Ethical Consideration

To ensure the truthfulness of the responses and to reduce the biases, ethical considerations such as the introduction of the field team, the purpose of the study, assurance to maintain the anonymity of the respondents while reporting the data, and their willingness to participate in the survey were prudently followed.

3.2 TASK-2: SEDIMENTATION RATE

3.2.1 Introduction

All reservoirs formed by dams on natural water courses are subject to some degree of sediment inflow and deposition. The problem confronting the project planner is to estimate the rate of deposition and the period of time before the sediment will interfere with the useful function of the reservoir. Provisions should be made for sufficient sediment storage in the reservoir at the time of design so as not to impair the reservoir functions during the useful life of the project or during the period of economic analysis.

There are a series of basic steps to follow in studying the sedimentation processes in reservoirs. First, sediment transported by the upstream river system into a reservoir is deposited and/or transported at a reduced rate further into the reservoir, the distance being dependent on the decreased water velocities. As sediment accumulates in the reservoir, storage capacity is reduced. The continued deposition develops distribution patterns within the reservoir which are greatly influenced by both operations of the reservoir and timing of large flood inflows.

The sediment related features requiring study are the sediment inflow, deposition, and degradation processes. Sedimentation processes in a reservoir are quite complex because of the wide variation in the many influencing factors. The most important being, (1) hydrological fluctuations in water and sediment inflow, (2) sediment particle size variation, (3) reservoir operation fluctuations, and (4) physical controls or size and shape of the reservoir. Other factors that for some reservoirs may be quite important are: vegetative growth in upper reaches, turbulence and/or density currents, erosion of deposited sediments and/or shoreline deposits, and operation for sluicing of sediment through the dam. It is because of this complexity that empirical relationships developed from surveys of existing reservoirs are being used to define sediment depositional patterns. Many mathematical models are being developed to simulate the physical processes of sediment transport and deposition in reservoirs.

3.2.2 Methods of determining sediment inflow

Sediment is the end product of erosion or wearing away of the land surface by the action of water, wind, ice, and gravity. Water resource development projects are most affected by sediment which is transported by water. The total amount of onsite sheet and gully erosion in a watershed is known as the gross erosion. However, all the eroded material does not enter the stream system; some of the material is deposited at natural or manmade barriers within the watershed and some may be deposited within the channels and their flood plains. The portion of eroded material which does travel through the drainage network to a downstream measuring or control point is referred to as the sediment yield. The sediment yield per unit of the drainage area is the sediment yield rate.

Most methods for predicting sediment yields are either directly or indirectly based on the results of measurements. Direct measurements of sediment yields are considered the most reliable method for the determination of sediment yields. This is accomplished by either surveying reservoirs or sampling the sediment load of a river. Other methods for predicting sediment yields depend on measurements to derive empirical relationships or utilize empirically checked procedures such as the sediment yield rate weighting factors or the Universal Soil-loss equation.

3.2.3 Sediment yield rate factors

The factors which determine the sediment yield of a watershed as mentioned earlier can be summarized as follows:

1. Rainfall amount and intensity
2. Soil type and geologic formation
3. Ground cover

4. Land use
5. Topography
6. Upland erosion (nature of drainage network-density, slope, shape, size, and alinement of channels)
7. Runoff
8. Sediment characteristics - grain size, mineralogy, etc.
9. Channel hydraulic characteristics

Some researchers have deemed it necessary to include some additional factors; however, even the nine above are interrelated. As an example, a heavy vegetative cover is dependent upon at least a moderate amount of rainfall; however, the ground cover conditions could be upset by tillage practices, overgrazing, or fire. Sediment transported from the drainage basin to a reservoir is controlled by the sediment transport characteristics of the river which is influenced by the first six factors but reflects a more direct combination of items 7, 8, and 9.

3.2.4 Reservoir resurvey data

Measurement of the sediment accumulation in a reservoir is considered by many engineers as the best method for determining the sediment yield. Surveys of existing reservoirs for determining loss of storage space and distribution of sediment deposits within the reservoir provide data on sediment yield rates as well as for operations purposes. It is important that when construction is completed on a dam, a plan be established for surveying or monitoring the sediment accumulation. Even before the construction of the dam is completed, a decision is needed on the basic method selected for future surveys and the technique for analyzing sediment accumulation.

The main purpose of a reservoir survey is to determine the storage capacity at the time of the survey which when compared to an earlier survey (usually the original survey) gives the sediment accumulation. The storage volume computations are made from an area-capacity corresponding to each elevation in the area-elevation data set and fitting the capacity-elevation relationship using either cubic spline or least square set of equations. The end product of the area-capacity computations is the plot of the areas and capacities for the original and new surveys. Other worthwhile analyses of data from reservoir sedimentation surveys are to make a plot of percent reservoir depth versus percent sediment deposit or to plot a sediment deposition profile throughout the length of the reservoir.

At the time of the reservoir survey, data are also needed on some of the characteristics of the sediments both as deposited and moving through the reservoir. Samples of deposited sediments should be spaced throughout the reservoir area to be representative of deposits in the top-set and fore-set slopes of the delta as well as at the bottom-set slopes in the deeper parts of the reservoir. Analysis of the samples collected consists of density, particle-size distribution and mineralogic composition. These data on deposited sediments are used for a better understanding as to the source of incoming sediments.

3.2.5 Sedimentation Rate

The reservoir sedimentation rate was determined according to the relationship given by "Design of Small Dams" by USBR. This relationship was developed for reservoirs in arid regions of United States between the sediment yield and drainage area. The equation for the plot is given as follows:

$$Q = 1.84A^{-0.24}$$

Where,

Q is the sediment yield in acre-ft per square mile

A is the drainage area in square miles

3.2.6 Reservoir sediment deposition

Once the estimated sediment inflow to a reservoir has been established, attention must be given to the effect the deposition of this sediment will have upon the life and daily operation of the reservoir. The mean annual sediment inflow, the trap efficiency of the reservoir, the ultimate density of the deposited sediment, and the distribution of the sediment within the reservoir, all must be considered in the design of the dam.

3.2.7 Trap efficiency

The trap efficiency of a reservoir is defined as the ratio of the quantity of deposited sediment to the total sediment inflow and is dependent primarily upon the sediment particle fall velocity and the rate of flow through the reservoir. Particle fall velocity may be influenced by size and shape of the particle, viscosity of the water, and chemical composition of the water. The rate of flow through the reservoir is determined by the volume of inflow with respect to available storage and the rate of outflow.

Methods for estimating reservoir trap efficiency are empirically based upon measured sediment deposits in a large number of reservoirs. Gunnar Brune (1953) has presented a set of envelope curves for use with normal ponded reservoirs using the capacity-inflow relationship of the reservoirs.

Using data from Tennessee Valley Authority reservoirs, M. A. Churchill (1948) developed a relationship between the percent of incoming sediment passing through a reservoir and the sedimentation index of the reservoir. The sedimentation index is defined as the ratio of the period of retention to the mean velocity through the reservoir. The Churchill curve has been converted to a truly dimensionless expression by multiplying the sedimentation index by “g”, acceleration due to gravity.

A general guideline is to use the Brune method for large storage or normal ponded reservoirs and the Churchill curve for settling basins, small reservoirs, flood retarding structures, semi-dry reservoirs or reservoirs that are continuously sluiced.

3.2.8 Density of deposited sediment

Samples of deposited sediments in reservoirs provide useful information on the density of deposits. The density of deposited material in terms of dry mass per unit volume is used to convert total sediment inflow to a reservoir from a mass to a volume. The conversion is necessary when total sediment inflow is computed from a measured suspended and bed material sediment sampling program. Basic factors influencing density of sediment deposits in a reservoir are (1) the manner in which the reservoir is operated, (2) the texture and size of deposited sediment particles, and (3) the compaction or consolidation rate of deposited sediments.

The reservoir operation is probably the most influential of these factors. Sediments that have deposited in reservoirs subjected to considerable drawdown are exposed for long periods and undergo a greater amount of consolidation. Reservoirs operating with a fairly stable pool do not allow the sediment deposits to dry out and consolidate to the same degree.

The size of the incoming sediment particles has a significant effect on density. Sediment deposits composed of silt and sand will have higher densities than those in which clay predominates. The classification of sediment according to size as proposed by the American Geophysical Union is given in Table 2.

Table 2: Classification of sediments according to size

Sediment Type	Size range in mm
Clay	Less than 0.004
Silt	0.004 to 0.062
Sand	0.062 to 2.0

The influence of reservoir operation is most significant because of the amount of consolidation or drying out that can occur in the clay fraction of the deposited material when a reservoir is subjected to considerable drawdown. The size of sediment particles entering the reservoir will also have an effect on density as shown by the variation in initial masses. Reservoir operations were classified according to operation as given in Table 3. Operation number 3 is selected for this study.

Table 3: Classification of reservoir operations

Operation	Reservoir Operation
1	Sediment always submerged or nearly submerged
2	Normally moderate to considerable reservoir drawdown
3	Reservoir normally empty
4	Riverbed sediments

Selection of the proper reservoir operation number usually can be made from the operation study prepared for the reservoir.

Once the reservoir operation number has been selected, the density of the sediment deposits can be estimated using the following equation:

$$Y = W_c p_c + W_m p_m + W_s p_s$$

Where,

$Y =$ unit weight in pounds per cubic foot (density in kilograms per cubic meter)

$p_c,\ p_m,\ p_s$ are the percentages of clay, silt and sand respectively of the incoming sediments.

$W_c,\ W_m,\ W_s$ are the coefficients of clay, silt and sand respectively which can be obtained from the following tabulation as shown in

Table 4.

Initial weight (initial mass) in lb/ft^3 (kg/m^3)

Table 4: Initial weight (mass) of clay, silt and sand

Operation	Initial weight (Initial mass) in lb/ft^3 (kg/m^3)		
	W_c	W_m	W_s
1	26 (416)	70 (1120)	97 (1550)
2	35 (561)	71 (1140)	97 (1550)
3	40 (641)	72 (1150)	97 (1550)
4	60 (961)	73 (1170)	97 (1550)

3.2.9 Reservoir Depletion Rate / Expected Life of Dam

The expected life of the dam was determined by calculating the reservoir depletion rate which depends upon the trap efficiency and the density of the sediments accumulated in the reservoir. The sediments trap efficiency for the weirs will be calculated with the help of either Brune Medium Curve or Churchill Curve as given by USBR Design of Small Dams. Whereas the density of the sediment material can be estimated by the above relationship based on grain size analysis of the stream bed materials. The sediment samples were collected from the upstream of the small dams to ascertain the size and classification of the soil.

3.2.10 Soil Sample Collection and Depth of Sediment Deposition

Soil Samples were collected from the ponding areas of Dams carefully along the changing elevation i.e. contours so that we have a representative sample, after collecting the sample it was put carefully into marked sample collection bag.

While collecting sample sediment deposit depth/thickness was also noted in order to do that augurs and other digging tools were used a scale was used for measuring the depth, and multiple measurements were done so as to give a representative average and result in GIS analysis.

While doing so area was also observed for the classification i.e. land use land cover (LULC).

3.2.11 Softwares used

The following softwares were used while conducting this study for the purposes given under each.

ArcGIS was used for:

(i) Delineating the catchment
(ii) Calculating the storage and changes in storage of Dam Pond/Reservoir
(iii) Finding the land use land cover of the catchment.

HEC-HMS was used for:

(i) Rainfall runoff modelling
(ii) Finding the average annual inflows
(iii) Inflows during 2020 and 2021

Google Earth was used for:

(i) Locating the Dams and digitizing the structures
(ii) Supervising land use land cover (LULC)

3.2.12 Digital Elevation Model (DEM)

Copernicus DEM was used for delineating the catchment and calculating the storage of Dam. Copernicus DEM is by far the latest openly available digital elevation model.

4 FINDINGS, RESULTS, AND DISCUSSION

4.1 TASK 1: SOCIO-ECONOMIC IMPACTS OF RECHARGE DAMS

The socio-economic impact of an intervention is predominantly linked to the situation of the community's condition before that intervention. Although the interventions aim to bring positive impacts and improve the well-being of the targeted communities, sometimes it gets negative impacts, or only the communities can perceive it negatively. To see the real impacts, the responses of different informed community members need to be recorded and analyzed.

4.1.1 Respondents' Profile

In this section dam wise gender, age, and family size of respondents are discussed.

4.1.1.1 Gender

Both male and female community members were interviewed during the data collection. Nevertheless, considering the socio-cultural setting and associated barriers and limitations, the permission of male members (generally the household heads), was sought to interview the female members of the community. In places where the male members were uncomfortable and did not allow interviewing female members, the participation of the female respondents became lower than half of the total participants of that locality. The percentage responses of male and female participants at each dam reflect this feature of the respondents.

The data shows the variation in gender participation concerning the area and location of the small dam. As given in Figure 1 the highest female participation was observed at Konkar, Jungshahi, and Karamtiani as 55%, 47%, and 35% respectively. Whereas, no female participation could be ensured at Sureshi, Tikho-II, Aripir, and Naing-II dams. The highest female participation in the said areas was probably for the reason that these small dams are nearby Karachi city and have an impact of urban settlements. However, the lowest or no female participation was observed in areas which are situated in the middle of arid zones and away from urban settlements. The cultural practices have also impacted the female participation in the survey as zero female participation areas have Baloch and other tribal cultural practices.

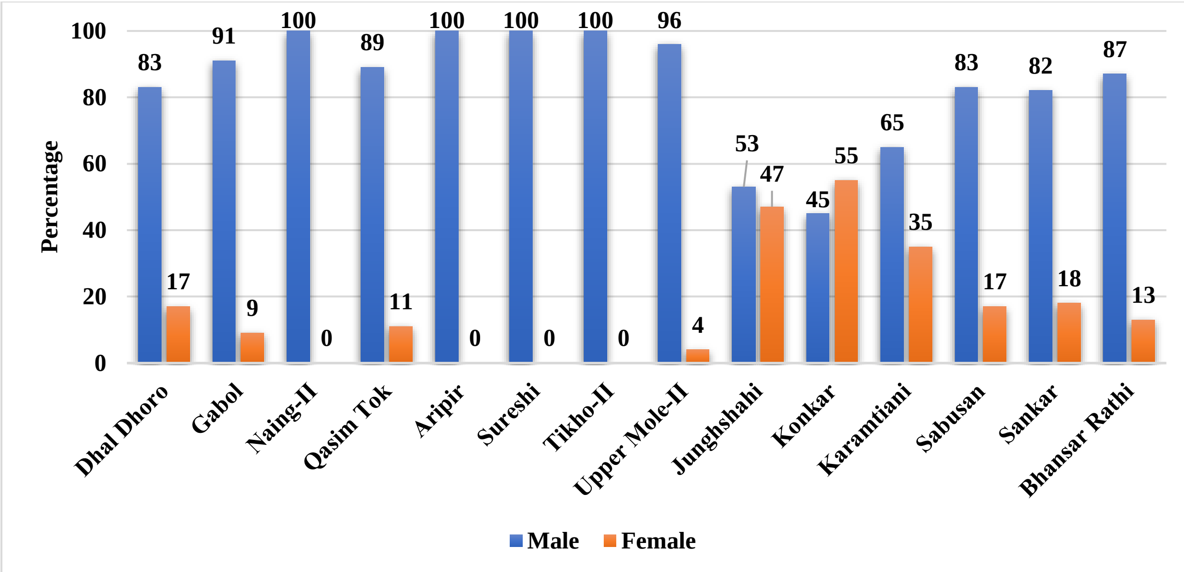


Figure 1: Gender-wise Respondents

4.1.1.2 Age

Age was another aspect that was considered to get responses from active and well-informed community members. The data shows the mixed age group of respondents at all dams. The age of the respondents ranged between 20 to 85 years, making the dataset representative of all ages including youth. The lowest average age of 36 years of respondents was observed at Dhal Dhoro small dam area, and the highest average age of 47 years was observed at Junghshahi small dam area. The average age of the respondents at other small dams is given in Table 5.

Table 5: Age of Respondents

Name of Dam	Maximum	Minimum	Average
Dhal Dhoro	80	22	36
Gabol	74	25	43
Naing-II	70	21	40
Qasim Tok	70	25	41
Aripir	62	20	38
Sureshi	66	21	40
Tikho-II	60	18	37
Upper Mole-II	70	25	43
Junghshahi	74	22	47
Konkar	70	20	38
Karamtiani	85	22	42
Sabusan	72	18	41
Sankar	62	20	38
Bhansar Rathi	80	21	44

4.1.1.3 Family Size

Generally, the economic activities of the family members are associated with the family size. Therefore, it helps to define and explore the family's dependence on resources and the impacts of the development-related interventions. The largest average family size has been observed at Sureshi, Upper Mole-II, Aripir, and Naing-II, with the size of 14, 13, 13, and 11 family members, respectively. The data reveals that in these areas, people defined family as a "combined kitchen" instead of Nikkah or Marriage. The data shows that joint family system exists in these areas. The average family size on other dams is given in

Table 6. The data reveals that at Naing-II, Qasim Tok, Tikho-II, Upper Mole – II, Bhansar Rathi has more females than males.

Table 6: Average Household Size of Respondents

Name of Dam	Total	Male	Female
Dhal Dhoro	7	4	3
Gabol	7	4	3
Naing-II	11	5	6
Qasim Tok	7	3	4
Aripir	13	7	6
Sureshi	14	7	7
Tikho-II	9	4	5
Upper Mole-II	13	6	7
Junghshahi	8	4	4
Konkar	8	4	4
Karamtiani	8	4	4
Sabusan	8	4	4
Sankar	9	5	4
Bhansar Rathi	9	4	5

4.1.2 Source of Income

4.1.2.1 Main Source of Income

Overall, agriculture, labor, and livestock were reported as the main sources of income by respondents of all 14 dams. While small businesses, government and private jobs, and home-based embroidery work were also reported as income sources. The percentage responses of the community regarding their main source of income are given in Table 7.

Agriculture has been reported as the main source of income at the Dhal Dhoro dam, Gabol dam, Naing-II dam, and Aripir dam areas. The livestock has been reported as the main source of income at Junghshahi dam and Karamtiani dam. During male FGDs, the participants informed that they keep livestock for selling at the Karachi market, especially on the eve of Eid-ul-Adha. Labor has been reported as the main source of income at Qasim Tok, Sureshi, Upper Mole-II, Sabusan, Sankar, and Bhansar Rathi. It was revealed during discussions with the community that along with daily wage labor in local agriculture fields, people often go for wage labor in nearby cities and towns. At Sabusan, male FGD participants informed that at least one person from each household works at Karachi and Hyderabad on daily wages, whereas at a male FGD of Sankar dam, participants informed that almost half of the villagers are seasonal migrants, especially in wheat and sugarcane harvesting season they migrate to Sindh for agriculture labor work.

*Table 7: Main Source of Income (%)**

Name of Dam	Agriculture	Livestock	Labor	Business	Job	Embroidery
Dhal Dhoro	67	11	33	0	17	0
Gabol	73	32	50	5	0	0
Naing-II	83	39	11	0	6	0
Qasim Tok	33	11	67	0	11	0
Aripir	80	0	20	0	0	0
Sureshi	56	11	61	6	17	0
Tikho-II	65	0	65	20	0	0
Upper Mole-II	22	4	67	4	4	0
Junghshahi	25	45	30	20	35	5
Konkar	0	3	53	8	45	0
Karamtiani	14	64	50	43	21	0
Sabusan	34	10	86	3	0	0
Sankar	26	19	70	7	11	0
Bhansar Rathi	46	15	64	5	12	0

*** Respondents were allowed to choose multiple options as their source of income**

4.1.2.2 Loan

People go for loans either to expand their existing business or for subsistence. Nevertheless, people mainly take subsistence loans in arid and rain-fed rural settings. To identify the structure of financing facilities in the dam areas/villages, the survey asked respondents whether they take loans or not. The percentage responses of the respondents' regarding taking loans are given in Figure 2. The data reveals that the majority of respondents, around 62%, do not avail of any formal or informal loans. But the dams-wise situation was different, wherein 50%, 67%, and 76% of respondents at Gabol, Qasim Tok, and Sabusan dams informed that they take formal loans.

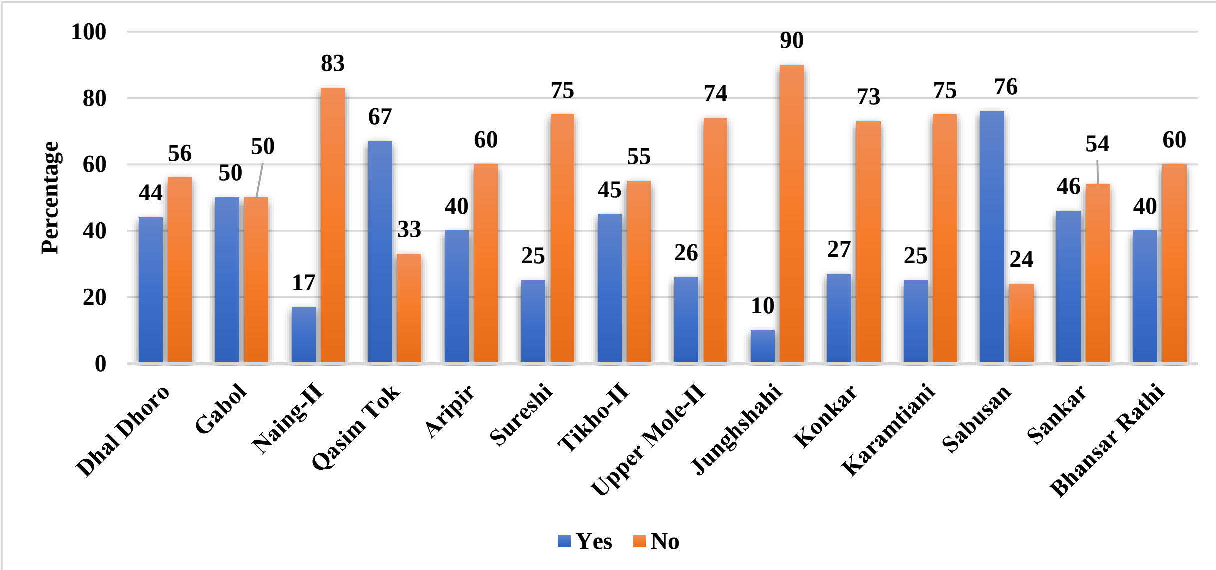


Figure 2: Loan

Further, most of the respondents reported that they take informal loans except those at Tikho-II dam, Upper Mole-II, Sabusan, Sankar, and Bhansar Rathi. Further respondents from these areas informed that they take loans from microfinance organizations such as Thardeep Rural Development Program (TRDP) in Tharparkar, Jamshoro and Dadu Districts, and Baanhn Beli at Nagarparkar. It was interesting to observe that people preferred to go for a formal loan facility, if it was available for them in the area. However, it still requires a new product design to encourage formal loans in these areas. The Microfinance Institutes (MFIs) need some innovative products to cater to the needs of the small dam areas. In some newly constructed small dam areas, such as Dhal Dhoro, Naing-II, Qasim Tok, Sureshi, Junghshahi, and Karamtiani respondents shared they still take informal loans as no or limited formal financing facility is available. The percentage responses of the respondents regarding the source of taking loans are given in Figure 3. A participant in a male FGD stated;

"why will you go to seth (informal lender) if a formal financing facility (bank/MFI) is available".

Whereas a notable key informant stated;

"……now we hope that these organizations (MFIs, NGOs) will come in our area after the dam construction as water availability will increase the chances of more reliable income."

MFIs must offer carefully designed products as per the need of the area. Such as Junghshahi small dam area is untapped with regard to formal financing facility where the main source of income of people is livestock.

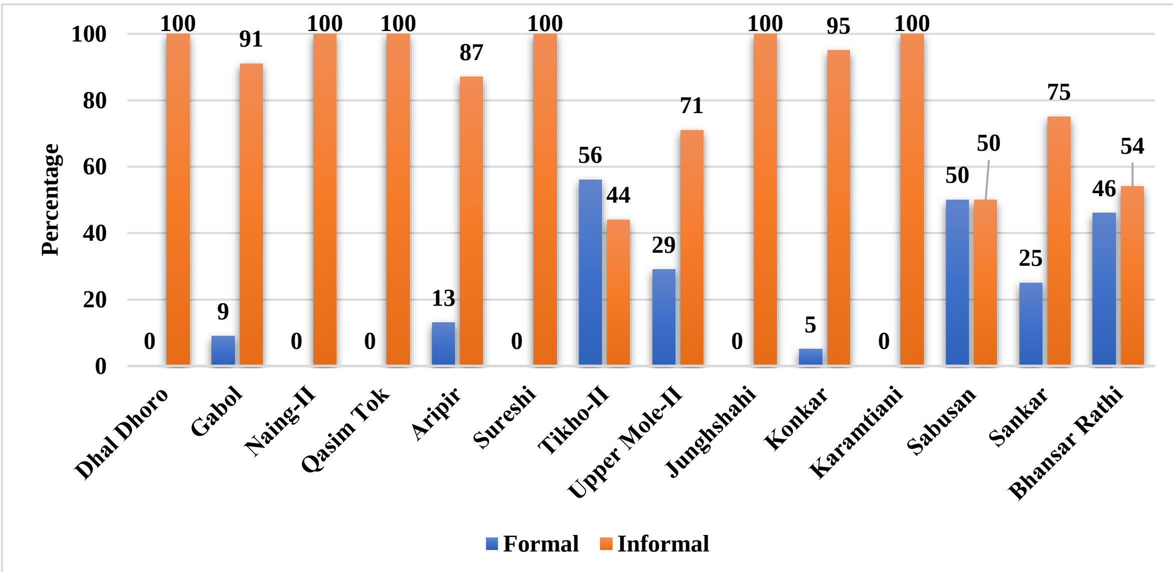


Figure 3: Formal or Informal Loan

Further, most of the participants disagreed with the statement (see Figure 4) that loan requirements had increased after the construction of the dam except at the Gabol dam, where 55% of people agreed that there is an incremental change in taking loans after the construction of the dam. A local key informant stated that;

"... it (loan demand) will increase in future, as so far our dam has filled only once since its completion two years back".

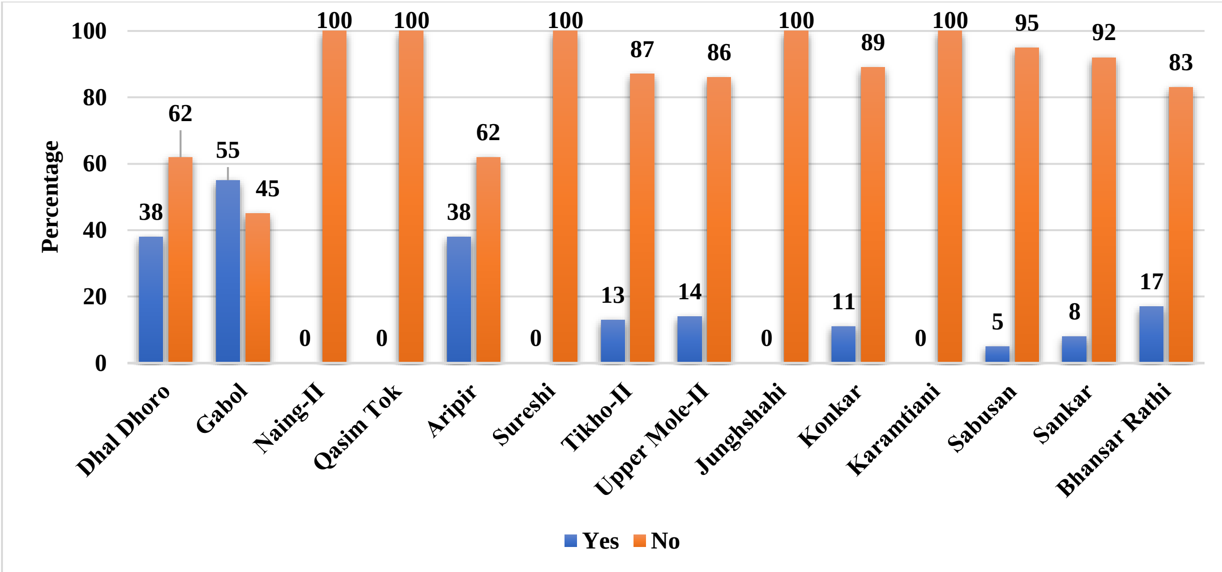


Figure 4: Change in Duration of Taking Loan after Construction of Dam

4.1.2.3 Increase in Income

Availability of water is instrumental towards the increase in the income of the rural people unless it comes in the form of a flood. The small dams were constructed to store water for a certain period and recharge the groundwater. It has allowed the local people to increase their income through different uses of water from the small dams for an extended period. In response to a question concerning the increase in family income after the construction of the dam (see Figure 5), the majority of respondents at eleven dams responded positively except for three dams namely; Konkar, Karamtiani, Sabusan. However, during the discussion with the community at Konkar and Karamtiani, participants stated that:

"since the dams have yet not filled therefore we are not in a position to tell the impact of dam on family income",

Figure 5 reflects that the construction of dams has positively impacted people's income, and most of the respondents are found satisfied with dams regarding their income increase. Nevertheless, some dams have recently been completed and their long-term impacts on communities' income are yet to come in the coming years.

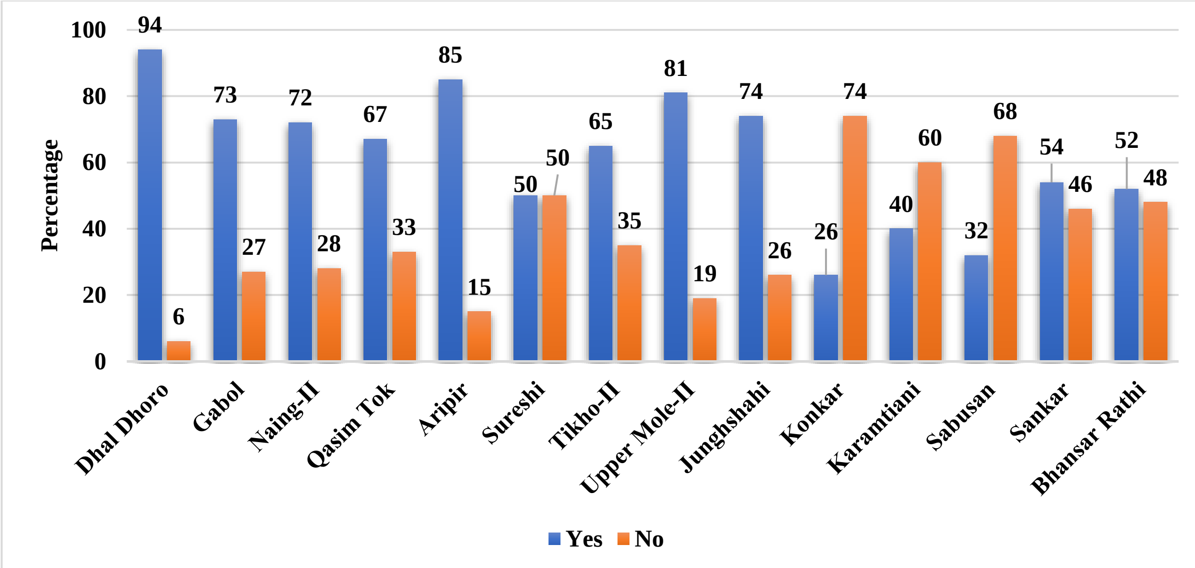


Figure 5: Increase in Family Income after Construction of Dam

Further, the respondents who reported increase in their family income after the dam construction believed that their income has increased mainly from agriculture, livestock, and agricultural labor. The respondents also reported an increase in business and job (see Table 8).

Table 8: Increase in Income Type (%)*

Name of Dam	Agriculture	Livestock	Agricultural Labor	Business	Job
Dhal Dhoro	76	12	29	0	12
Gabol	94	38	25	6	0
Naing-II	100	62	0	0	0
Qasim Tok	83	67	17	0	0
Aripir	76	24	82	6	6
Sureshi	40	10	80	10	20
Tikho-II	62	15	77	8	0
Upper Mole-II	59	27	77	9	9
Junghshahi	50	86	29	36	21
Konkar	11	47	58	11	37
Karamtiani	25	88	50	50	13
Sabusan	33	78	22	11	0
Sankar	60	73	20	7	7
Bhansar Rathi	43	87	17	7	3

*** Respondents were allowed to choose multiple options as their income type increased.**

The agricultural yield per acre and area under cultivation has found positive changes after dam construction at all sites. The agricultural income calculations are based on the yields of different crops. The data reveals that the approximate increase in agriculture income stand as 33% for the communities at all 14 dams as given in Table 9.

The maximum increase in income has been reported for the community of Junghshahi dam area i.e. 75% whereas, the minimum increase in income was reported for Sureshi dam community i.e. 1%. Moreover, it is evident from the data that at Junghshahi dam area, wheat and tomato crops have been introduced and promoted which has enhanced the income by 150% and 163% respectively. The income from the newly emerging Chili crop in the Naing-II dam area has increased by 120%. At Konkar and Karamtiani dam area, people are adopting new crops and mostly moving from traditional crops to orchards to take advantage of their location near Karachi markets.

Table 9: Crop-wise Percentage Increase in Agri-Income

Name Of Dam	Crop-Wise Income Enhancement Data in Percentage (%)												Percentage Increase in Agri-Income
	Millet	Sorghum	Guar	Sesame	Mung	Moth	Caster	Onion	Wheat	Chili	Cotton	Tomato	
Dhal Dhoro	-	-	-	-	-	-	-	55	27	64	-	-	49
Gabol	-	-	-	-	-	-	-	53	47	67	-	-	56
Naing-II	-	-	0	-	-	-	-	14	16	120	-	-	38
Qasim Tok	-	-	64	-	-	-	-	-38	54		-	-	27
Aripir	-	-	7	-	-	-	-	12	50	52	-	-	30
Sureshi	-	5		-	-	-	-	15	-	-	-	-	10
Tikho-II	-	-	-	-	-	-	-	27	18	-	50	-	32
Upper Mole-II	-	14	11	-	-	-	-	16	12	-	-		13
Junghshahi	16	10	34	-	-	-	-		150	-	-	163	75
Konkar	-	-	-	-	-	-	-	-	-	-	-	-	No Crop Data
Karamtiani	-	-	-	-	-	-	-	-	-	-	-	-	No Crop Data
Sabusan	17	32	29	3	16	4	31						19
Sankar	45	-	21	44	40	22	-	-	-	-	-	-	34
Bhansar Rathi	25	-	25	9	31	30	-	-	-	-	-	-	24

4.1.3 Satisfaction from Construction of the Dam

100% of respondents at Dhal Dhoro dam, Gabol dam, Naing-II dam, Qasim Tok dam, and Aripir dam believed that the dam benefitted them. While 96% at Sankar dam and 93% at Bhansar Rathi and Upper Mole-II dam, 85% at Tikho-II dam, 80% at Junghshahi dam, 75% at Karamtiani dam, 76% at Sabusan dam, and 59% at Konkar dam responded that the dam was beneficial for them. On the other hand, respondents of only one dam Sureshi expressed their un-satisfaction (see Figure 6). Upon inquiring during FGD with males, it was shared that:

"size of the dam is small that even it cannot stop the water of one good rain and overflows quickly".

The Konkar and Karamtiani participants shared that they are still waiting for their dams to be filled, and respondents at Sabusan indicated location of the dam was an issue.

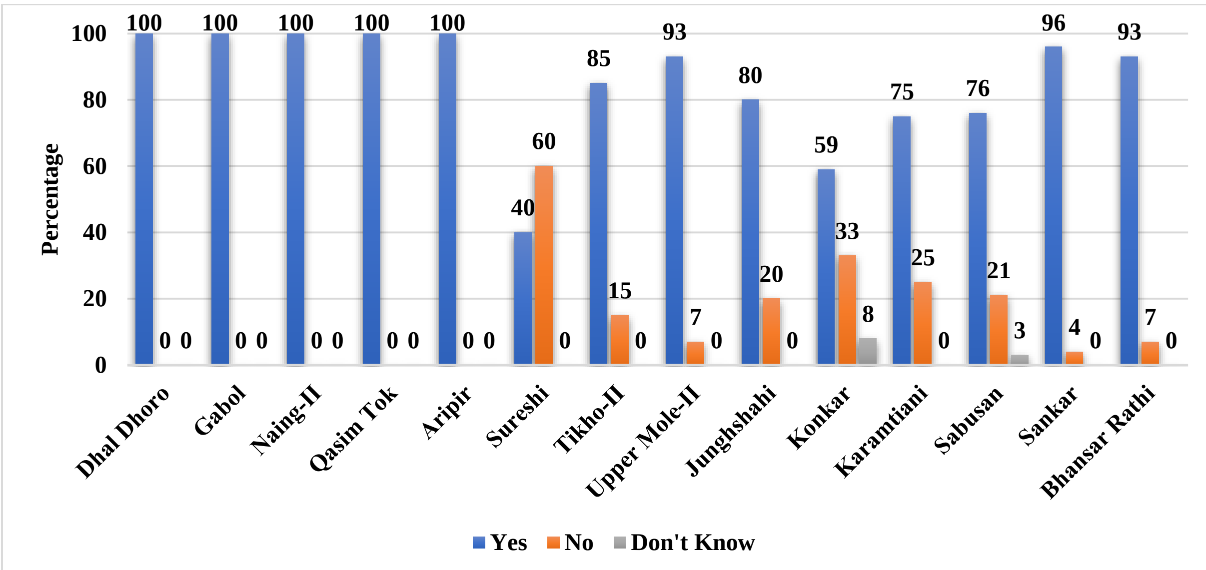


Figure 6 : Construction of Dam is Beneficial

A key informant clearly stated that the community perception regarding the size and location of the dam is just their view as the size and location of dams are purely technical and decided based on feasibility studies. The respondents were asked to present their views on the potential benefits of the dams with respect to a) improvement in the availability of water for domestic consumption and drinking, b) increased water availability for livestock, c) increased water availability for agriculture, and d) groundwater recharged (see Table 10).

During the discussion at Dhal Dhoro dam with males, respondents stated that:

"not only has water availability for drinking and domestic use improved, but now we have improved water availability for our livestock and agriculture as well".

Another participant stated that:

"groundwater recharge has improved and now we get drinking water to feed ourselves and our livestock round the year, otherwise, we used to walk miles to fetch water."

A female participant of a FGD stated that:

"earlier, we used to bore the pipe at 200 feet, but now after the dam, the groundwater is available at 70 to 80 feet."

At Gabol dam, respondents shared that the overall water situation has improved, especially for human and livestock consumption. They stated that:

"Before dam construction, the water availability was only for a few months, but now we consume stored water up to 6 months and for remaining time period we use groundwater as the dam has improved the water table."

A female FGD participant at Gabol informed that;

"the color and taste of the groundwater has improved, and earlier it used to take us 3 hours to get water during the dry season, but now we save at least 2 hours in fetching water"

At Naing-II, participants believed that after dam construction water availability has improved at all levels for humans, livestock, and agriculture. The survey data reveals that 100% of respondents believed that the groundwater situation has improved. The same was confirmed during FGDs which indicated that;

"before construction of dam there was no water available in last months of the year (march to June), but after the dam, the water table has increased, and water is available throughout the year."

Another male participant of the FGD stated that:

"For drinking purposes, we dependent on company[1] water supply, but now we fetch water from our bores - not only for ourselves but for our livestock as well, now we don't wait for company water supply."

FGD female. Upon inquiring the quality of water

[1] Oil & Gas Company

"the bore (Hand pump) installed at the dam has best quality and taste and the quality and taste of bores (hand pumps) in our homes has decreased in the last months of the year (May-June)."

During female FGD at Qasim Tok, participants agreed that after the construction of the dam water availability situation has improved at all levels, but 100% of respondents agreed that water availability has significantly improved for livestock. This shows that the people of the area were mainly worried about the water availability for their livestock. Female participants at Aripir agreed that after the construction of the dam water availability situation has improved at all levels.

A female FGD participant stated that:

"….earlier we were too worried about livestock water, but now we have water availability for livestock first few months from dam directly and in later months from groundwater bores".

Further, female FGD participants stated that:

"if the dam is filled for a few months even it leaves a great impact on groundwater quality, earlier it used to be bitter, but now it is sweat, and we feel that because of good quality of water, we have reduced number disease incidences during the year".

At Sureshi dam, as a whole, participants were satisfied with increased water availability. Data shows that more participants were satisfied with the water availability for agriculture (75%), for livestock (50%), drinking water (38%), and for groundwater recharge (13%). It was perceived by participants of the FGD that size of the dam is so small that it cannot hold much water, and even if fully filled, it can hold water for just 2 to 4 months depending on rainfall.

At Tikho-II dam, overall, participants were satisfied with increased water availability. Data reveals that more participants were satisfied with the water availability for agriculture (70%), for livestock (75%), for groundwater recharge (70%), and drinking water (20%). It was revealed during FGDs and by local key informants that people were of the view that;

"currently drinking water issue in terms of quantity and quality is resolved only for a few months, and we hope once we have good rainfall, it will be resolved for a longer period."

Overall, participants were satisfied with increased water availability at the Upper Mole-II dam. Data reveals that more participants were satisfied with the water availability for agriculture (88%), livestock (84%), groundwater recharge (72%), and drinking and domestic water (32%).

At Jungshahi dam, overall, participants were satisfied with increased water availability. Data reveals that more participants were satisfied with the water availability for livestock (100%), for drinking and domestic water (100%), for agriculture (56%), and for groundwater recharge (94%). The female FGD participants shared that

"earlier (before dam), we used to fetch water from the common well of the village, but now we have boreholes at our homes, and we use that water for domestic, drinking, and livestock" "now I find some time to relax."

The community members in FGDs stated that:

"….so far it has been two years since the dam is constructed and since then we have not received much rains, but we are sure that it will certainly benefit as we have seen that people feel happy and satisfied where other dams are constructed in the surrounding areas."

Further, a local key informant shared that:

"just imagine after construction of dam, despite ban, the water tanker mafia is active around the dam and extracting groundwater".

At Karamtiani dam overall participants were satisfied with increased water availability. Data reveals that participants were satisfied with the water availability for domestic and drinking water (100%), livestock (93%), agriculture (71%), and groundwater recharge (93%).

It was stated by a participant that;

"though we are not allowed to have boreholes by Zameedar (landowner), we observe that water availability has increased as the water pumps nearby our village has more water".

The participants of Sabusan dam were satisfied with increased water availability. Data reveals that participants were satisfied with the water availability for domestic and drinking water (82%), for livestock (82%), for agriculture (23%), and for groundwater recharge (55%).

The participants of Sankar dam were satisfied with increased water availability. Data reveals that participants were satisfied with the water availability for domestic and drinking water (89%), for livestock (89%), agriculture (19%), and groundwater recharge (6%).

The participants of Bhansar Rathi dam were satisfied with increased water availability. Data reveals that participants were satisfied with the water availability for domestic and drinking water (43%), for livestock (95%), for agriculture (9%), and for groundwater recharge (48%).

Table 10: Benefits of Construction of the Dam (%)*

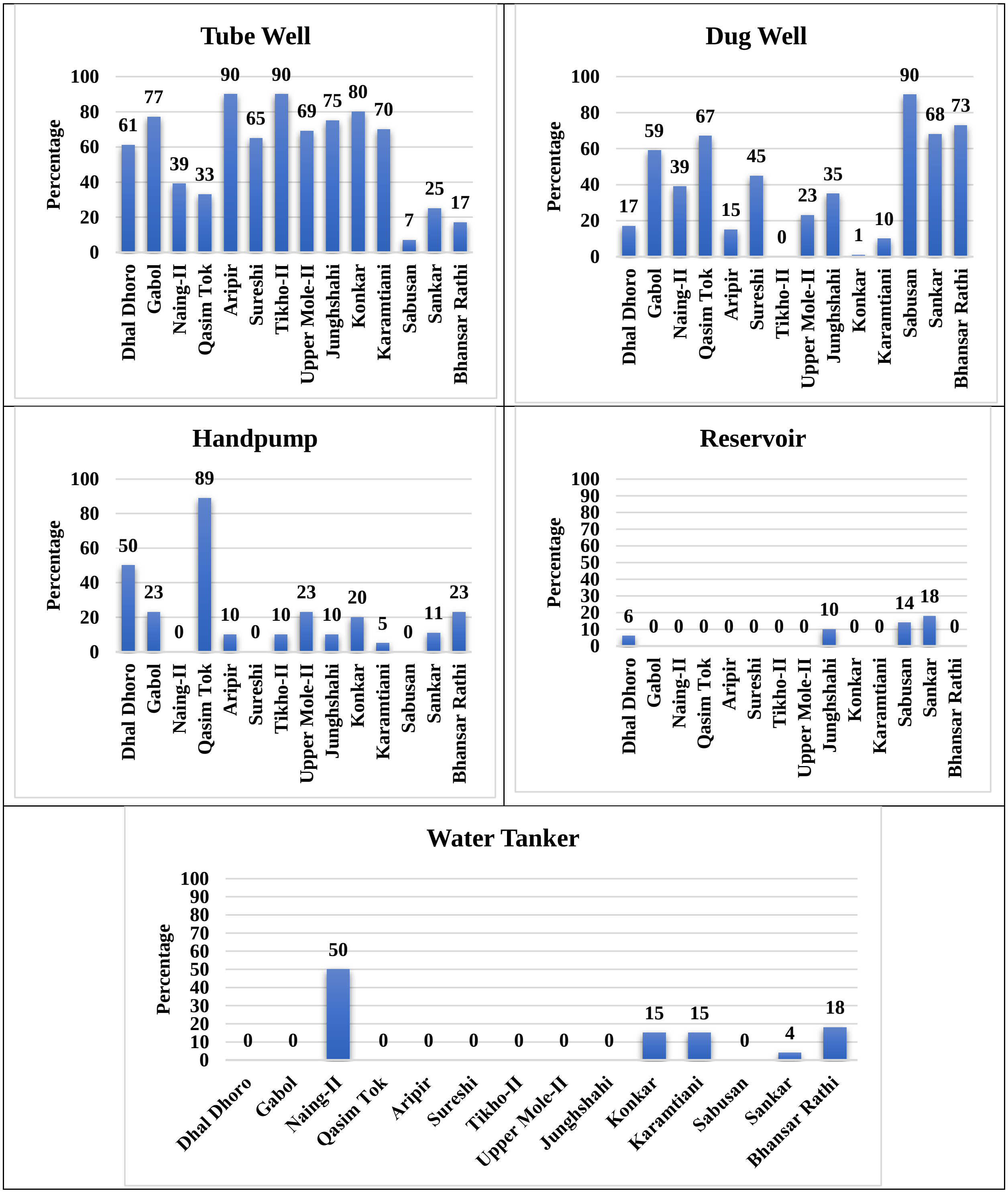
Name of Dam	Improvement in water availability for domestic consumption	Improvement in water availability for livestock	Improvement in water availability for agriculture	Groundwater recharge
Dhal Dhoro	100	89	72	78
Gabol	86	82	41	91
Naing-II	67	100	72	100
Qasim Tok	78	100	33	56
Aripir	20	95	100	95
Sureshi	38	50	75	13
Tikho-II	20	75	70	70
Upper Mole-II	24	84	88	72
Junghshahi	100	100	56	94
Konkar	93	64	26	57
Karamtiani	100	93	71	93
Sabusan	82	82	23	55
Sankar	89	89	19	6
Bhansar Rathi	43	95	9	48

*** Respondents were allowed to choose multiple options as benefits of dam**

4.1.4 Access to Drinking Water Facilities

4.1.4.1 Source of Drinking Water

As given in Figure 7, except for all Thar Parkar region's small dams and two dams in the Upper Kohistan region (i.e., Naing-II and Qasim Tok), tube well has been reported as the main source of drinking water. Whereas, in Thar Parkar region, the dug well was found to be the main source of drinking water. Furthermore, it was reported that hand pumps were installed and used for drinking purposes at all dams. Interestingly, certain percentages at Naing-II, Konkar, Karamtiani, Sankar, and Bhansar Rathi dams responded that they purchase water through water tankers. The results also show that majority of respondents had multiple drinking water sources subject to the availability of the water.



* Respondents were allowed to choose multiple options as their source of drinking water

*Figure 7: Source of Drinking Water**

4.1.4.2 Water Quality

According to the survey participants, the water quality has improved almost at all dams after the construction of dams. However, responsents at Sureshi, Qasim Tok and Tikho II did not highlight the brackish water issue in their area even before the construction of the dam. This community perception may be validated through lab testing of the water quality. Improved ground water quality is one key outcome of the small dams in the arid zone of Sindh. The percentage distribution of the responses related to water quality are given in Table 11.

Table 11: Water Quality (%)

Name of Dam	Before Dam			After Dam		
	Sweet	Brackish	Varying	Sweet	Brackish	Varying
Dhal Dhoro	89	11	0	100	0	0
Gabol	90	10	0	95	5	0
Naing-II	76	24	0	76	24	0
Qasim Tok	100	0	0	100	0	0
Aripir	75	20	5	90	10	0
Sureshi	100	0	0	100	0	0
Tikho-II	100	0	0	100	0	0
Upper Mole-II	48	52	0	81	19	0
Junghshahi	75	25	0	95	5	0
Konkar	62	38	0	96	4	0
Karamtiani	55	35	10	90	0	10
Sabusan	69	28	3	69	28	3
Sankar	56	44	0	93	7	0
Bhansar Rathi	58	32	10	68	22	10

4.1.4.3 Change in Water Table

It was observed that majority of the people living around all studies dams think that the water table in their respective areas has increased upward after construction of the dam as shown in Figure 8. The improvement in the water table in the small dams' areas after the construction of the dam is a great outcome since one of the key purposes of these dams is to recharge the groundwater in rain-fed areas. Most of the dams have recently been completed in the last two to three years and during this period, these areas did not receive much rainfall but still, the water table seems to be recharged from the improvement in the water tables. However, according to the notable KIIs and FGD participants at various dams, the average water table level has risen between 25 to 50 feet. It is anticipated that in future years when these dam areas receive a sufficient amount of rain and the dams are spilling over, the groundwater situation in terms of recharge and quality will further improve significantly.

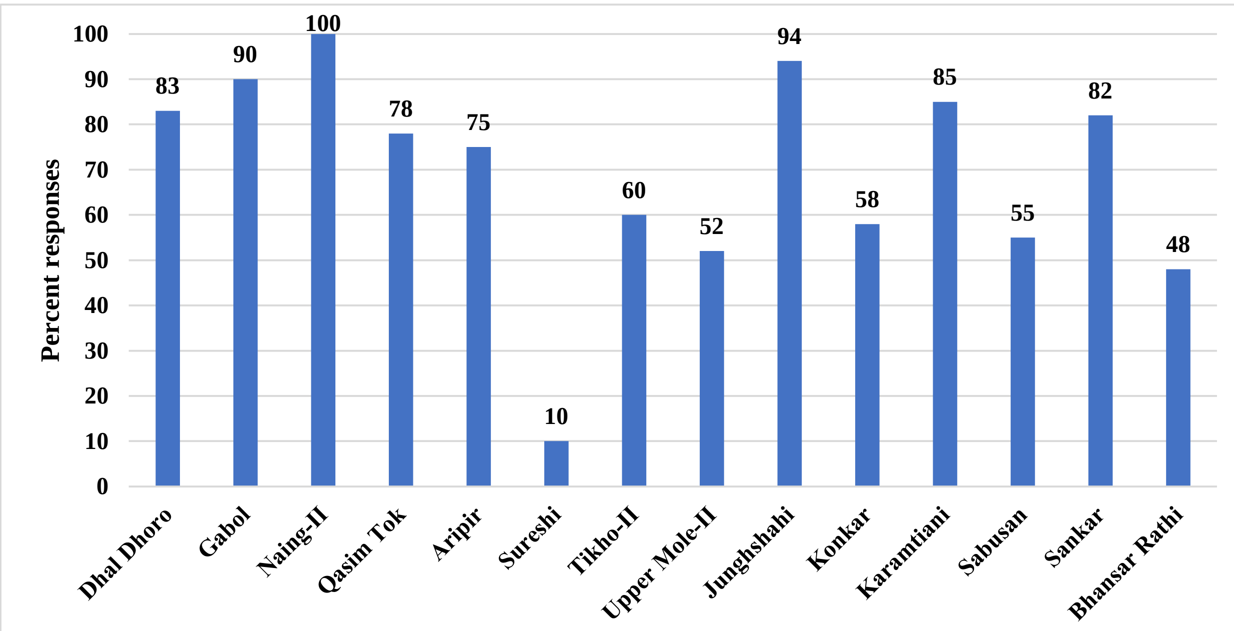


Figure 8: Percentage Responses Associated to the Water Table Rise After the Construction of Dam.

4.1.5 Agriculture

Agriculture is one of the main sources of income in rain-fed areas. It is also the main source of food grain for humans and grassland for livestock. Mostly rain-fed crops are cultivated in these areas but after the introduction of solar tube wells cash crops are cultivated due to increased availability of groundwater and low operational and maintenance cost.

Table 12: Traditional & Emerging Crops

Name of Dam	Traditional Crops							Emerging Crops				
	Millet	Sorghum	Guar	Sesame	Mung	Moth	Casterbean	Onion	Wheat	Chili	Cotton	Tomato
Dhal Dhoro								✓	✓	✓		
Gabol								✓	✓	✓		
Naing-II			✓					✓	✓	✓		
Qasim Tok			✓					✓	✓			
Aripir			✓					✓	✓	✓		
Sureshi		✓	✓						✓			
Tikho-II								✓	✓		✓	
Upper Mole-II		✓	✓					✓	✓			
Junghshahi	✓	✓	✓						✓			✓
Konkar												
Karamtiani												
Sabusan	✓	✓	✓	✓	✓	✓	✓					
Sankar	✓		✓	✓	✓	✓						
Bhansar Rathi	✓		✓	✓	✓	✓						

Table 12 provides the data on the type of traditional and emerging crops observed and reported by the survey respondents. It is evident from the table that guar is a crop cultivated in nine dam areas and Casterbean is the crop that has been reported being cultivated in Sabusan area only. It was reported that during the past few years as the result of the improved water table, availability of groundwater and introduction of solar tube wells in many of the dam areas, especially in Kohistan region farmers have started cultivating cash crops such as onions, wheat, chili, cotton, and tomato. Dam-wise data on cultivated crops, their area, and yields have been analyzed and given in annex-5.

4.1.5.1 Change in Cropped Area

The majority of survey respondents shared that their cropped area has increased since the construction of the dam due to increased water availability. The highest increase in cropped area was reported at Dhal Dhoro dam by 38%. However, no change in cropped area was reported at

Sureshi and Tikho II (see Table 13). Whereas it was found at Konkar and Karamtiani dams that most of the landholders lived in Karachi city, and the survey team was unable to approach them. Further, it was also shared by respondents that the majority of locals have already sold their lands to outsiders.

Table 13: Average Change in Cropped Area of Respondents

Name of Dam	Percentage Increase or Decrease After Dam
Dhal Dhoro	38%
Gabol	19%
Naing-II	22%
Qasim Tok	27%
Aripir	14%
Sureshi	No Change
Tikho-II	No Change
Upper Mole-II	4%
Junghshahi	34%
Konkar	Not Applicable
Karamtiani	Not Applicable
Sabusan	No change
Sankar	7%
Bhansar Rathi	7%

4.1.5.2 Change in Crop Yield

In order to understand the impact of different dams on crop yield, the percentage changes under different crops have been analyzed as shown in Table 14. It was observed that the construction of dams has significantly increased the crop yield of different crops in most of the dams. The increase in the per acre yield has ultimately improved the family income of the communities living in the vicinity of the dams. It is interesting to note that the percentage change in the area under non-traditional crops including onion, wheat, chili, and tomato is higher than in traditional crops. It reflects that in the future, people will be growing non-traditional crops and will be earning a higher income.

Table 14: Percentage Increase/Decrease in Crop Yield

Name Of Dam	Crop-Wise Percentage Increase/Decrease											
	Millet	Sorghum	Guar	Sesame	Mung	Moth	Haran	Onion	Wheat	Chili	Cotton	Tomato
Dhal Dhoro	--	--	--	--	--	--	--	55%	27%	64%	--	--
Gabol	--	--	--	--	--	--	--	53%	47%	67%	--	--
Naing-II	--	--	NC*	--	--	--	--	14%	16%	120%	--	--
Qasim Tok	--	--	64%	--	--	--	--	-38%	54%		--	--
Aripir	--	--	7%	--	--	--	--	12%	50%	52%	--	--
Sureshi	--	3%	NC*	--	--	--	--	1%	--	--	--	--
Tikho-II	--			--	--	--	--	27%	18%	--	50%	--
Upper Mole-II	--	14%	11%	--	--	--	--	16%	12%	--	--	--
Junghshahi	16%	10%	34%	--	--	--	--	--	150%	--	--	163%
Konkar	--	--	--	--	--	--	--	--	--	--	--	--
Karamtiani	--	--	--	--	--	--	--	--	--	--	--	--
Sabusan	17%	32%	29%	3%	16%	4%	31%	--	--	--	--	--
Sankar	45%	--	21%	44%	40%	22%	--	--	--	--	--	--
Bhansar Rathi	25%	--	25%	9%	31%	30%	--	--	--	--	--	--

* No Change

-- Crops are not cultivated

4.1.5.3 Land Holding[2]

The average landholding of respondents on the different dams can be categorized as small landholding which ranges between 5 to 18.8 acres (Table 15). Since the groundwater availability has increased for a longer period in a year along with improved water table, the farmers with very small land holding have started obtaining land on lease to cultivate cash crops like onions and tomatoes, etc. as shown in Table 8 above. Detail on landholding breakup on owned and leased landholding of the participants is given in annex-6.

[2] As this is un-surveyed area and does not come under any canal command area, therefore mapping of land area is not fixed and people commonly use the unit "acre" for landholding, therefore this report has used the term acre for landholding.

Table 15: Land Holding

Name of Dam	Total Land (Acres)		
	Maximum	Minimum	Average
Dhal Dhoro	100	1.5	11
Gabol	20	1	4.4
Naing-II	97	4	20
Qasim Tok	45	3	12.6
Aripir	22	2	9
Sureshi	30	1	5.8
Tikho-II	30	2	6.6
Upper Mole-II	200	1	16
Junghshahi	8	1	5
Konkar	24	2	6.5
Karamtiani	10	1	6
Sabusan	75	1	19
Sankar	150	2	17
Bhansar Rathi	70	1	18.5

"after construction of the dam, the water table is raised and maintained for a longer period which has encouraged people for regular cultivation of crops through the installation of solar tube wells" (a participant of male FGD at Konkar)

"Common crops growing in this region are wheat, onion, guar, and cotton. Due to reliable availability of water we are now thinking to grow vegetables" (a male FGD participant)

"Community and government need to come up with a policy or direction for solar tube well installation such as the size of solar pump, solar system, timing of pumping and further government also needs to modernize agriculture to reap maximum benefits of the increased water availability after construction of the dams" (stated by a key informant)

A key informant also informed that:

"We have already intervened by introducing and providing kitchen gardening kits with the help of another word bank assisted Sindh Government's project called SIAPEP and now there is a need to make policy for developing new command areas based on HEIS practices."

4.1.5.4 Source of Irrigation Water

Rainwater and tube wells have been reported as the main sources of irrigation across all dams. According to the respondents of Dhal Dhoro, Gabol, Qasim Tok, Tikho-II, and Upper Mole-II dams, the main source of irrigation water before the construction of the dam was rainwater but after the construction of the dam tube well has become the major source of irrigation. However, the respondents of the Naing-II, Aripir, Konkar, and Karamtiani dams reported that tube wells have been the source of irrigation before and after the construction of the dam. Whereas, on the other hand, rainwater continues to be the source of irrigation even after the construction of the dam. The percentage responses related to the sources of irrigation water are given in Table 16.

Table 16: Source of Irrigation Water (%)

Name of Dam		Tube Well	Dug Well	Dam	Rain	Tube Well & Rain
Dhal Dhoro	**Before Dam**	13	40	0	47	0
	After Dam	67	0	13	20	0
Gabol	**Before Dam**	19	10	0	71	0
	After Dam	95	0	0	5	0
Naing-II	**Before Dam**	78	6	0	17	0
	After Dam	94	6	0	0	0
Qasim Tok	**Before Dam**	43	0	0	57	0
	After Dam	100	0	0	0	0
Aripir	**Before Dam**	89	0	0	11	0
	After Dam	100	0	0	0	0
Sureshi	**Before Dam**	5	0	0	95	0
	After Dam	5	0	0	95	0
Tikho-II	**Before Dam**	80	0	0	0	20
	After Dam	80	0	0	0	20
Upper Mole-II	**Before Dam**	42	8	0	50	0
	After Dam	50	8	0	42	0
Junghshahi	**Before Dam**	21	7	0	57	15
	After Dam	29	7	0	57	7
Konkar	**Before Dam**	74	0	0	11	15
	After Dam	81	0	0	4	15
Karamtiani	**Before Dam**	86	0	0	14	0
	After Dam	87	0	0	13	0
Sabusan	**Before Dam**	0	0	0	100	0
	After Dam	4	0	4	92	0
Sankar	**Before Dam**	4	0	0	96	0
	After Dam	4	0	7	89	0
Bhansar Rathi	**Before Dam**	0	0	0	100	0
	After Dam	2	0	0	98	0

Since, small dams are rainwater harvesting storage reservoirs therefore it was important to know the duration the dams were able to retain water after those were filled. Further that how much time the ground water level remains stable after it was raised upward after the rainfall and used for irrigation. The respondents of the Dhal

Dhoro, Gabol, Naing-II, Aripir, Upper Mole-II, Konkar, Karamtiani, Sankar, and Bhansar Rathi dams reported an improvement in the adequacy of irrigation water after the construction of the dam.

According to the respondents, the adequacy of available water for irrigation has improved throughout the year with periodic gaps (Table 17) at Gabol, Upper Mole-II, Naing-II, Aripir, Konkar, Karamtiani, and Bhansar Rathi dam.

Table 17: Satisfaction with Increased Monthly Water Availability (% Responses)

Name of Dam	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Gabol	29	24	24	24	24	24	71	90	52	29	29	29
Dhal Dhoro	0	0	0	0	0	7	50	79	29	7	7	0
Naing-II	29	29	29	29	29	29	65	100	29	29	29	29
Qasim Tok	0	0	0	0	0	20	80	60	60	0	20	0
Aripir	42	42	32	21	16	16	16	89	95	47	37	37
Sureshi	5	5	5	5	5	11	58	100	74	11	11	5
Tikho-II	70	70	70	70	70	70	70	100	75	70	70	70
Upper Mole-II	38	33	25	13	13	13	21	96	92	50	42	42
Junghshahi	23	8	15	15	8	23	31	77	15	8	8	8
Konkar	15	13	15	30	38	53	68	63	28	20	15	28
Karamtiani	7	7	7	7	13	33	67	93	27	7	7	7
Sabusan	0	0	0	0	23	35	54	73	38	8	8	0
Sankar	0	0	0	4	4	58	81	73	46	12	8	8
Bhansar Rathi	7	5	5	3	3	35	80	82	52	28	27	7

4.1.6 Livestock

Livestock is one of the main sources of income for people in rain-fed areas. The respondents reported that they raise cows, goats, sheep, donkeys, and chickens. During FGDs at various locations, either with males or females, participants were of the view that:

> *"...dams have not only increased water availability but also water quality, which helps raise healthy livestock/cattle, due to that we are getting more milk and better prices as well".*

It seems that dams are not only increasing water security but food security as well. Increased milk production will be helpful in decreasing malnutrition in children. A local key informant stated that:

"….earlier we used to move our animals in Sindh (canal command areas) during the dry season, but during last year a very limited number of people moved their animals to Sindh".

As a result of water availability after the construction of dams, the people at different dams reported improvement in the health of animals which has resulted in enhancement of milk production and they are getting better prices while selling the animals (annex-7). Resultantly, people are buying more animals.

4.1.6.1 Pastureland

Majority of the respondents at Dhal Dhoro, Gabol, Naing-II, Qasim Tok, Aripir, Tikho-II, Upper Mole-II, Junghshahi, Konkar, Karamtiani, Sabusan, Sankar, and Bhansar Rathi dams reported a significant change in pastureland area after the construction of small dams as given in Figure 9.

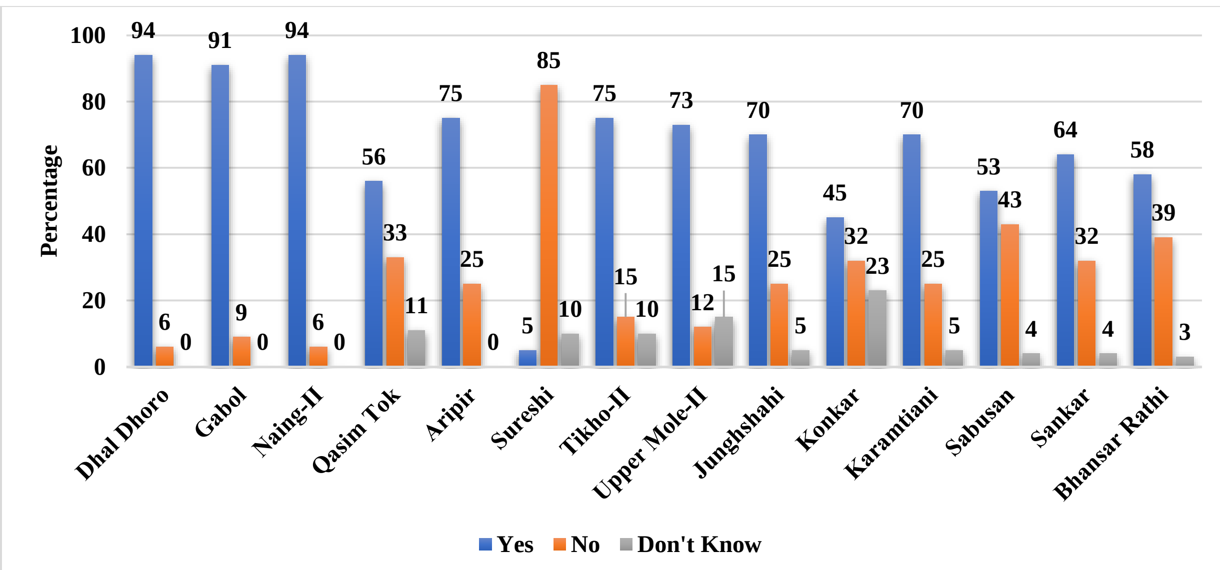


Figure 9: Change in Pastureland after Construction of the Dam

It can be seen in Table 18 that majority of the respondents were of view that there is increase in grass production in pastureland. While a limited percentage of respondents at a few dam reported increase in pastureland area and improvement in quality of grass.

Table 18: Type of Change in Pastureland (%)

Name of Dam	Increase in Grass Production	Pastureland Area has Increased	Quality of Grass has Improved
Dhal Dhoro	81	19	0
Gabol	100	0	0
Naing-II	100	0	0
Qasim Tok	100	0	0
Aripir	100	0	0
Sureshi	100	0	0
Tikho-II	100	0	0
Upper Mole-II	100	0	0
Junghshahi	100	0	0
Konkar	83	0	17
Karamtiani	69	23	8
Sabusan	87	13	0
Sankar	88	12	0
Bhansar Rathi	91	6	3

4.1.7 Migration

The livelihood in rain-fed areas mainly depends on rainfall. A wet year means good agricultural yield and grass production in pastureland, ultimately good income. Whereas a dry year affects the agriculture yield and grass production, ultimately affecting the income of people. Therefore, people living at dams areas usually migrate temporarily and sometimes permanently to other areas for their livelihood. A key local informant informed that:

"….earlier we used to move our animals in Sindh (canal command areas) during dry seasons, but during last year a very limited number of people moved their animals to Sindh".

Participants also informed the steps of migration, especially for livestock feeding which are as follows;

1) *"Once we are out of the water we try to find nearby ponds and move our animals."*

2) *"In case the pond is little far away we move for specific number of days which vary between 5 to 10 days. During this period, we do not move our milking animals, as they are kept at homes for feeding our families."*

3) *"Once we are out of water from those ponds then we move our animals to canal command areas."*

But after the construction of dams,

"due to increased water availability, we have witnessed that people from other nearby villages/areas bring their animals to the dam site to feed their animals"

It is reported by the majority of the respondents at Dhal Dhoro, Gabol, Qasim Tok, Sureshi, Junghshahi, Sabusan, Sankar, and Bhansar Rathi dams that there is a migration trend. While no migration trend has been reported in Naing-II, Aripir, Tikho-II, Upper Mole-II, Konkar, and Karamtiani dams. The responses to the migration trend are given in Figure 10.

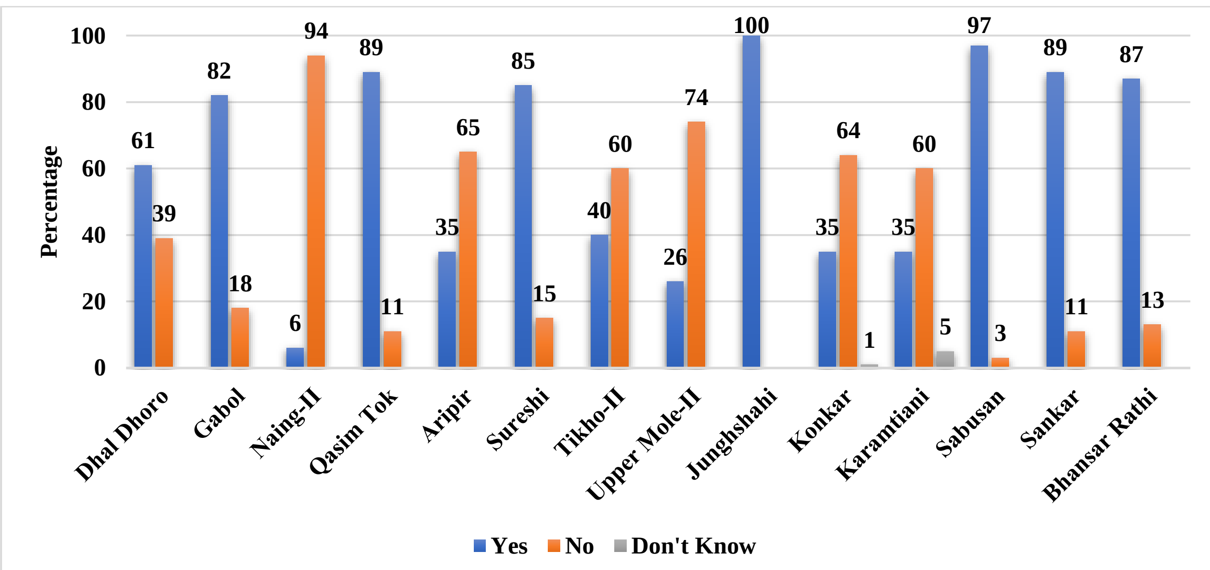


Figure 10: Migration Trend

The majority of the respondents at Konkar dam were of the view that there is migration-in in the dam area. Whereas, the majority of respondents at Dhal Dhoro, Qasim Tok, Junghshahi, Sabusan, Sankar, and Bhansar Rathi dams reported migration-out. While the majority of the respondents at Naing-II, Aripir, Sureshi, Upper Mole-II, and Karamtiani dams indicated both migration-in and migration-out in their area. The percentage responses of the migration type are given in Figure 11.

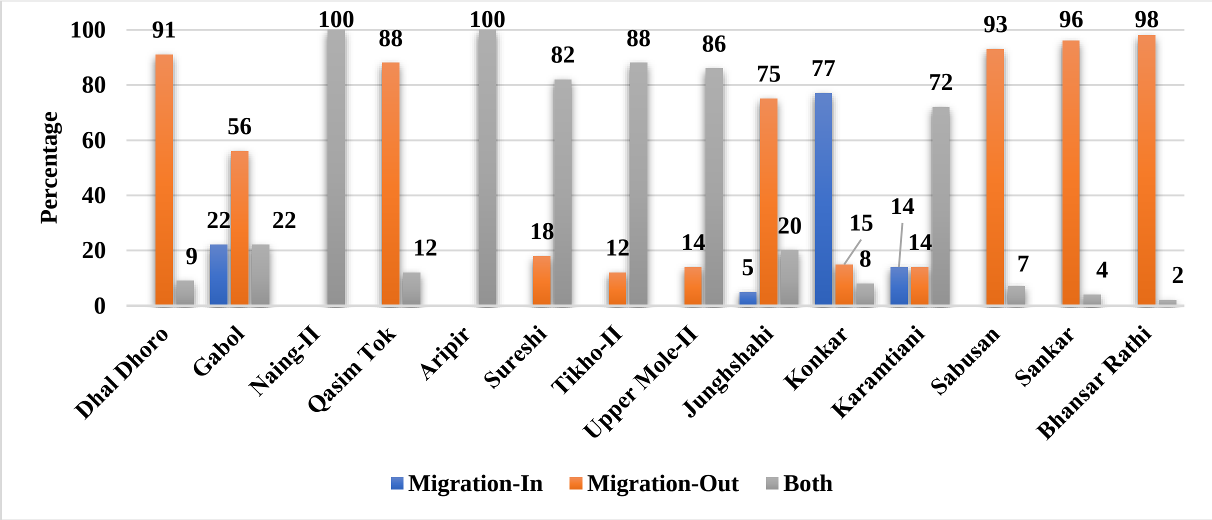


Figure 11: Migration Type

Figure 12 and Figure 13 below show the migration-in and migration-out trends at each dam. Almost on all dams, it can be seen that the migration-out has decreased after the construction of the small dams, which is a positive outcome of the construction of the small dams.

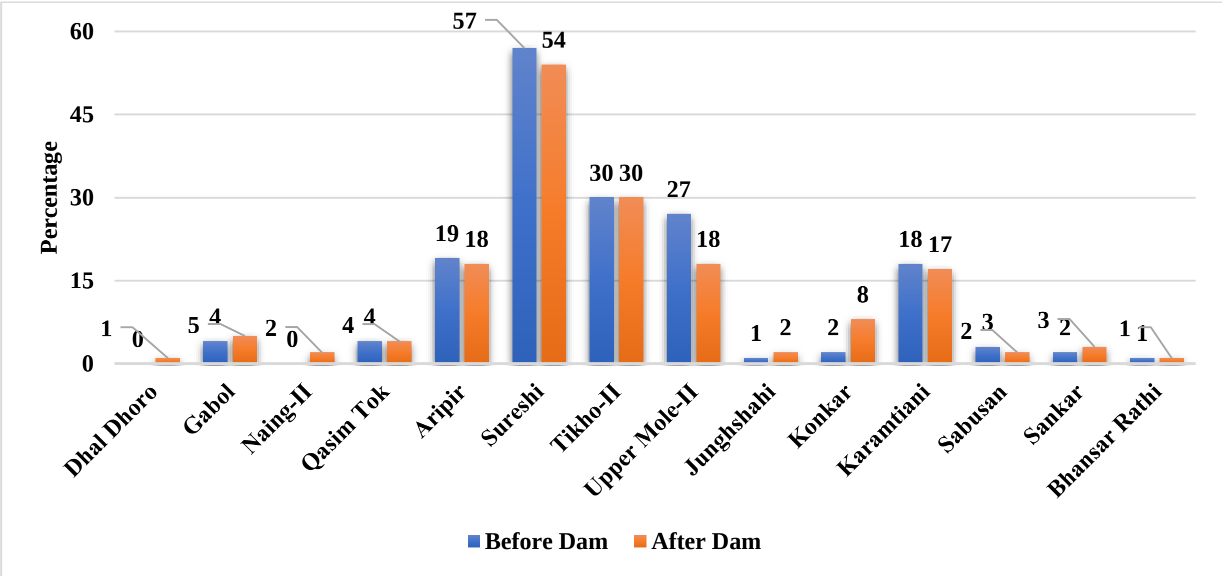


Figure 12: Migration-In

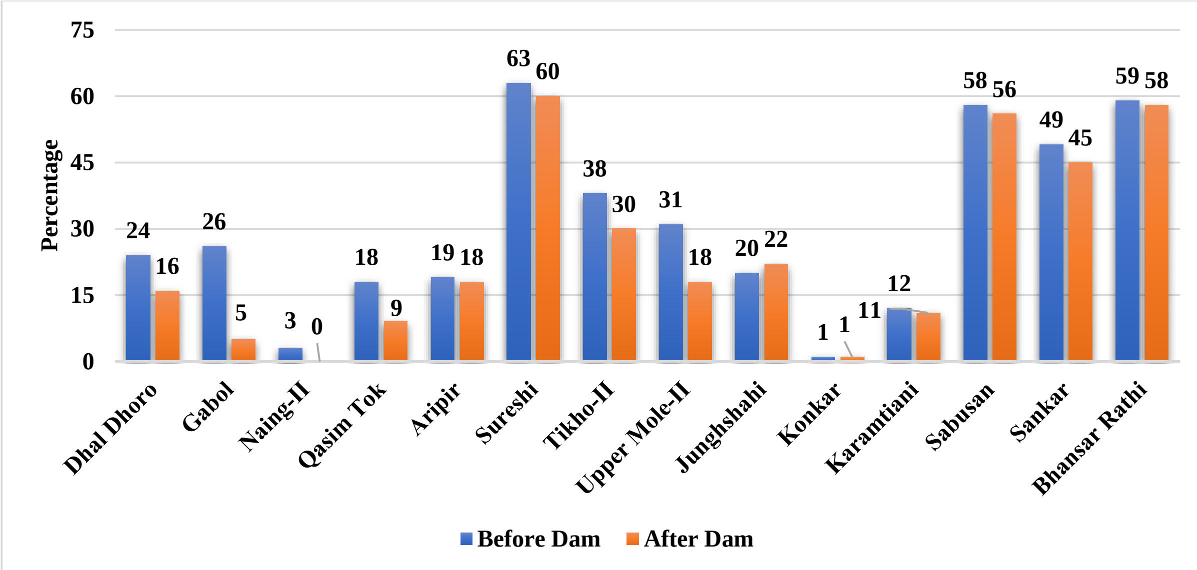


Figure 13: Migration-Out

Furthermore, the majority of the respondents at almost all dams reported temporary migration before and after the construction of the small dams.

Table 19: Temporary & Permanent Migration (%)

Name of Dam	Temporary		Permanent	
	Before Dam	After Dam	Before Dam	After Dam
Dhal Dhoro	82	100	18	0
Gabol	77	69	23	31
Naing-II	100	100	0	0
Qasim Tok	86	100	14	0
Aripir	97	100	3	0
Sureshi	99	99	1	1
Tikho-II	94	93	6	7
Upper Mole-II	92	98	8	2
Junghshahi	5	22	95	78
Konkar	40	19	60	81
Karamtiani	100	100	0	0
Sabusan	100	100	0	0
Sankar	96	96	4	4
Bhansar Rathi	98	98	2	2

4.1.8 Kitchen Gardening

Growing vegetables and fruits for household use in the house backyard or nearby piece of land is termed as kitchen gardening. Almost at all dams, it was reported that people, especially females are engaged in kitchen gardening. However, in certain dam areas, this practice is increased due to enhanced water availability (Figure 14). The community usually grows vegetables of bottle gourd, apple gourd, and ladyfinger.

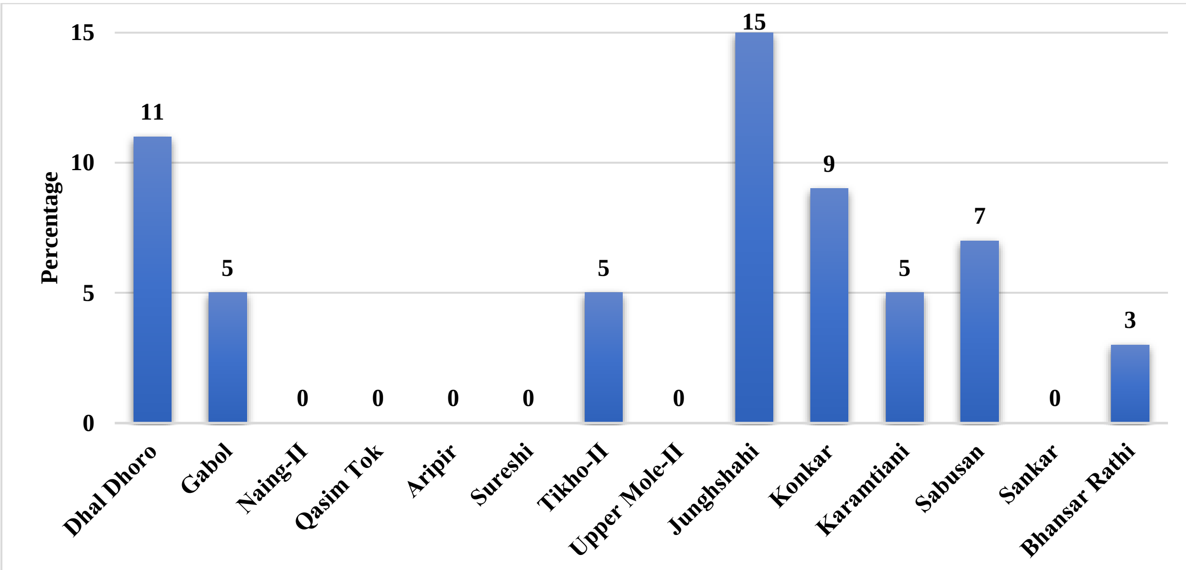


Figure 14: Kitchen Gardening

4.1.9 Water Related Conflicts

The respondents of Dhal Dhoro, Gabol, Qasim Tok, Tikho-II, Junghshahi, Konkar, Karamtiani, Sabusan, Sankar, and Bhansar Rathi dams reported a reduction in the conflicts over drinking water after the construction of small dams. The maximum decrease was reported at the Junghshahi dam where 75% of respondents said there were conflicts on drinking water before the construction of the dam which significantly reduced after the construction of the dams. Moreover, the respondents of Dhal Dhoro, Junghshahi, Konkar, and Karamtiani dams reported a reduction in the conflicts on irrigation water after construction of small dams. Furthermore, the respondents of Gabol, Naing-II, Junghshahi, Konkar, Karamtiani, Sabusan, Sankar, and Bhansar Rathi dams also reported reduction in the conflicts on livestock drinking water after construction of small dams. The conflicts associated to drinking water, irrigation water and livestock are given in Figure 15, Figure 16 and Figure 17 respectively.

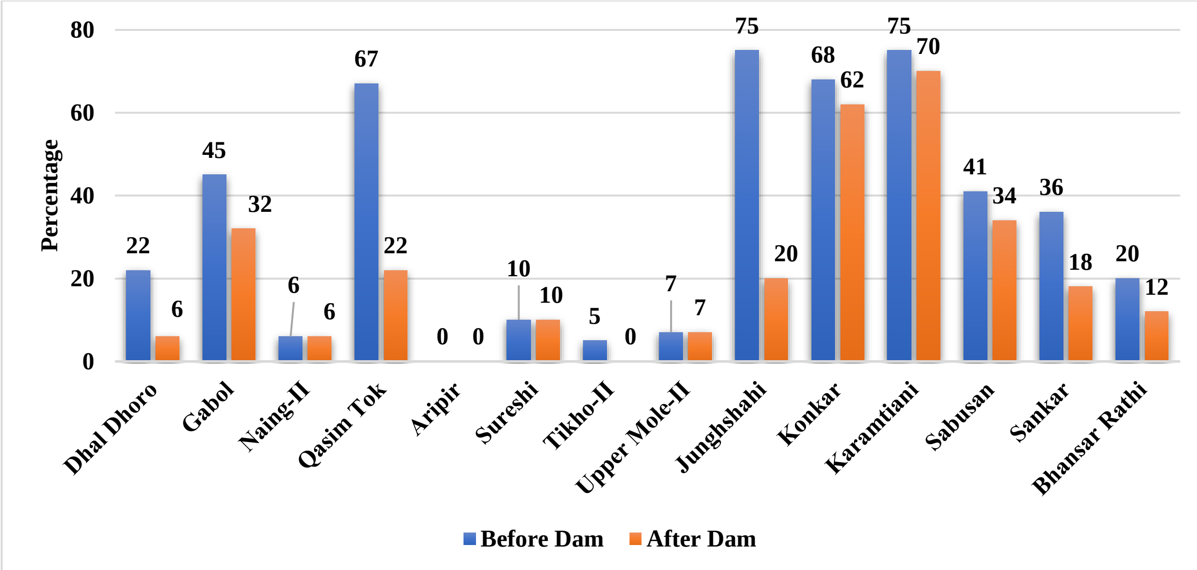


Figure 15: Conflicts on Drinking Water

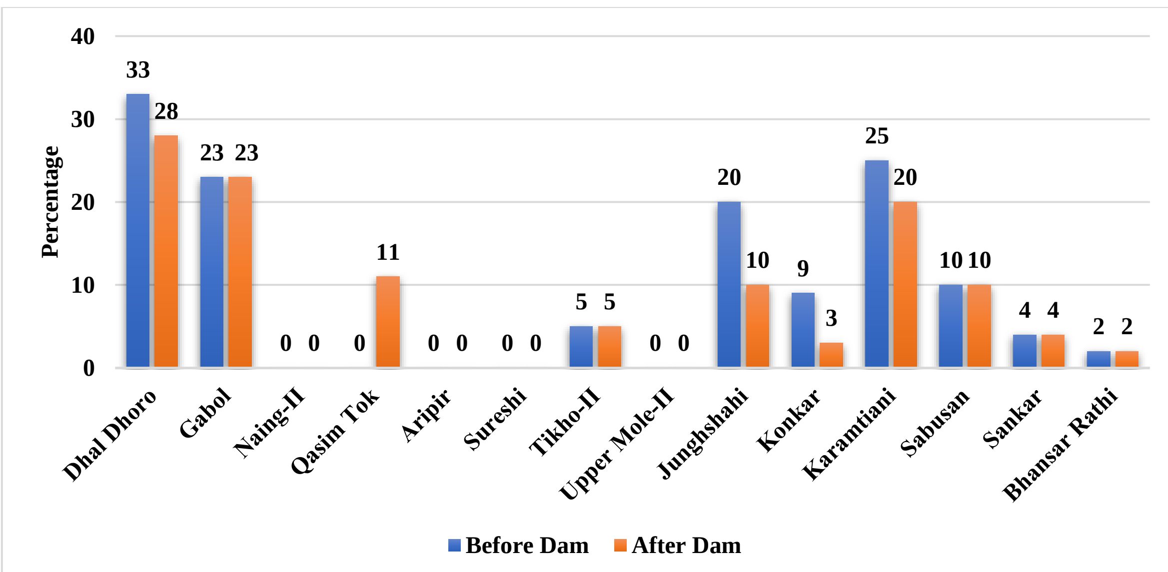


Figure 16: Conflicts on Irrigation Water

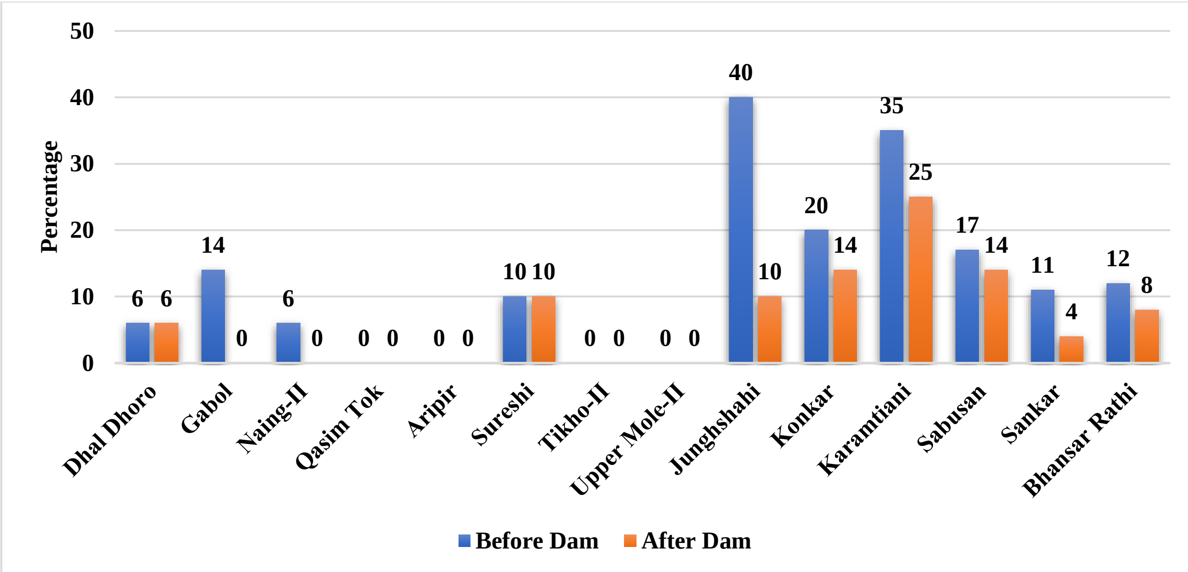


Figure 17: Conflicts on Livestock Drinking Water

4.1.10 Cross-Cutting Themes

4.1.10.1 Months of Water Scarcity

When respondents were asked about the water scare months before and after the construction of the dam. The respondents of the Gabol, Qasim Tok, Aripir, Upper Mole-II, Konkar, Karamtiani, Sabusan, Sankar, and Bhansar Rathi dams reported that months of water scarcity are reduced after the construction of the dams. On the other hand, respondents of the Dhal Dhoro, Naing-II, and Junghshahi dams were of the view that water scarcity has reduced in some months and increased in others after the construction of the dam. While respondents of the Sureshi, and Tikho-II dams said neither water scare month has reduced nor increased after construction of the dam.

4.1.10.2 Time Required to Fetch Water

According to the respondents at all dams except at Sureshi dam time to fetch drinking water has significantly reduced after the construction of the small dams. Maximum time saved was reported at Qasim Tok dam i.e., 72%. The time required for fetching water at each dam location before and after the construction of the dams is given in Table 20.

Table 20: Time Required for Fetching Drinking Water

Name of Dam	Average Time (Hours)		Percentage of Time Saved (%)
	Before Dam	After Dam	
Dhal Dhoro	0.82	0.37	54
Gabol	1.63	0.85	48
Naing-II	0.98	0.72	27
Qasim Tok	0.98	0.27	72
Aripir	0.6	0.4	33
Sureshi	1.74	1.74	0
Tikho-II	0.57	0.54	7
Upper Mole-II	1	0.92	8
Junghshahi	1.53	0.46	70
Konkar	1.28	0.75	41
Karamtiani	1.6	1	37
Sabusan	1.95	1.43	27
Sankar	2.7	1.1	59
Bhansar Rathi	1.6	1.3	19

Further, the respondents at all dams except at Sureshi dam time to take livestock for water has also reduced after the construction of the small dams. Maximum time saved was reported at Junghshahi i.e., 65%. The time required to take livestock for water at each dam location before and after the construction of the dams is given in Table 21.

Table 21: Time Required to Take Livestock for Water

Name of Dam	Average Time (Hours)		Percentage of Time Saved (%)
	Before Dam	After Dam	
Dhal Dhoro	1.63	0.66	59
Gabol	2.21	1.14	48
Naing-II	1.24	0.62	50
Qasim Tok	1.43	0.81	43
Aripir	0.6	0.5	17
Sureshi	2	2	0
Tikho-II	0.76	0.73	3
Upper Mole-II	1.5	1.3	11
Junghshahi	2.11	0.73	65
Konkar	2.62	1.38	47
Karamtiani	4.68	3.24	31
Sabusan	2.39	1.8	25
Sankar	3.1	1.4	55
Bhansar Rathi	1.6	1.2	25

The respondents reported that the saved time is utilized in enhanced agricultural work, cattle look after, wage labor, household work, embroidery, Sewing clothes, etc.

4.1.10.3 Change in Disease occurrence

Majority of the respondents at Dhal Dhoro, Aripir, and Junghshahi dams have reported a reduction in disease occurrence after the construction of the small dams. The common occurring diseases reported by respondents were fever, flu, cough, motion, vomiting, malaria, stomach pain, kidney stones, and hepatitis B. This may be for the reason that groundwater used for drinking is recharged and its quality has improved, which may be lab tested to verification. The percentage responses of change in occurrence of diseases due to construction of the dam are given in Table 22.

Table 22: Change in Occurrence of Disease due to Construction of Dam (%)

Name of Dam	Yes	No	Don't Know
Dhal Dhoro	67	22	11
Gabol	36	55	9
Naing-II	11	78	11
Qasim Tok	0	100	0
Aripir	45	35	20
Sureshi	5	80	15
Tikho-II	10	50	40
Upper Mole-II	33	41	26
Junghshahi	53	37	10
Konkar	32	58	10
Karamtiani	30	65	5
Sabusan	31	66	3
Sankar	36	64	0
Bhansar Rathi	40	50	10

4.2 TASK 2: CALCULATION OF SEDIMENTATION AND EXPECTED LIFE OF DAMS

4.2.1 Deposited Sediments Analysis

Hydrometer analysis was carried out in the laboratory for soil texture i.e. classification of soil according to the percentage of soil particle sizes. Analysis was done using the ICARDA manual.

Table 23 shows the percentages of different soil types calculated and density in the last column calculated with USBR Small Dams Formula as given below:

$$Y = W_c p_c + W_m p_m + W_s p_s$$

Where,

W_c, W_m, W_s are the coefficients of clay, silt, and sand respectively;

p_c, p_m, p_s are the percentages of clay, silt and sand respectively.

Table 23: Detailed analysis of the sediment deposits at each dam.

Texture and Sediment Density				
Name	Percentages			Density (lb/f^3)
	Clay	Silt	Sand	
Dhal Dhoro	12.5	45.0	42.5	81.5
Gabol	27.5	65.0	7.5	71.2
Naing II	30.0	57.5	12.5	72.1
Qasim Tok	12.5	85.0	2.5	72.0
AriPir	15.0	80.0	5.0	72.3
Sureshi	27.5	25.0	47.5	80.7
Tikho II	40.0	52.5	7.5	69.6
Upper Mole II	22.5	75.0	2.5	70.7
Jungshahi	47.5	50.0	2.5	67.4
Konkar	41.7	20.4	37.9	76.6
Karmatiani	42.9	34.6	22.5	72.8
Sabusan	35.8	50.0	14.2	71.7
Sankar	15.0	15.0	70.0	87.7
Bhansar/Rathi	10.0	5.0	85.0	91.9

4.2.2 Rainfall-Runoff Modeling

NRCS Curve Number method was used in HEC-HMS for modeling rainfall-runoff which required the following data:

(a) Catchment Area,
(b) Curve Number,
(c) Initial Abstraction,
(d) Lag Time and
(e) Rainfall Data.

The calculation for each is described in the subsequent sections below.

(a) Catchment Area

Digital elevation model (DEM) was used for calculating and delineating the catchment area of dams. Table 24 shows the areas of dams calculated using Copernicus DEM. The calculated catchment areas are compared with the areas calculated during the feasibility reports. The results are almost the same and the discrepancy in a few is due to the reason that new dams have been constructed in the upper catchments of the streams.

Table 24: Delineation of the catchment areas in square miles.

Name	Area in Sq. Miles (Calculated Now)	Area in Sq. Miles (Feasibility Report)
Dhal Dhoro II	8.4	9.1
Gabol	69.0	69.9
Naing II	238.5	238.8
Qasim Tok	4.7	4.5
AriPir	37.3	36.5
Sureshi	7.1	7.3
Tikho II	76.4	78.7
Upper Mole II	52.1	90.1
Jungshahi	31.2	32.3
Konkar	61.2	3.6
Karmathani	16.3	17.0
Sabusan	4.5	5.1
Sankar	9.7	4.0
Bhansar Rathi	19.6	8.5

(b) Curve Number

There are mainly two types of land area in our study region number one rocky area and number two barren soil area. Using GIS the areas for the two have been calculated.

Land Use Land Cover

To calculate land use land cover (LULC), satellite data from Landsat-8 Satellite was downloaded. The catchment areas of dams were first of all extracted. After extracting the desired area it was carefully classified into two above-mentioned regions using the field knowledge and visible features in tile and other satellite imagery.

After calculating the different land areas, each type of land area was assigned a suitable curve number (CN) using USDA guidelines and composite curve numbers for the whole catchment were thus calculated. The calculations are shown in Table 25.

Table 25: Calculation of the percentage of soil types and composite curve numbers for each dam catchment area.

Name	Area Sq. Mi	Barren Soil Area Sq. Mi	% Barren Soil Area	Rocky Area Sq. Mi	% Rocky Area	Composite curve number (CN)
Dhal Dhoro II	8.4	4.2	49.5	4.2	50.5	86.11
Gabol	69.0	36.8	53.3	32.2	46.7	85.22
Naing II	238.5	127.5	53.4	111.0	46.6	85.17
Qasim Tok	4.7	1.4	30.4	3.3	69.6	90.72
AriPir	37.3	12.6	33.7	24.7	66.3	89.91
Sureshi	7.1	1.0	13.8	6.1	86.2	94.69
Tikho II	76.4	11.7	15.3	64.7	84.7	94.32
Upper Mole II	52.1	21.3	40.8	30.8	59.2	88.21
Jungshahi	31.2	24.0	77.0	7.2	23.0	79.51
Konkar	61.2	37.5	61.3	23.7	38.7	83.28
Karmathani	16.3	8.7	53.5	7.6	46.5	85.16
Sabusan	4.5	4.3	94.8	0.2	5.2	75.26
Sankar	9.7	9.7	100.0	0.0	0.0	74.00
Bhansar Rathi	19.6	19.6	100.0	0.0	0.0	74.00

(c) Initial Abstraction

Initial abstraction was calculated using the formula given by USDA as below:

$$\text{Initial Abstraction} = 0.2\ \text{Surface Storage}$$

$$\text{Whereas, Surface Storage} = 1000/(\text{Curve Number}) - 10$$

Table 26 shows the initial abstraction in inches in each catchment.

Table 26: Calculations for the surface storages and initial abstractions in each dam catchment.

Name	Composite curve number (CN)	Surface Storage (in)	Initial abstraction (in)
Dhal Dhoro II	86.1	1.61	0.32
Gabol	85.2	1.73	0.35
Naing II	85.2	1.74	0.35
Qasim Tok	90.7	1.02	0.20
AriPir	89.9	1.12	0.22
Sureshi	94.7	0.56	0.11
Tikho II	94.3	0.60	0.12
Upper Mole II	88.2	1.34	0.27
Jungshahi	79.5	2.58	0.52
Konkar	83.3	2.01	0.40
Karmathani	85.2	1.74	0.35
Sabusan	75.3	3.29	0.66
Sankar	74.0	3.51	0.70
Bhansar Rathi	74.0	3.51	0.70

(d) Lag Time

NRCS Lag time was calculated using the Formula from the NRCS guideline as given below:

$$Lag\ time = L^{0.8}(S+1)^{0.7}/(1900\ Y^{0.5})$$

Where L = hydraulic length of the watershed (ft)

Lag time = basin lag (hr)

S = (1000/CN)-10 where CN = NRCS curve number

Y = average watershed land slope (percent)

Table 27 below shows the lag time in hours calculated for each dam using the hydraulic length of the watershed, curve number, and average watershed slope in percentage.

Table 27: Calculations for the lag time in hours at each dam catchment.

Name	length L (ft.)	% Slope	Surface Storage (in)	Initial abstraction (in)	Lag time (hr)
Dhal Dhoro II	36497.42	1.64	1.61	0.32	3.6
Gabol	76165.86	0.64	1.73	0.35	10.7
Naing II	160523.60	0.46	1.74	0.35	22.9
Qasim Tok	14136.08	0.36	1.02	0.20	3.0
AriPir	109846.25	0.65	1.12	0.22	11.9
Sureshi	19575.46	0.48	0.56	0.11	2.8
Tikho II	112084.72	0.46	0.60	0.12	11.8
Upper Mole II	84589.36	0.59	1.34	0.27	10.9
Jungshahi	76841.23	0.78	2.58	0.52	11.8
Konkar	136527.67	0.59	2.01	0.40	19.1
Karmathani	53029.51	0.76	1.74	0.35	7.4
Sabusan	28423.42	1.08	3.29	0.66	5.1
Sankar	13917.08	0.38	3.51	0.70	5.1
Bhansar Rathi	49878.52	0.24	3.51	0.70	17.7

(e) Rainfall Data

Closest station average rainfall was used for average inflow data from (SDO, 2015a) (SDO, 2015b) (SDO, 2010)

4.2.3 Trap Efficiency

Trap efficiency is determined from Churchill Curve, for that ratio of storage to average annual inflow is needed. Table 28 shows the calculations for trap efficiency for each dam. The second column shows the storage capacities in acre-ft of dams, the third column shows the annual inflows in acre-ft calculated using the HEC HMS and third column is the ratio of storage to inflows and last column gives us the trap efficiencies determined using the Churchill Curve as shown in Figure 18 taken from Small Dams USBR.

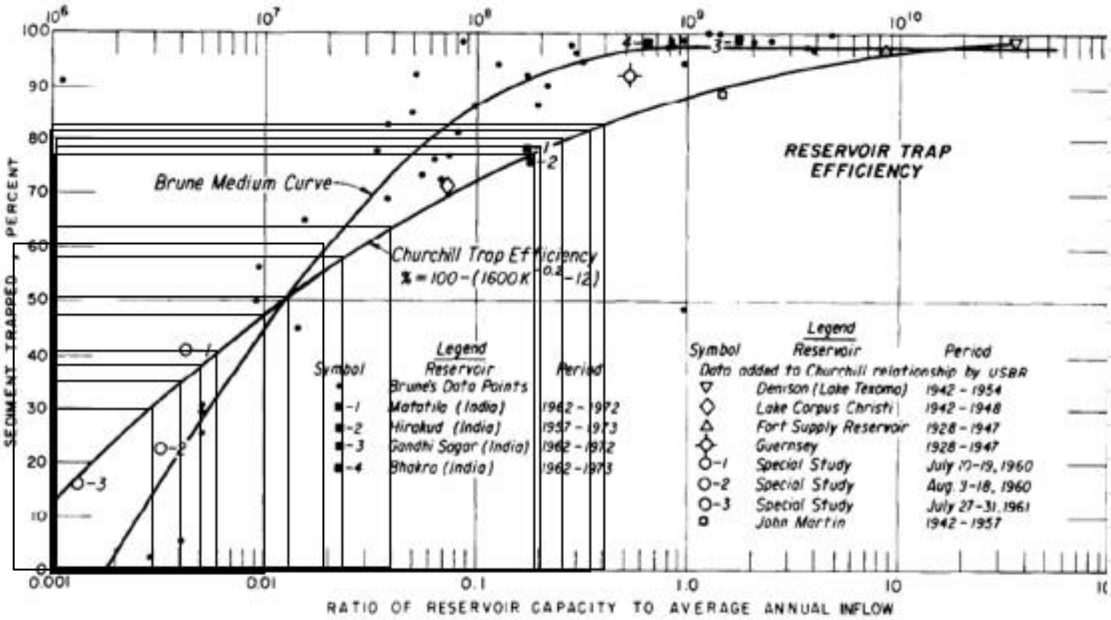


Figure 18: Churchill Curve

Table 28: Calculation for the trap efficiency at each dam.

Dam	Annual Inflow (Ac-ft)	Storage (Ac-ft)	Storage/inflow	Trap Efficiency
Dhal Dhoro II	2972.2	116.6	0.039	62
Gabol	24030.3	110.1	0.005	41
Naing II	82988.3	268.9	0.003	29
Qasim Tok	1799.9	720.4	0.400	82
AriPir	14095.9	188.7	0.013	58
Sureshi	483.3	160.5	0.332	81
Tikho II	31002.8	119.6	0.004	34
Upper Mole II	19128.1	117.7	0.006	41
Jungshahi	9745.1	309.0	0.032	60
Konkar	20567.8	61.5	0.003	29
Karmathani	5666.8	58.3	0.010	46
Sabusan	2198.7	426.1	0.194	78
Sankar	4658.1	979.3	0.210	79
Bhansar Rathi	9370.1	2373.1	0.253	80

4.2.4 Changes in Storage

Table 29 shows the calculations for the change in storage in two years since the dams went into operation. In this table second column gives storage in ac-ft at completion of the dam, third column is the current storage (May/June 2022) and the fourth column shows the percentage of the storage silted so far. The results are quiet encouraging and in most of the cases capacity of the dams have not reduced much except for two dams i.e. Tikho II and Jungshahi Dams.

Table 29: Calculation for the changes in storage and percentage silted in each dam.

Name	Storage at Completion (ac-ft)	Storage Current May/June 2022 (ac-ft)	Change (ac-ft)	% change
Dhal Dhoro II	116.6	114.2	2.4	2.1
Gabol	110.1	105.2	4.9	4.5
Naing II	268.9	251.2	17.7	6.6
Qasim Tok	720.4	695.5	24.9	3.5
AriPir	188.7	184.5	4.2	2.2
Sureshi	160.5	151.6	8.8	5.5
Tikho II	119.6	108.9	10.7	10.7
Upper Mole II	117.7	111.1	6.6	5.6
Jungshahi	309.0	288.2	20.8	16.1
Konkar	61.5	60.2	1.3	2.2
Karmathani	58.3	56.7	1.6	2.7
Sabusan	426.1	414.3	11.8	2.8
Sankar	979.3	952.8	26.5	2.7
Bhansar Rathi	2373.1	2330.5	42.6	1.8

4.2.5 Life of the Dam

At the current rate of deposition and life of the dams as calculated in Table 30. The highest rate of deposition is at Jungshahi and Tikho II Dams as mentioned earlier whereas the lowest is at Bhansar Rathi Dam. Most of the dams are predicted to have a life of more than 25 years.

Table 30: Life of the dam in years at the present rate of deposition.

Name	years to silt 25%	years to silt 50%	years to silt 75%	years to silt 100%
Dhal Dhoro II	11.9	23.8	35.8	47.7
Gabol	5.6	11.2	16.8	22.4
Naing II	3.8	7.6	11.4	15.2
Qasim Tok	7.2	14.4	21.7	28.9
AriPir	11.3	22.7	34.0	45.3
Sureshi	4.5	9.1	13.6	18.2
Tikho II	2.8	5.6	8.4	11.2
Upper Mole II	4.5	9.0	13.5	18.0
Jungshahi	3.7	7.4	11.1	14.8
Konkar	11.4	22.9	34.3	45.7
Karmathani	9.2	18.4	27.6	36.9
Sabusan	9.0	18.0	27.0	36.0
Sankar	9.2	18.5	27.7	36.9
Bhansar Rathi	13.9	27.9	41.8	55.7

4.2.6 Dam wise analysis for catchment area, land use land cover, sediment deposit, stage-area, and stage-capacity

Dam wise analysis for the following has been carried out in detail:

(a) Delineating the catchment/watershed area of the dam,

(b) Land use land cover in the catchment/watershed of the dam,

(c) Sediment deposited thus far in each reservoir,

(d) stage-surface area and stage-capacity (volume) curves of each reservoir

GIS maps have been prepared for the first three and graphs have been prepared for the fourth and have been shown in the subsequent sections hereunder.

4.2.6.1 Dhal Dhoro II Dam

Dhal Dhoro II dam is located at 26° 5'7.07"N, 67°45'56.90"E in Upper Kohistan Region. The catchment area of the Dam is 8.4 square miles (Table 24), out of which 49.5% is Barren soil and the rest 50.5 % is Rocky Area (Table 25). The total capacity of the dam is 116.6 ac-ft (Table 29). The maximum silt deposit is about 2 inches near the base of the dam, which has reduced the capacity of the dam by 2.4 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, and sediment deposited so far are prepared and given below in Figure 19 to Figure 21. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 22.

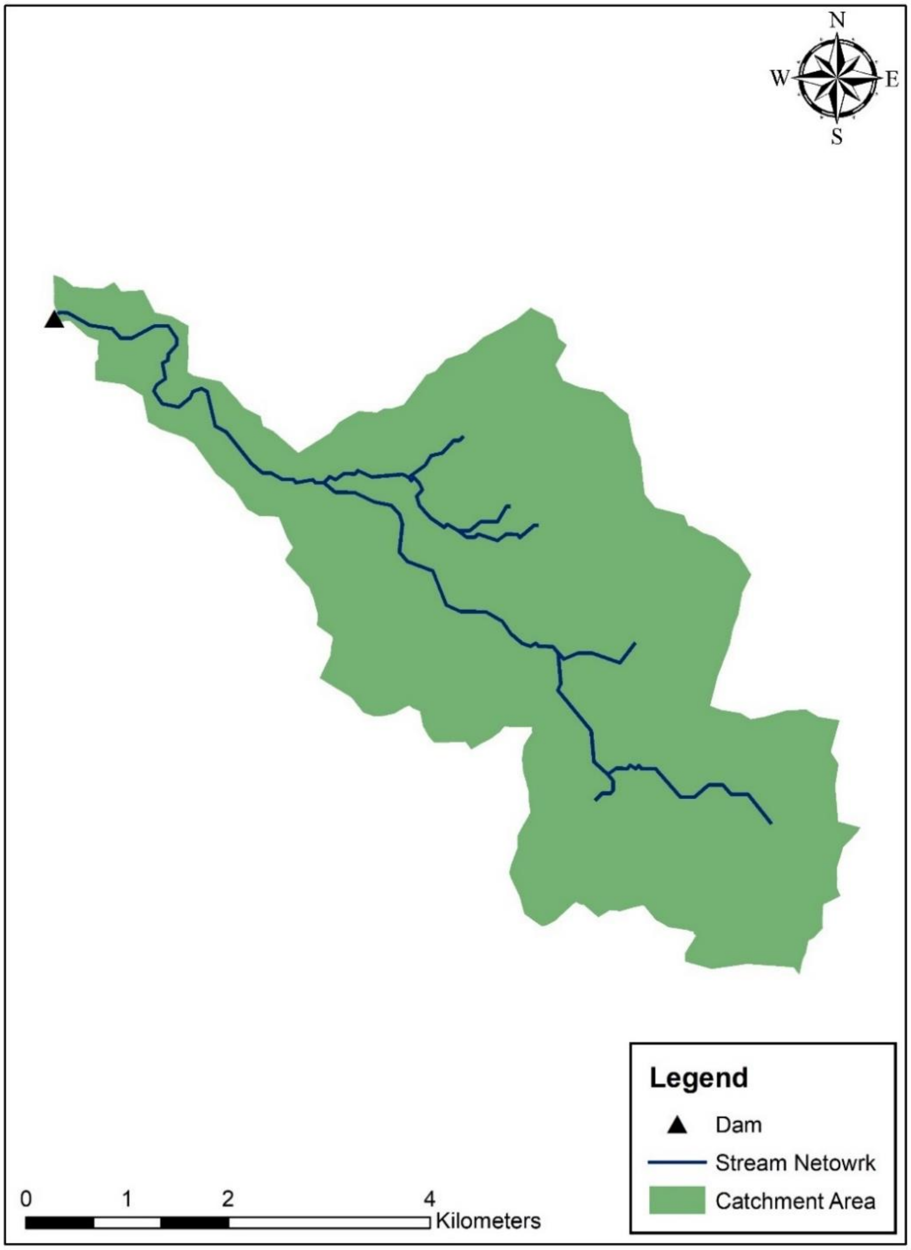


Figure 19: Catchment area of Dhal Dhoro II Dam.

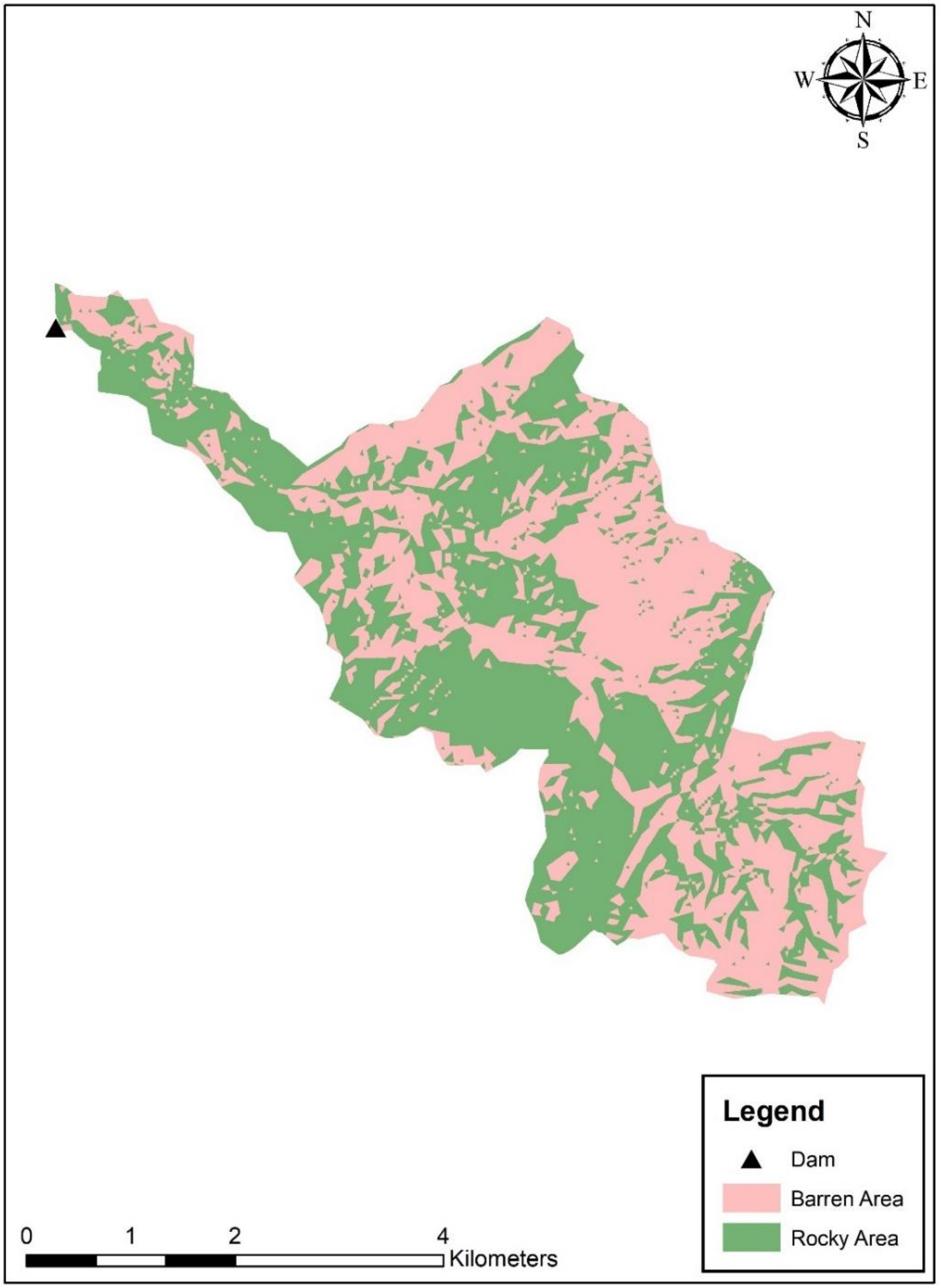


Figure 20: Land use land cover (LULC) in catchment area of Dhal Dhoro II dam.

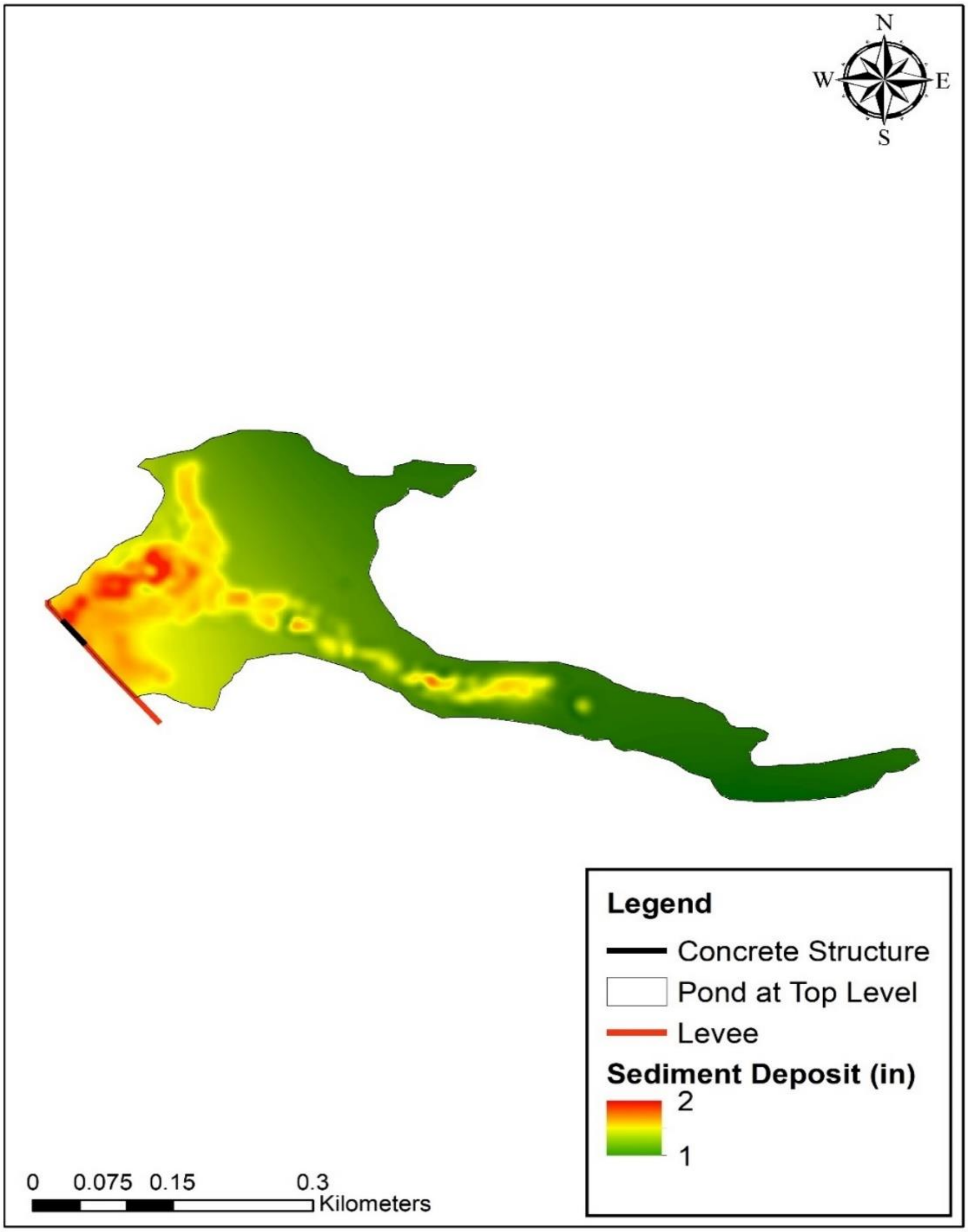


Figure 21: Sediment deposition in two years in the storage area of Dhal Dhoro II dam.

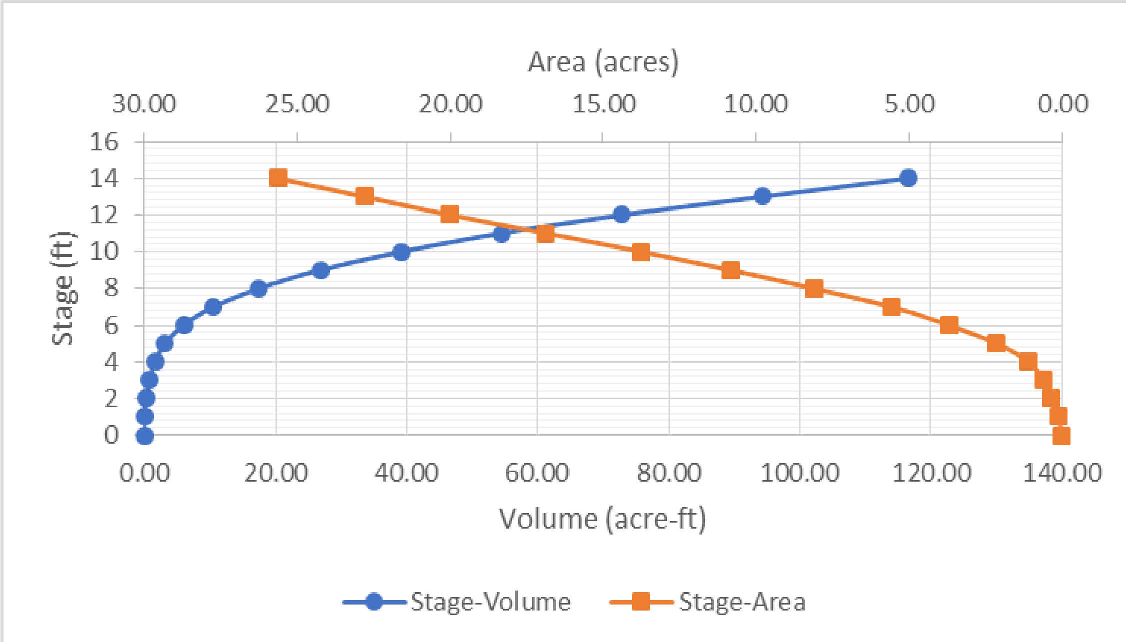


Figure 22: Stage-Area and Stage-capacity curves of Dhal Dhoro II dam.

4.2.6.2 Gabol Dam

Gabol Dam is located at 26° 4'47.89"N, 67°45'16.78"E in Upper Kohistan Region. Catchment area of the Dam is 69.0 square miles (Table 24), out of which 53.3% is Barren soil and rest 46.7 % is Rocky Area (Table 25). The total capacity of the dam is 110.1 ac-ft (Table 29). Maximum silt deposit is about 5 inches near the base of dam, which has reduced the capacity of dam by 4.9 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, sediment deposited so far are given below in Figure 23 to Figure 25. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 26.

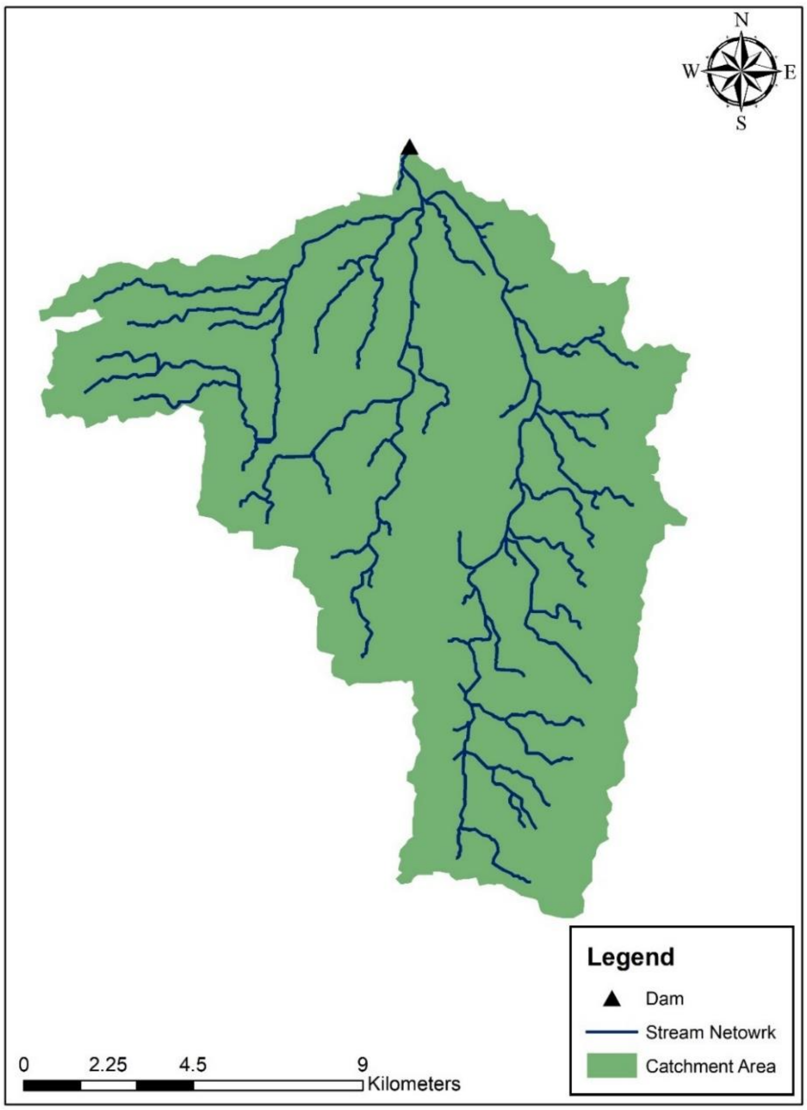


Figure 23: Catchment area of Gabol Dam.

Figure 24: Land use land cover (LULC) in the catchment area of Gabol dam.

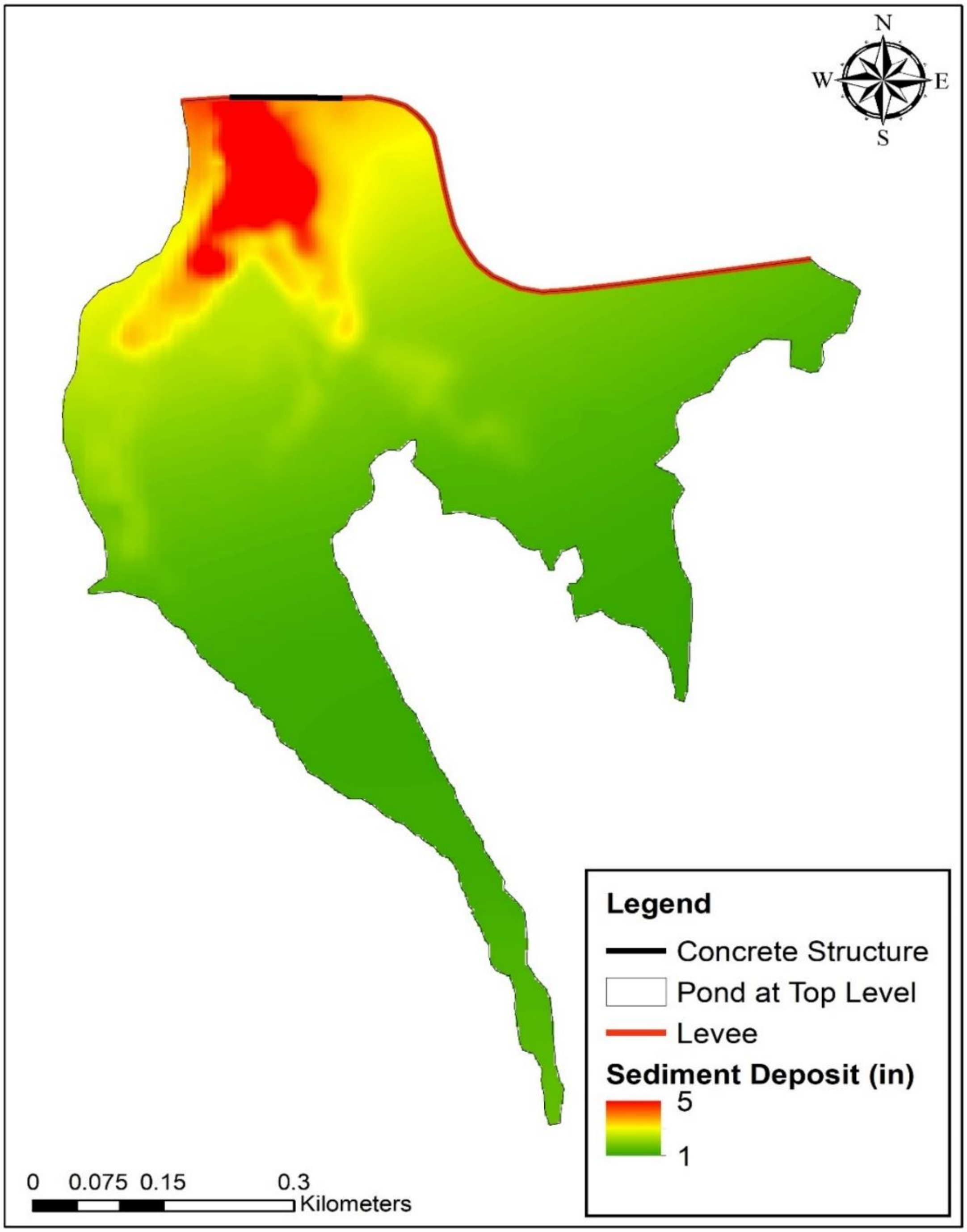


Figure 25: Sediment deposition in two years in the storage area of Gabol dam.

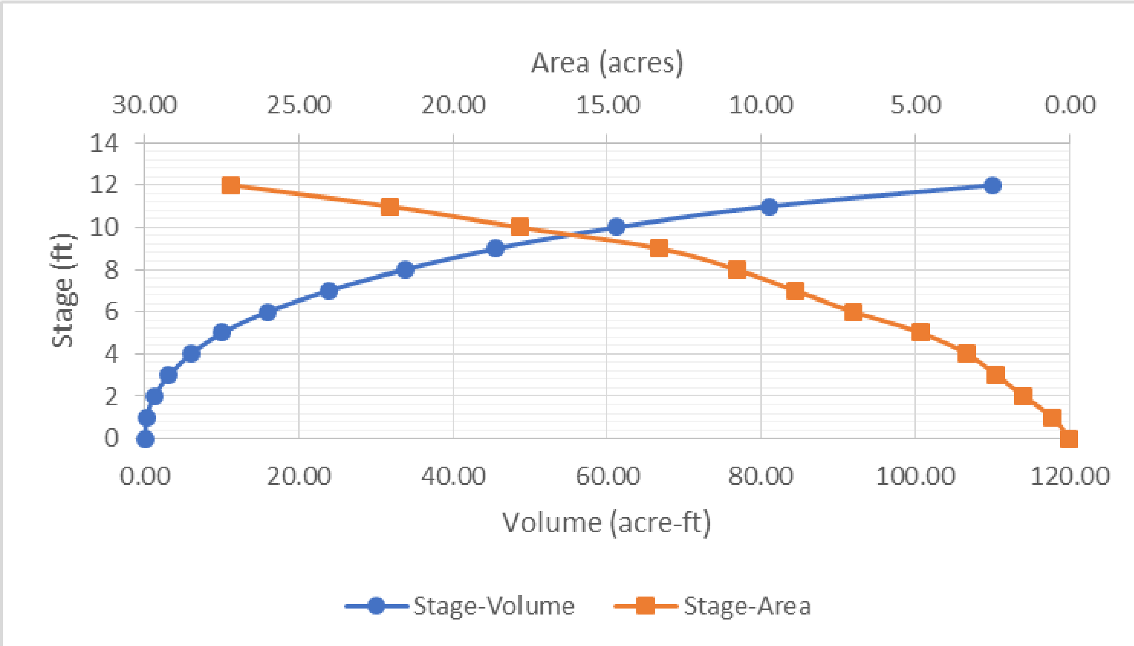


Figure 26: Stage-Area and Stage-capacity curves of Gabol dam.

4.2.6.3 Naing II Dam

Naing II dam is located at 26°14'32.11"N, 67°30'38.04"E in Upper Kohistan Region. The catchment area of the Dam is 238.5 square miles (Table 24), out of which 53.4% is Barren soil and the rest 46.6 % is Rocky Area (Table 25). The total capacity of the dam is 268.9 ac-ft (Table 29). The maximum silt deposit is about 6 inches near the base of the dam, which has reduced the capacity of the dam by 17.7 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, and sediment deposited so far are given below in Figure 27 toFigure 29. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 30.

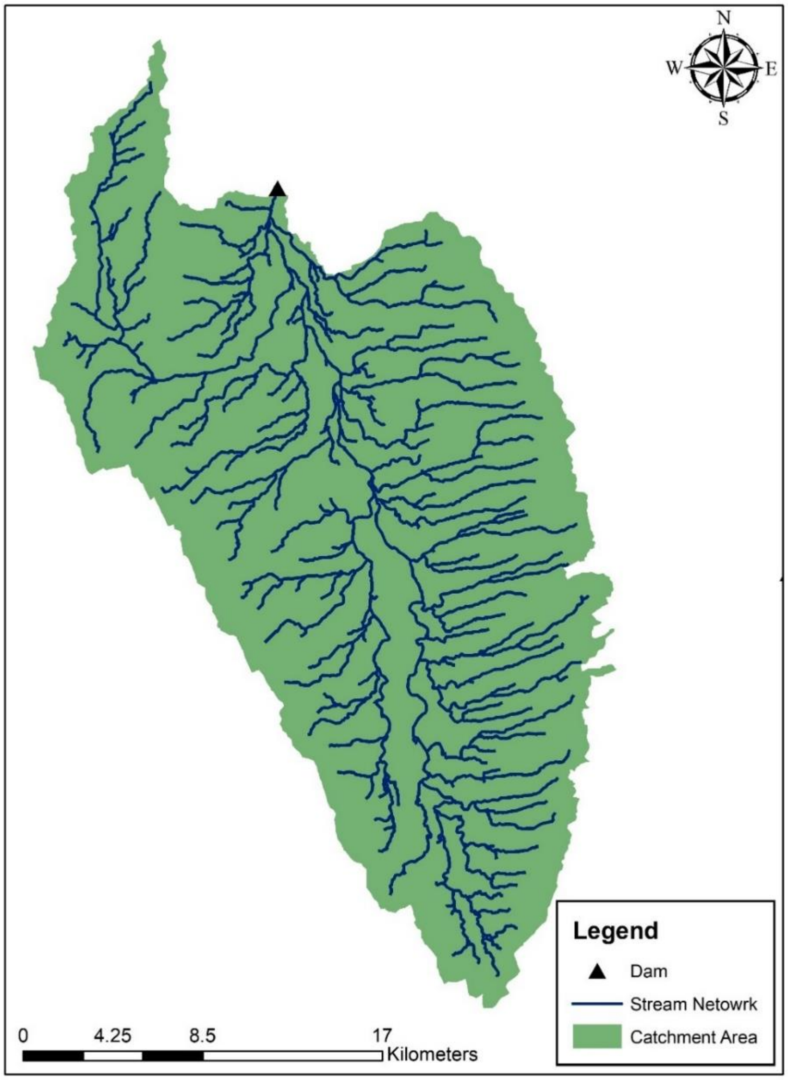


Figure 27: Catchment area of Naing II Dam.

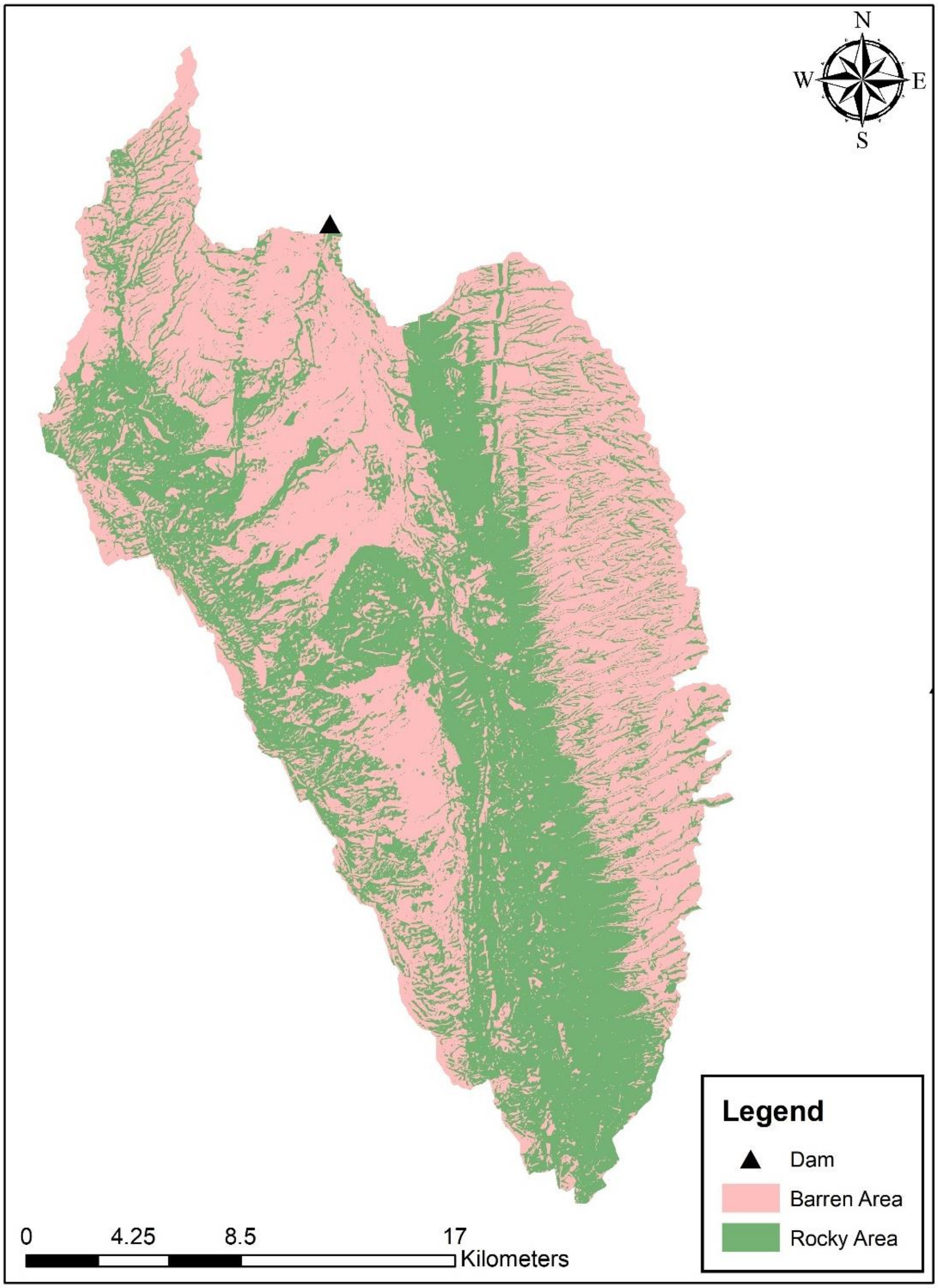


Figure 28: Land use land cover (LULC) in the catchment area of Naing II dam.

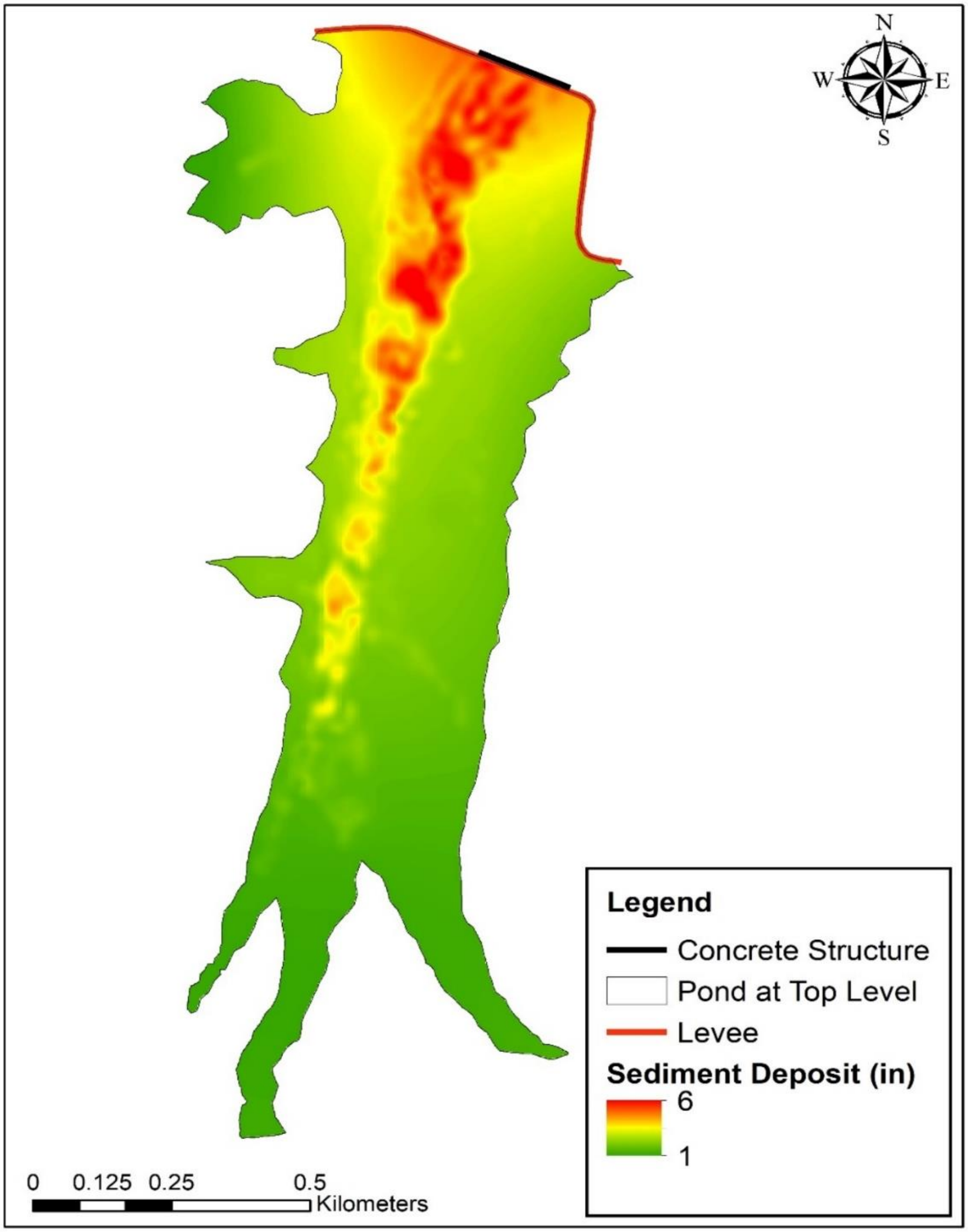


Figure 29: Sediment deposition in two years in the storage area of Naing II dam.

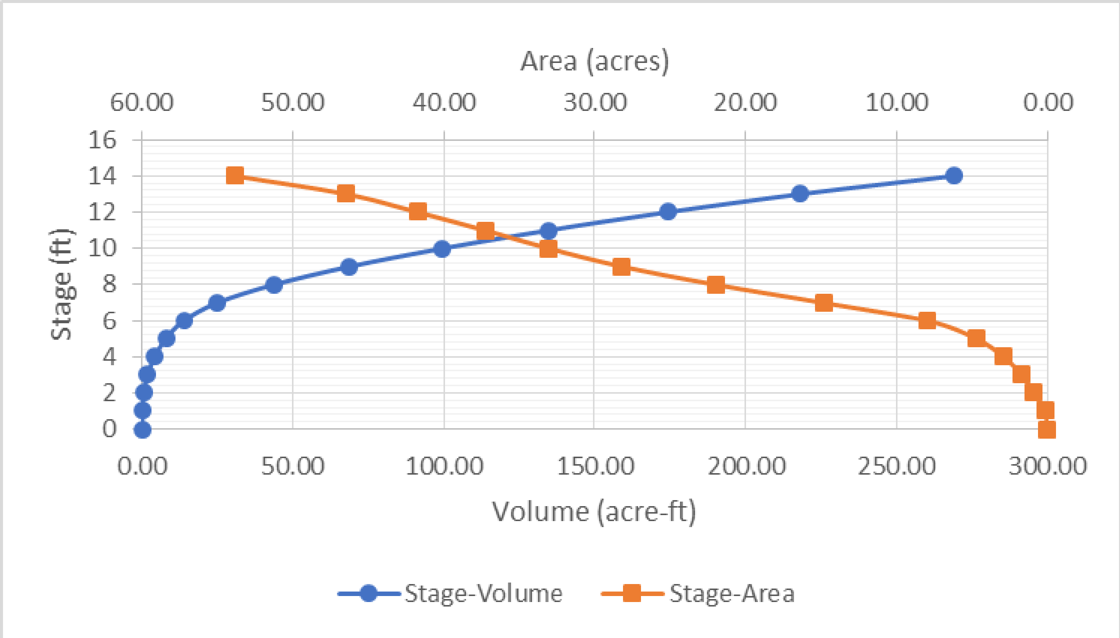


Figure 30: Stage-Area and Stage-capacity curves of Naing II dam.

4.2.6.4 Qasim Tok Dam

Qasim Tok dam is located at 26°33'56.80"N, 67°21'44.29"E in Upper Kohistan Region. Catchment area of the Dam is 4.7 square miles (Table 24), out of which 30.4% is Barren soil and rest 69.6 % is Rocky Area (Table 25). The total capacity of the dam is 720.4 ac-ft (Table 29). Maximum silt deposit is about 2 inches near the base of dam, which has reduced the capacity of dam by 24.9 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, sediment deposited so far are given below Figure 31 to Figure 33. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 34.

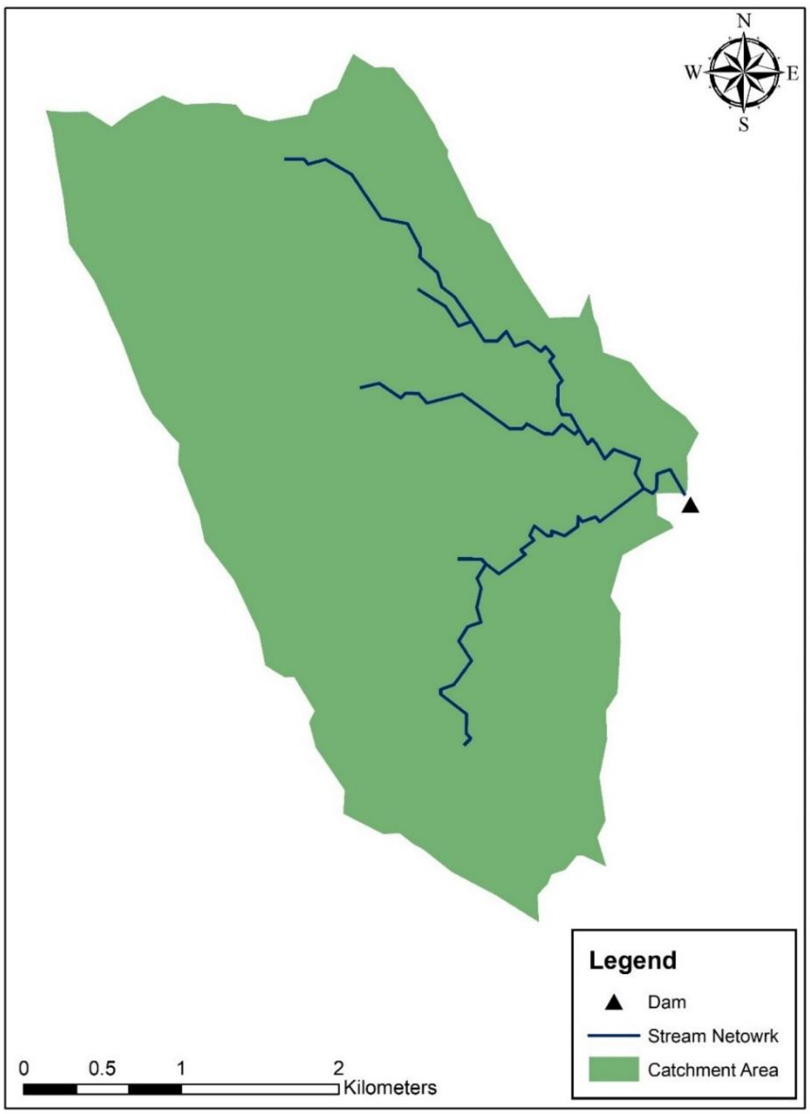


Figure 31: Catchment area of Qasim Tok Dam.

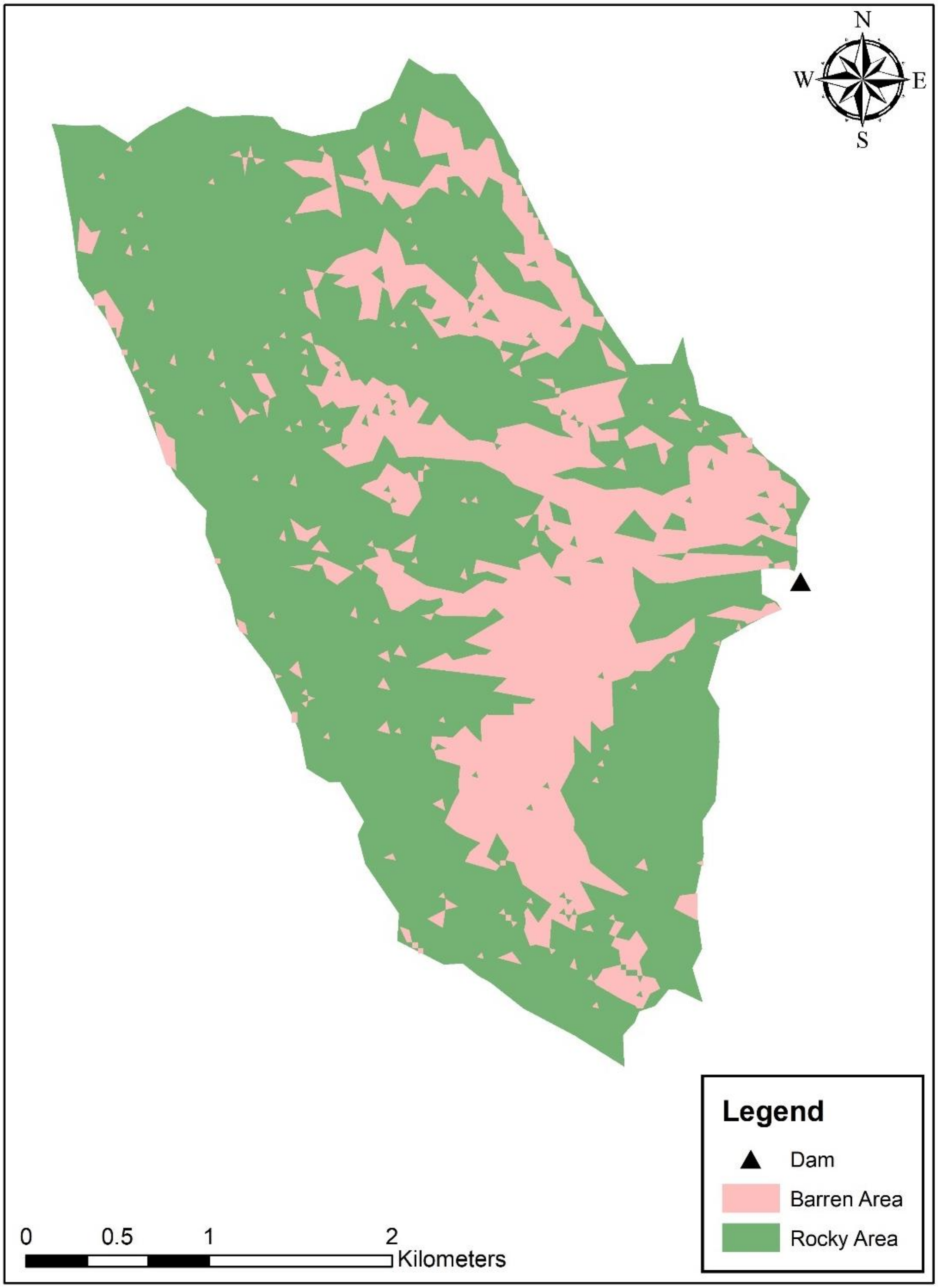


Figure 32: Land use land cover (LULC) in catchment area of Qasim Tok dam.

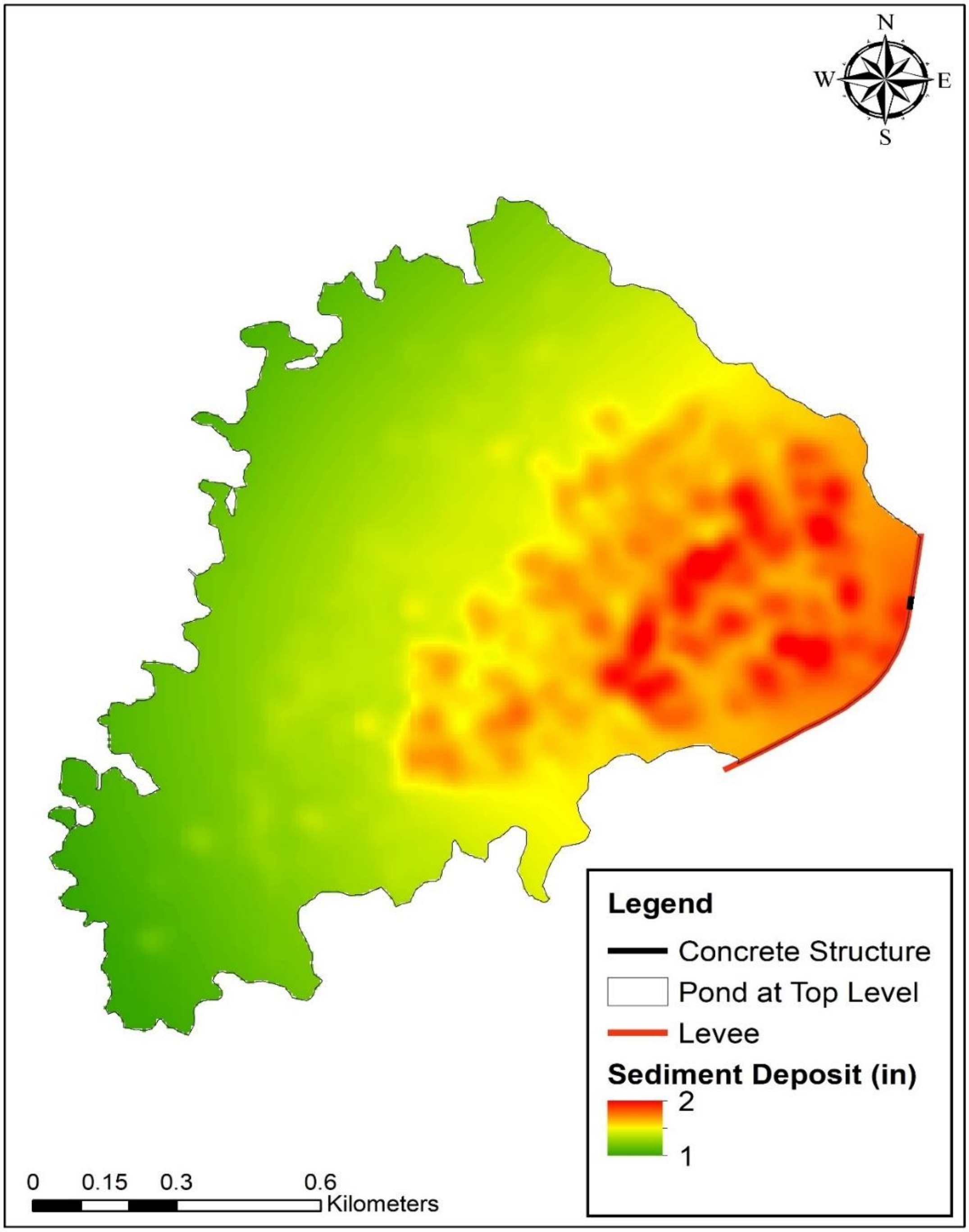


Figure 33: Sediment deposition in two years in the storage area of Qasim Tok dam.

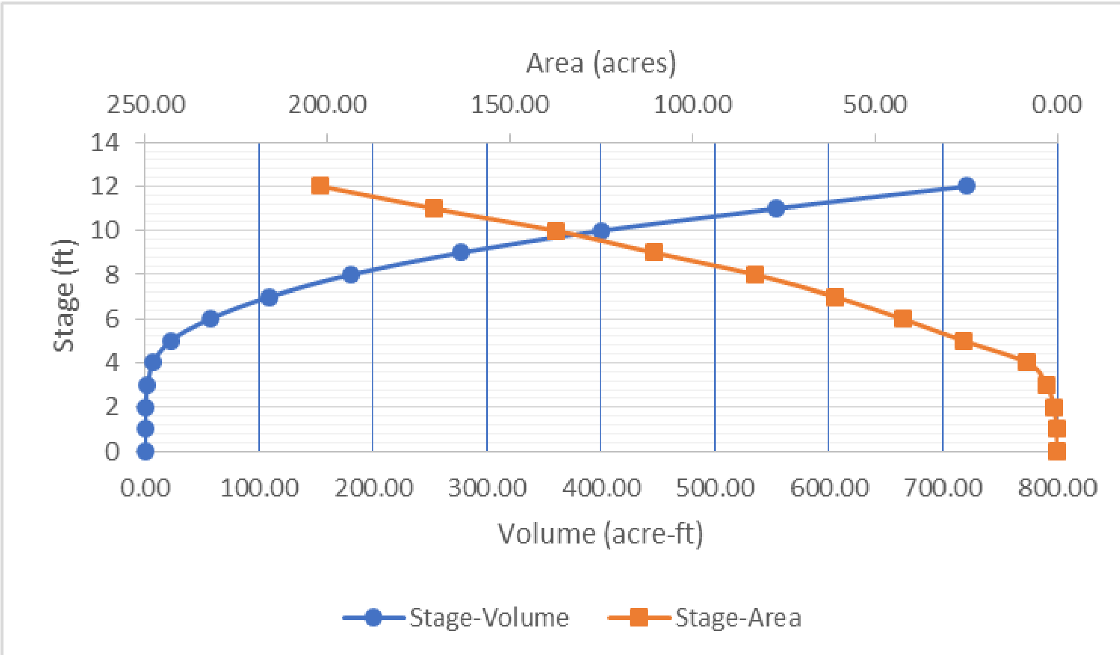


Figure 34: Stage-Area and Stage-capacity curves of Qasim Tok dam.

4.2.6.5 Ari Pir Dam

Ari Pir dam is located at 25°30'33.78''N, 67°27'56.37''E in Central Kohistan Region. Catchment area of the Dam is 37.3 square miles (Table 24), out of which 33.7% is Barren soil and rest 66.3 % is Rocky Area (Table 25). The total capacity of the dam is 188.7 ac-ft (Table 29). Maximum silt deposit is about 3 inches near the base of dam, which has reduced the capacity of dam by 4.2 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, sediment deposited so far are given below in Figure 35 to Figure 37. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 38.

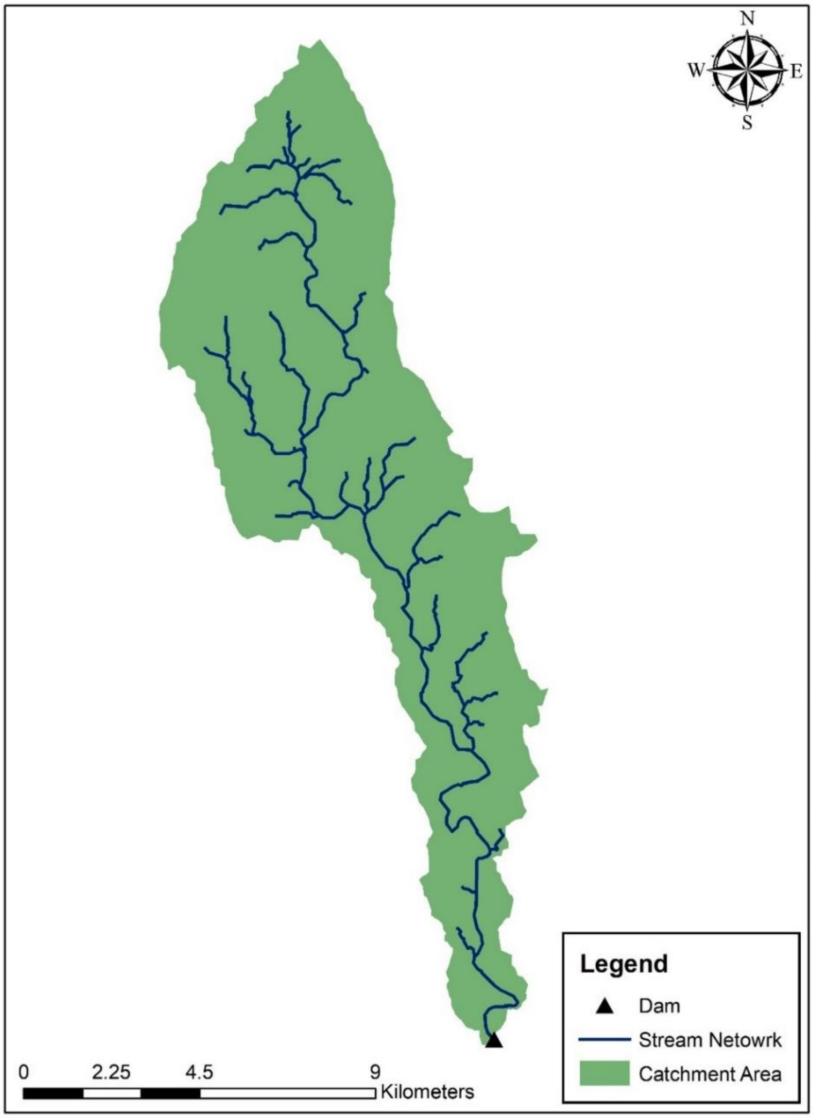


Figure 35: Catchment area of Ari Pir Dam.

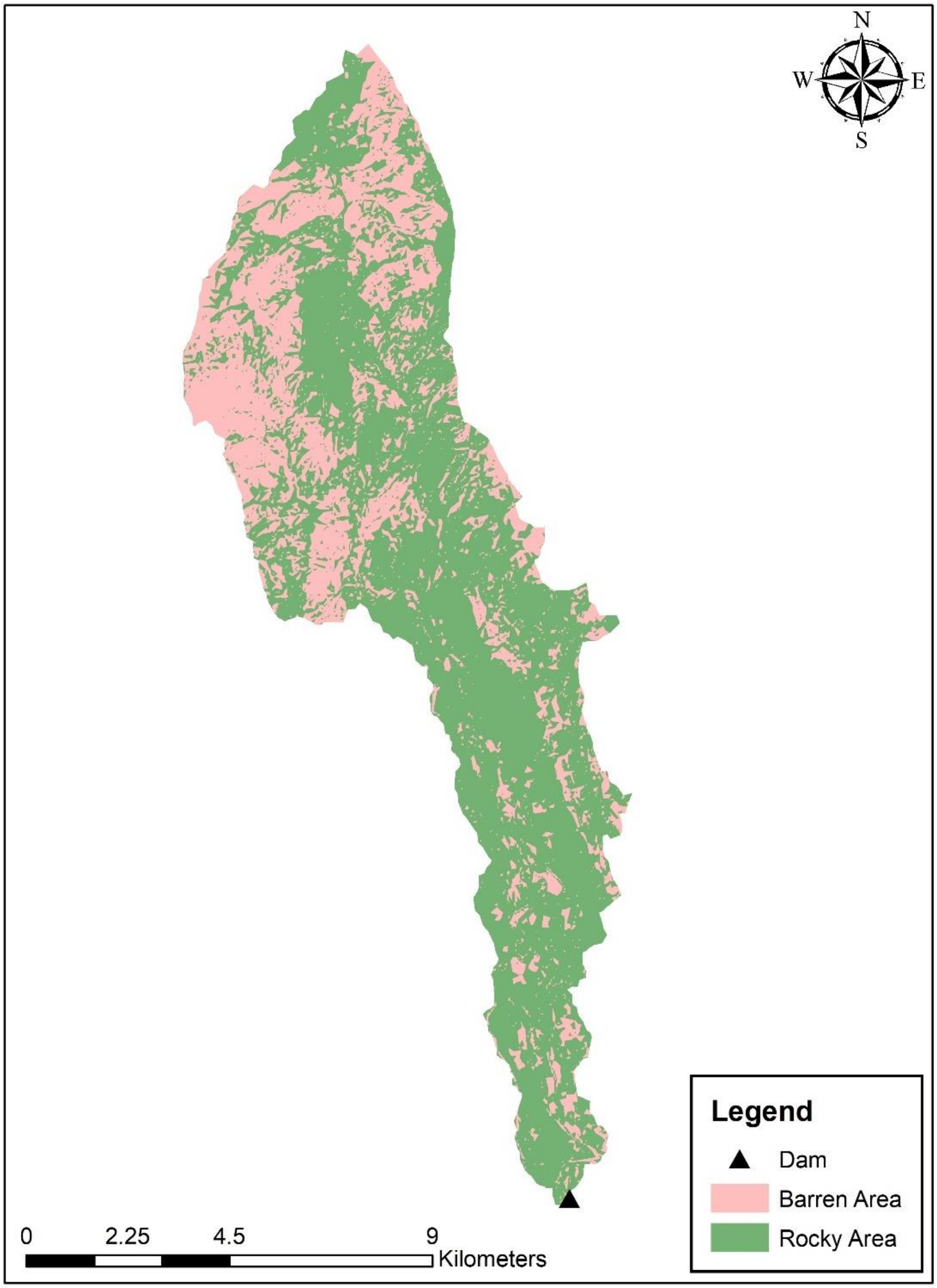


Figure 36: Land use land cover (LULC) in catchment area of Ari Pir dam.

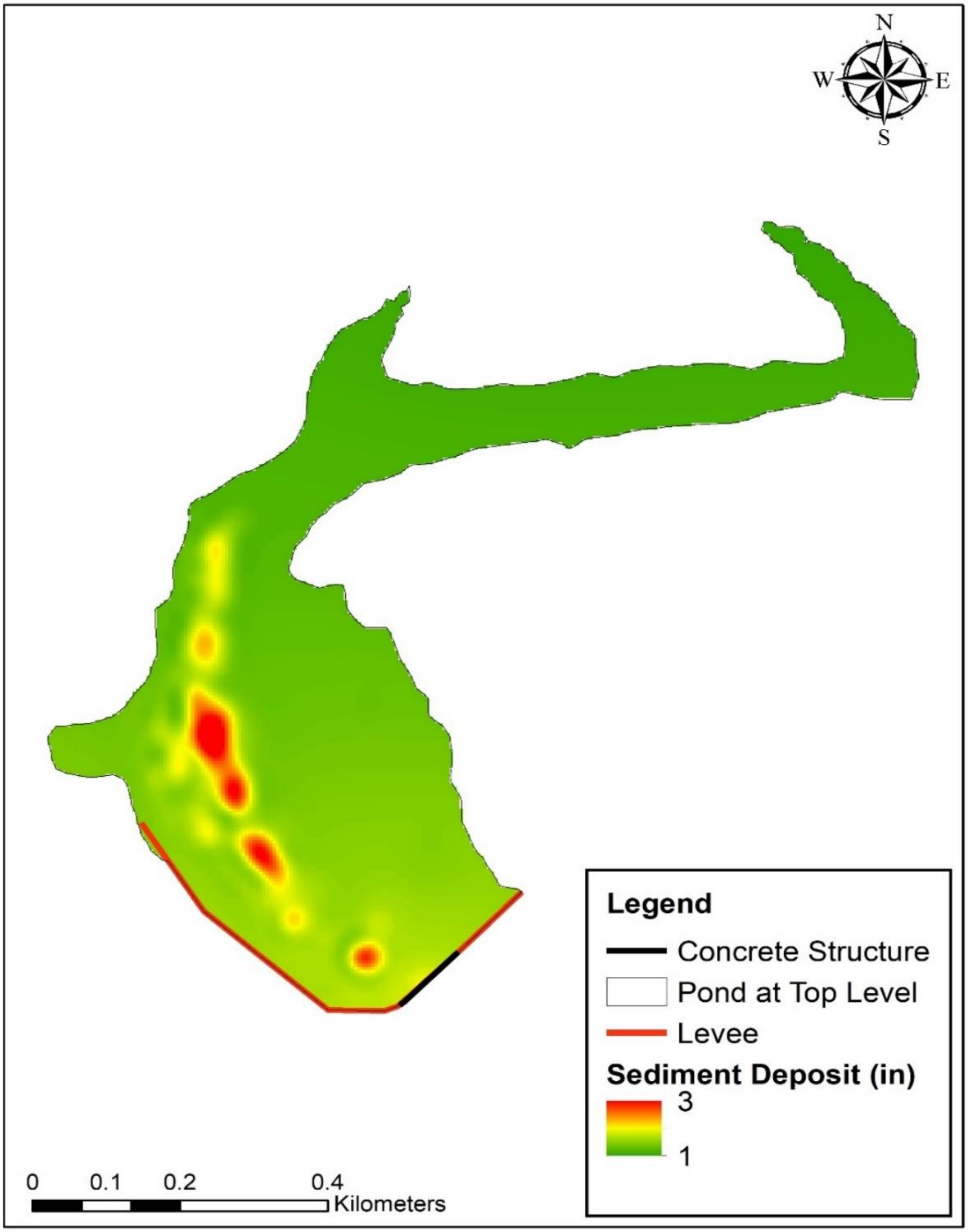


Figure 37: Sediment deposition in two years in the storage area of Ari Pir dam.

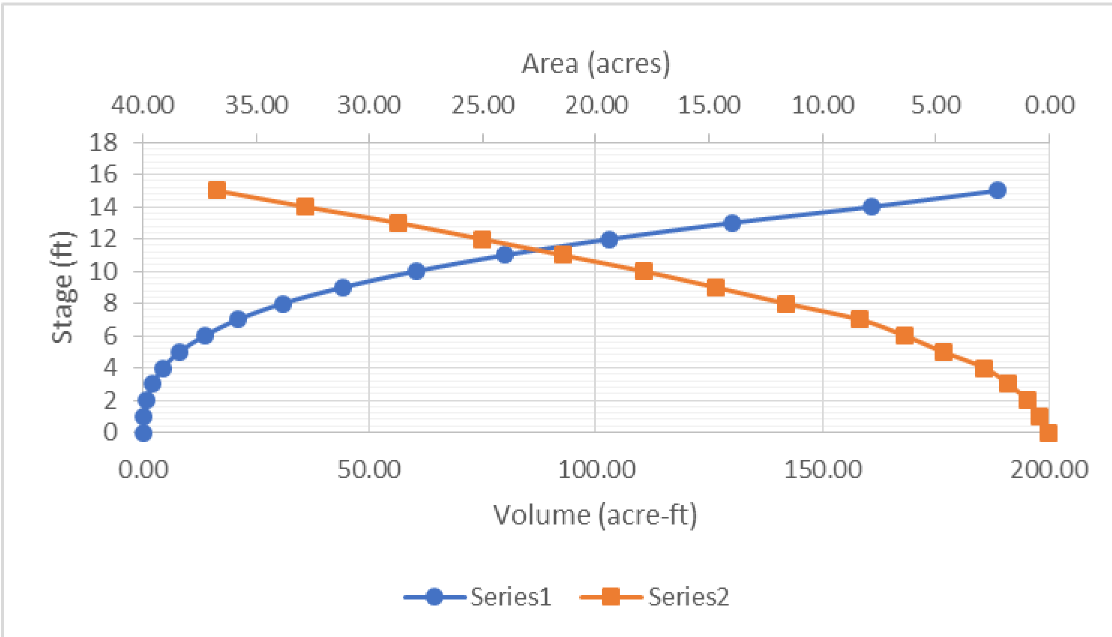


Figure 38: Stage-Area and Stage-capacity curves of Ari Pir dam.

4.2.6.6 Sureshi Dam

Sureshi dam is located at 25°31'44.75"N, 67°38'49.63"E in Central Kohistan Region. Catchment area of the Dam is 7.1 square miles (Table 24), out of which 13.8% is Barren soil and rest 86.2 % is Rocky Area (Table 25). The total capacity of the dam is 160.5 ac-ft (Table 29). Maximum silt deposit is about 4 inches near the base of dam, which has reduced the capacity of dam by 8.8 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, sediment deposited so far are given below in Figure 39 to Figure 41. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 42.

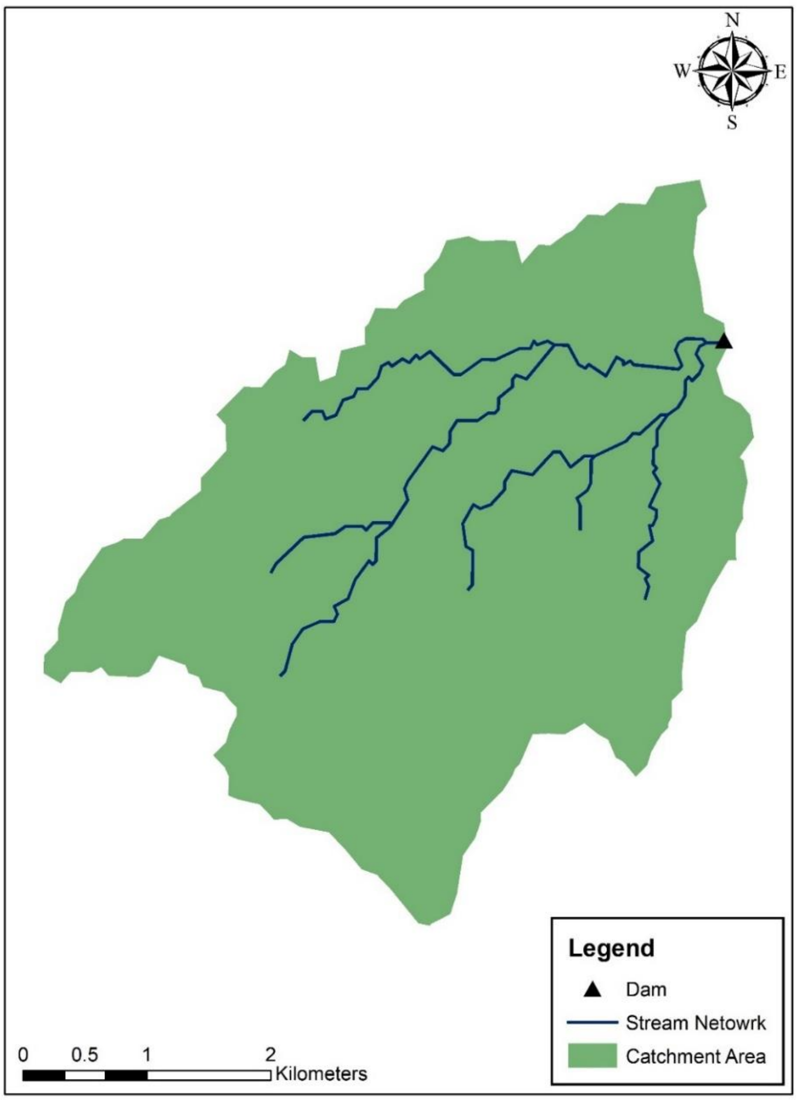


Figure 39: Catchment area of Sureshi Dam.

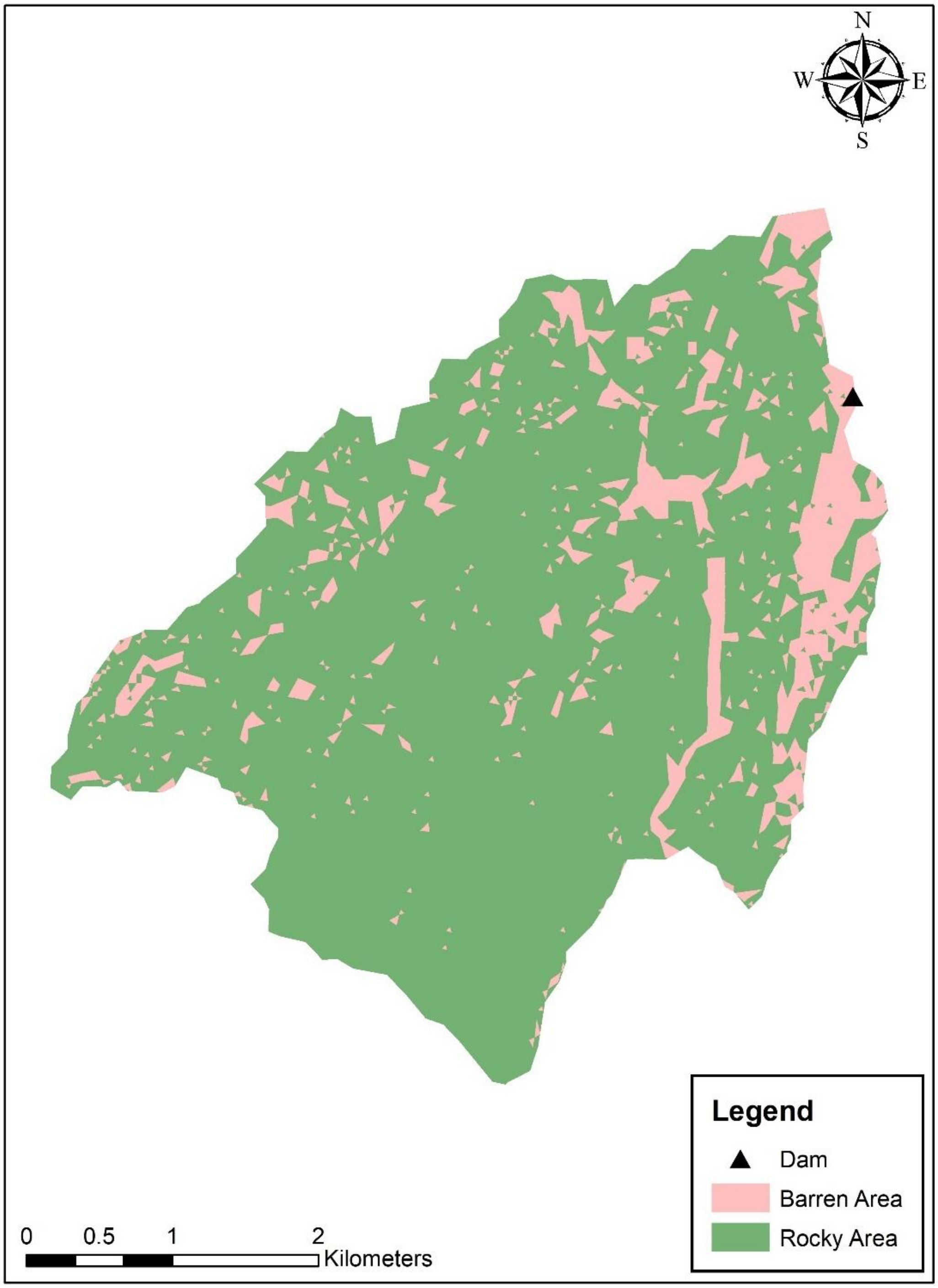


Figure 40: Land use land cover (LULC) in the catchment area of Sureshi dam.

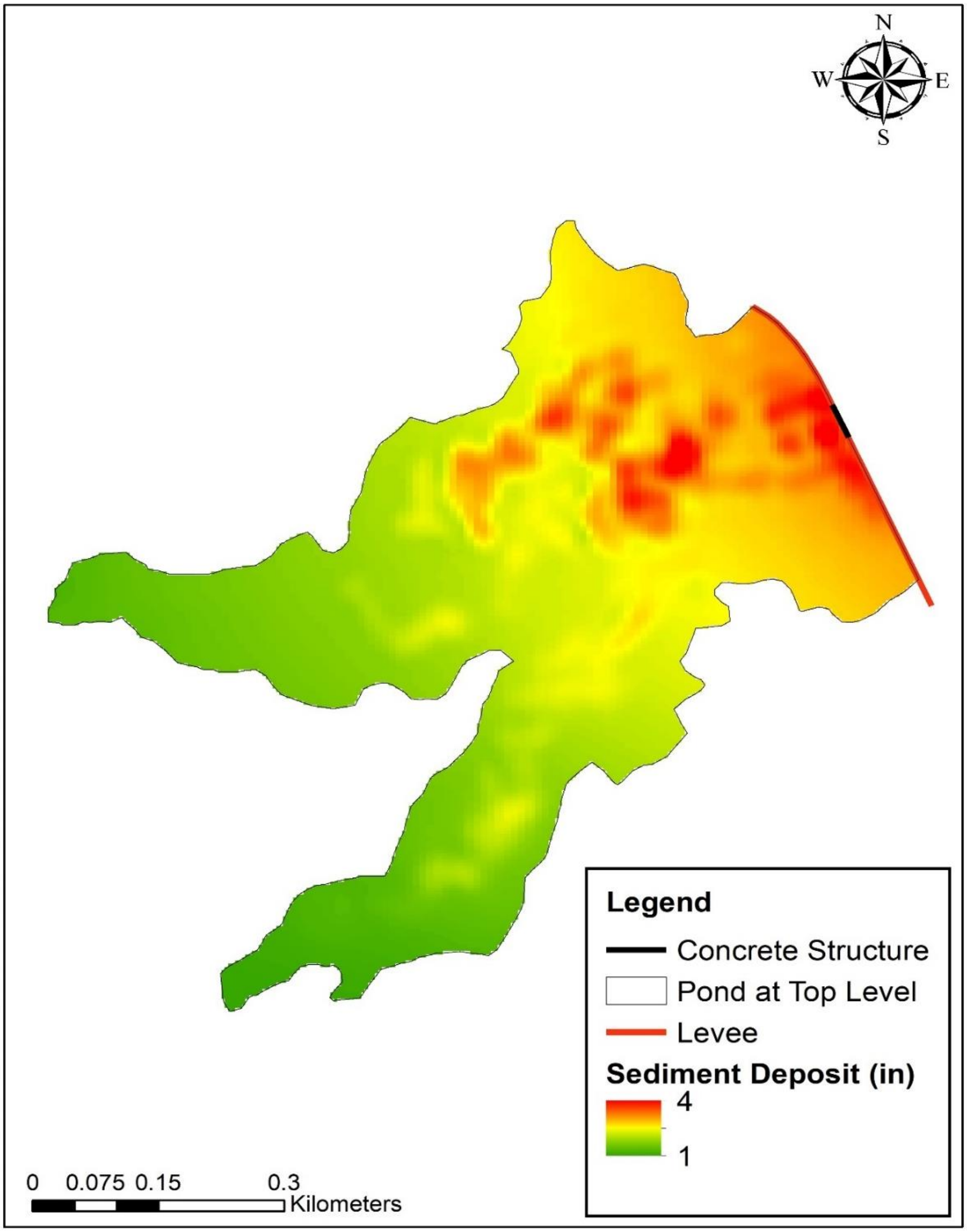


Figure 41: Sediment deposition in two years in the storage area of Sureshi dam.

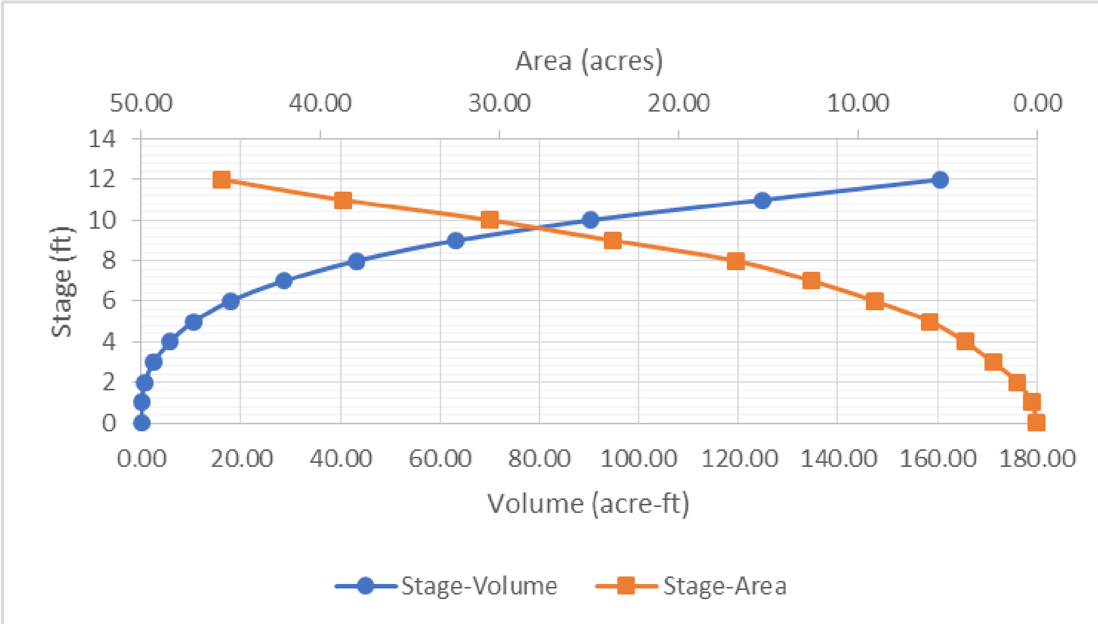


Figure 42: Stage-Area and Stage-capacity curves of Sureshi dam.

4.2.6.7 Tikho II Dam

Tikho II dam is located at 25°38'26.85''N, 67°37'36.52''E in Central Kohistan Region. Catchment area of the Dam is 76.4 square miles (Table 24), out of which 15.3% is Barren soil and rest 84.7 % is Rocky Area (Table 25). The total capacity of the dam is 119.6 ac-ft (Table 29). Maximum silt deposit is about 42 inches near the base of dam, which has reduced the capacity of dam by 10.7 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, sediment deposited so far are given below in Figure 43 to Figure 45. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 46.

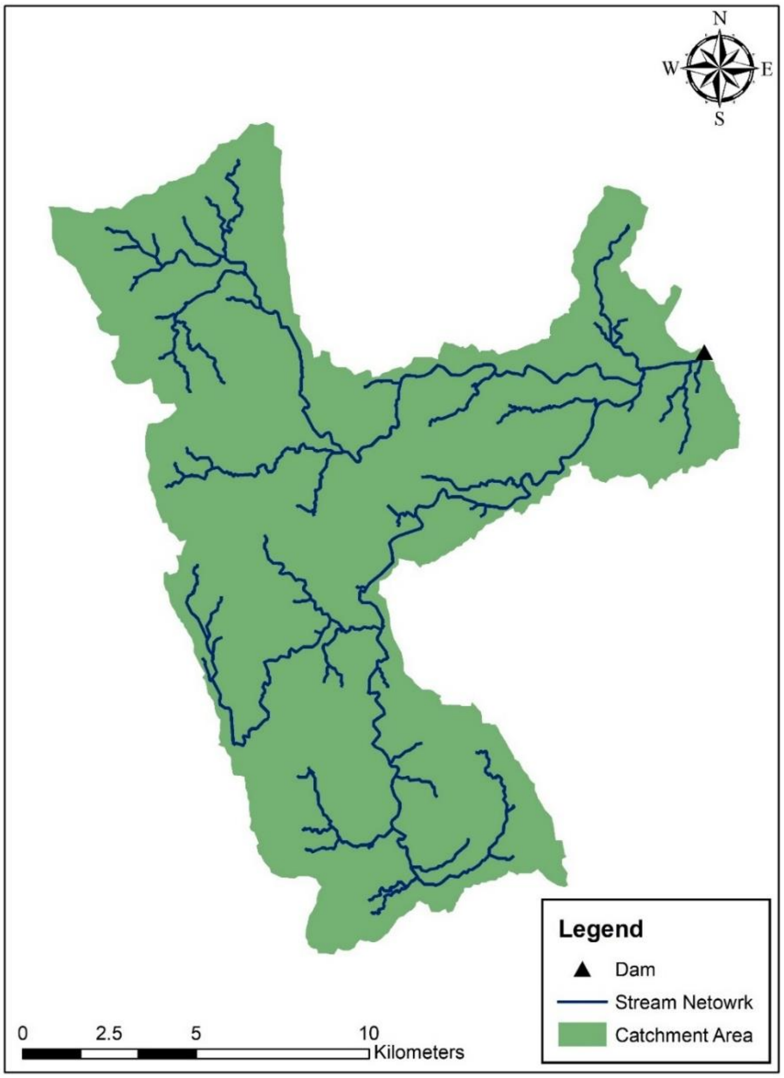


Figure 43: Catchment area of Tikho-II Dam

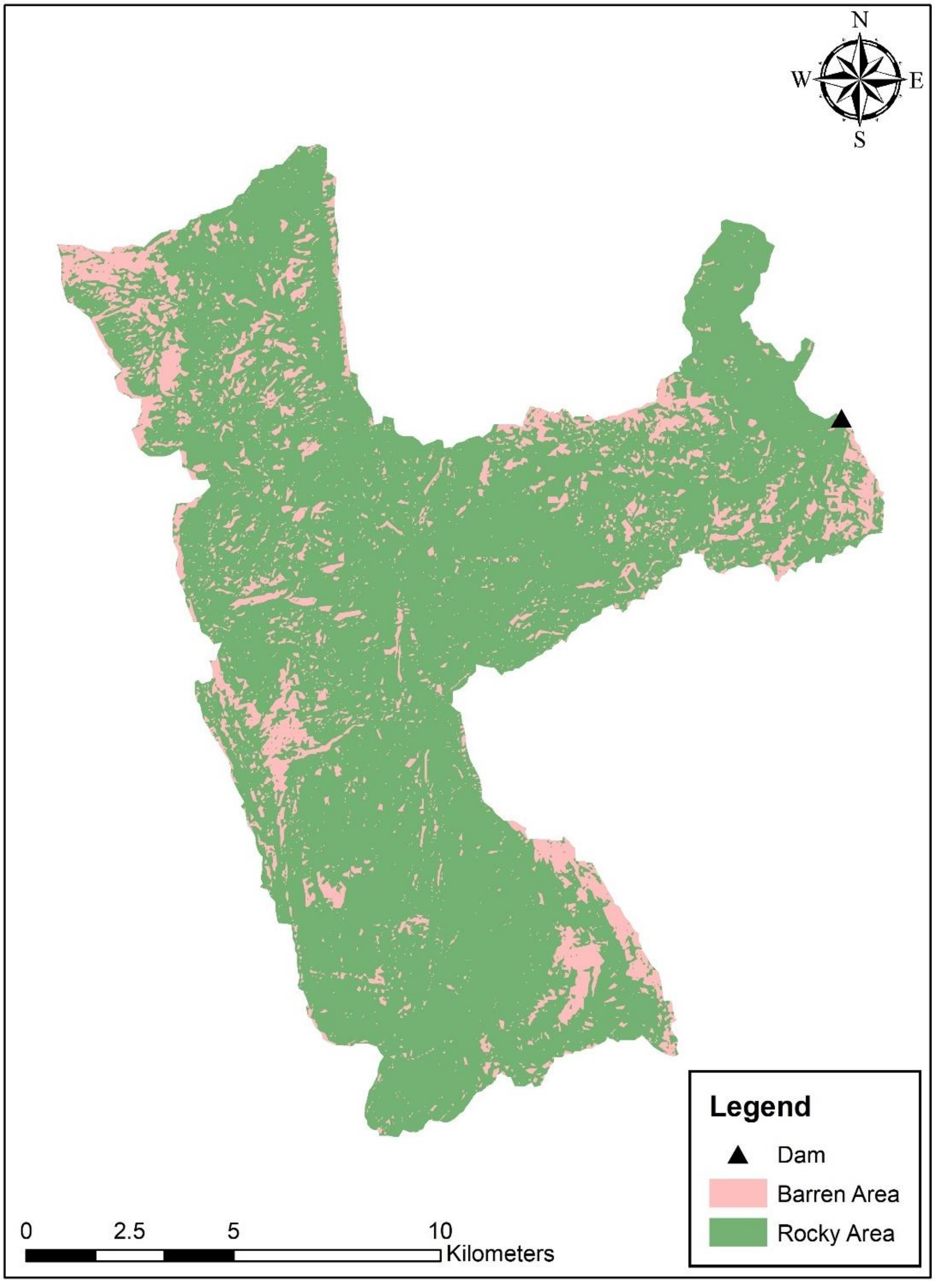


Figure 44: Land use land cover (LULC) in the catchment area of Tikho II dam.

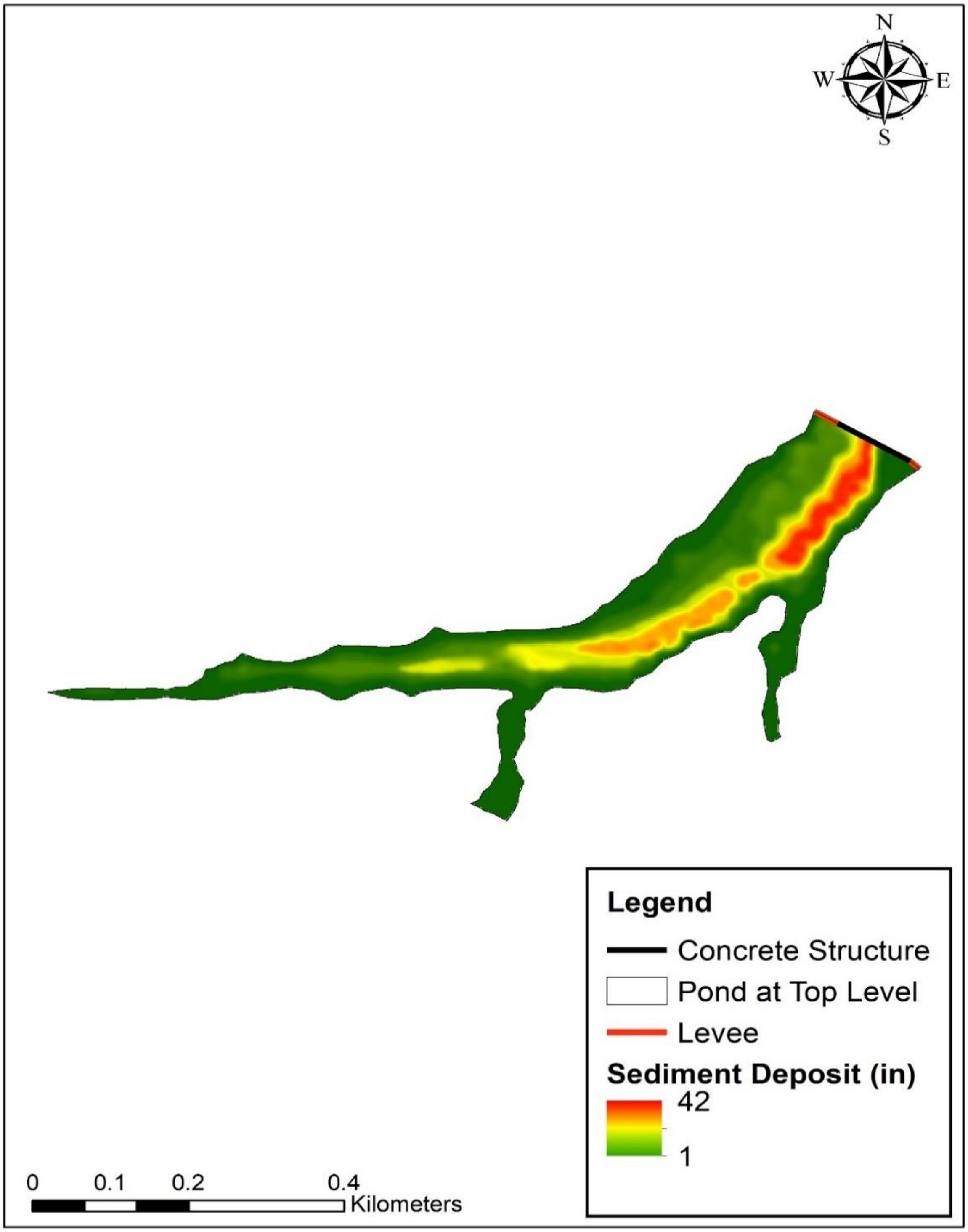


Figure 45: Sediment deposition in two years in the storage area of Tikho II dam.

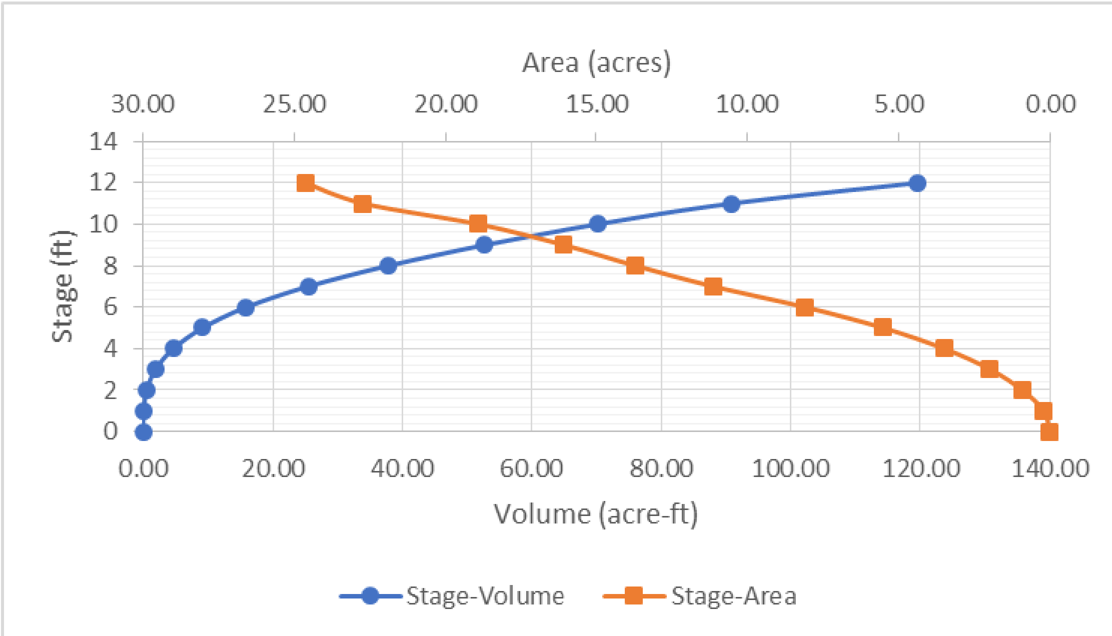


Figure 46: Stage-Area and Stage-capacity curves of Tikho II dam.

4.2.6.8 Upper Mole II Dam

Upper Mole II dam is located at 25°25'48.30"N, 67°27'17.28"E in Central Kohistan Region. Catchment area of the Dam is 52.1 square miles (Table 24), out of which 40.8% is Barren soil and rest 59.2 % is Rocky Area (Table 25). The total capacity of the dam is 117.7 ac-ft (Table 29). Maximum silt deposit is about 4 inches near the base of dam, which has reduced the capacity of dam by 6.6 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, sediment deposited so far are given below in Figure 47 to Figure 49. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 50.

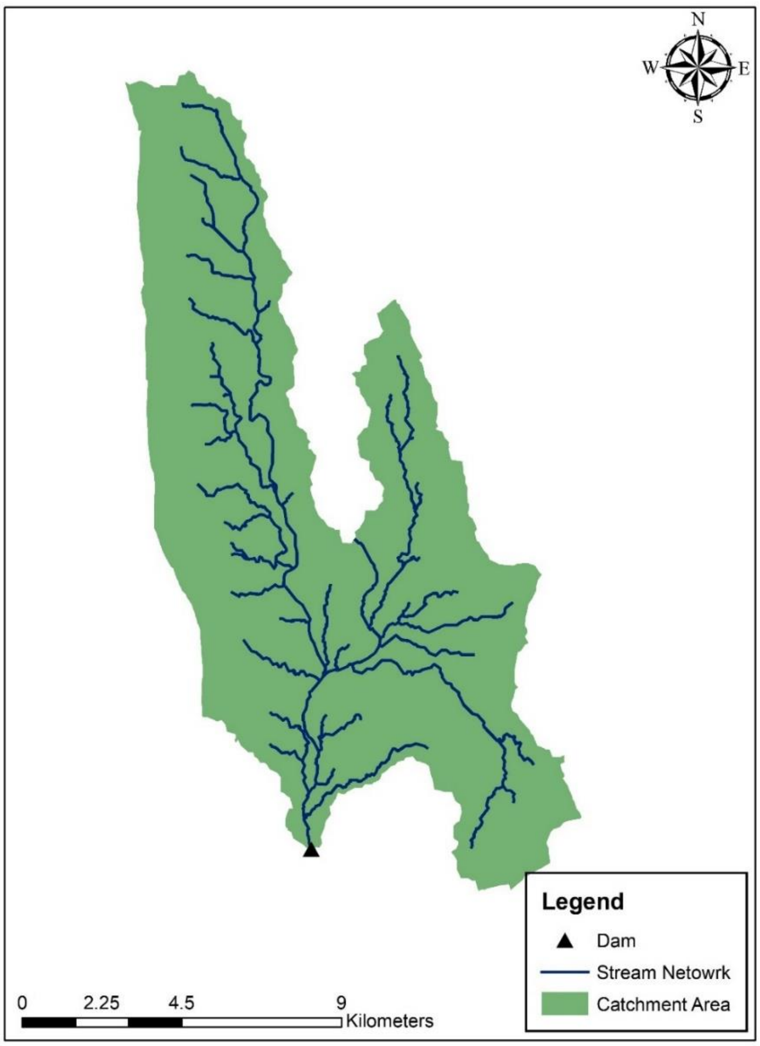


Figure 47: Catchment area of Upper Mole II Dam.

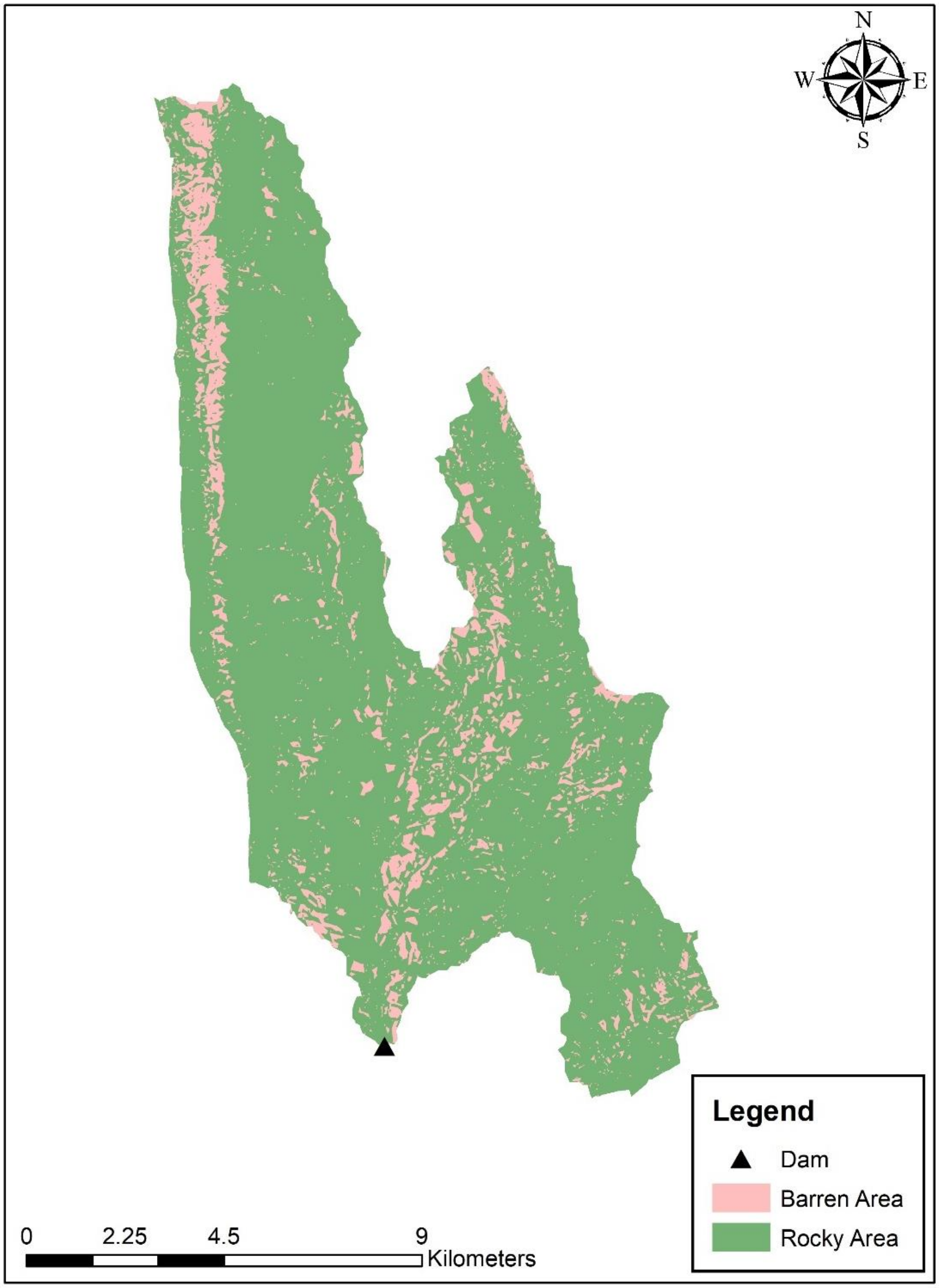


Figure 48: Land use land cover (LULC) in catchment area of Upper Mole II dam.

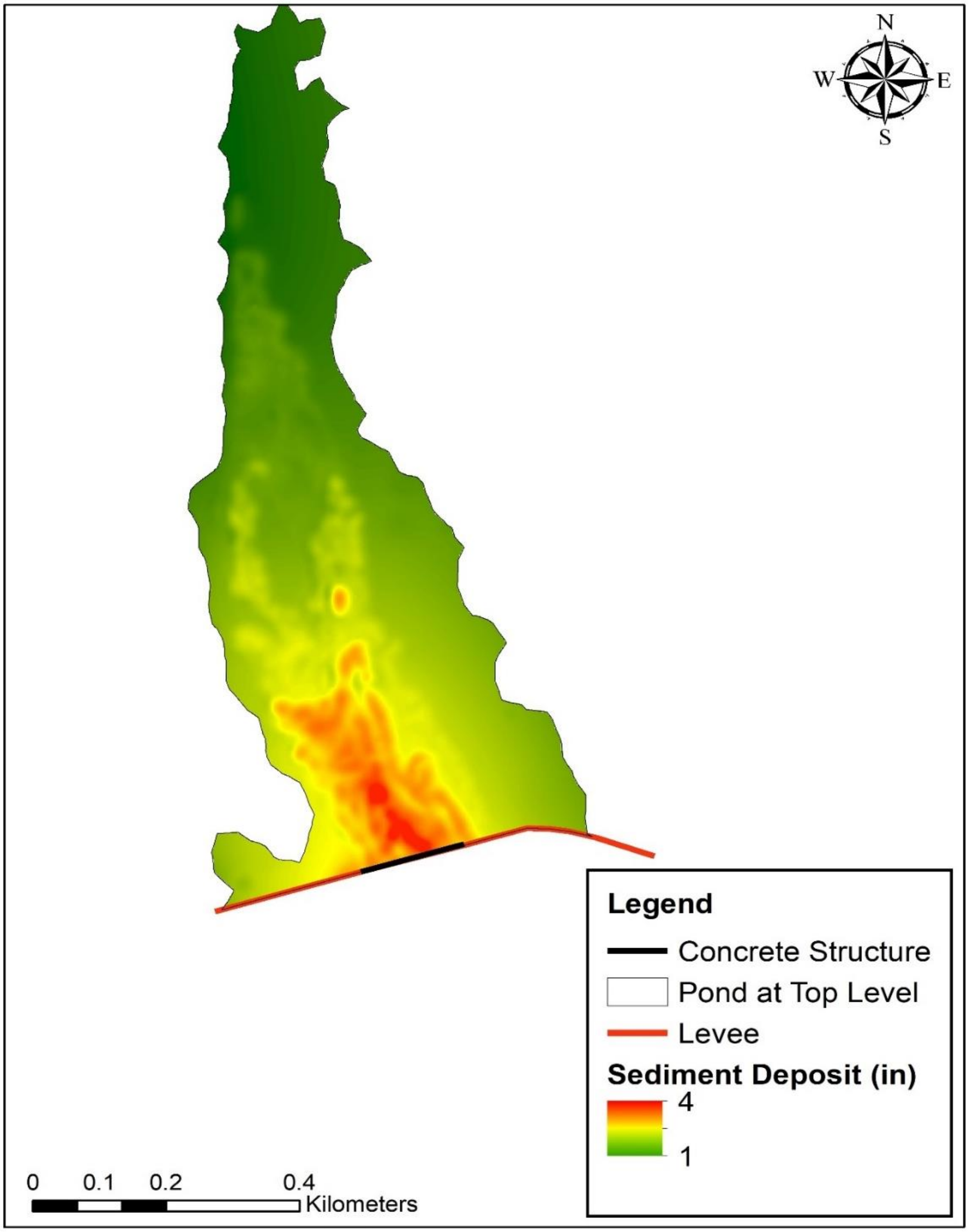


Figure 49: Sediment deposition in two years in the storage area of Upper Mole II dam.

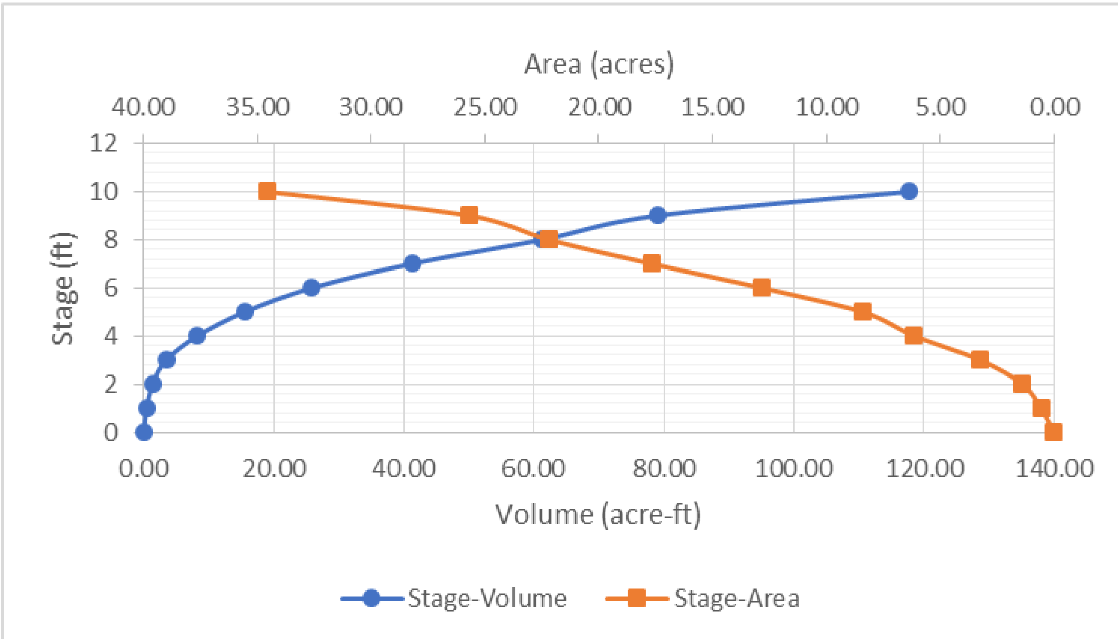


Figure 50: Stage-Area and Stage-capacity curves of Upper Mole II dam.

4.2.6.9 Jungshahi Dam

Jungshahi dam is located at 24°58'13.78''N, 67°36'17.73''E in Lower Kohistan Region. Catchment area of the Dam is 31.2 square miles (Table 24), out of which 77.0% is Barren soil and rest 23.0 % is Rocky Area (Table 25). The total capacity of the dam is 309.0 ac-ft (Table 29). Maximum silt deposit is about 36 inches near the base of dam, which has reduced the capacity of dam by 20.8 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, sediment deposited so far are given below in Figure 51 to Figure 53. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 54.

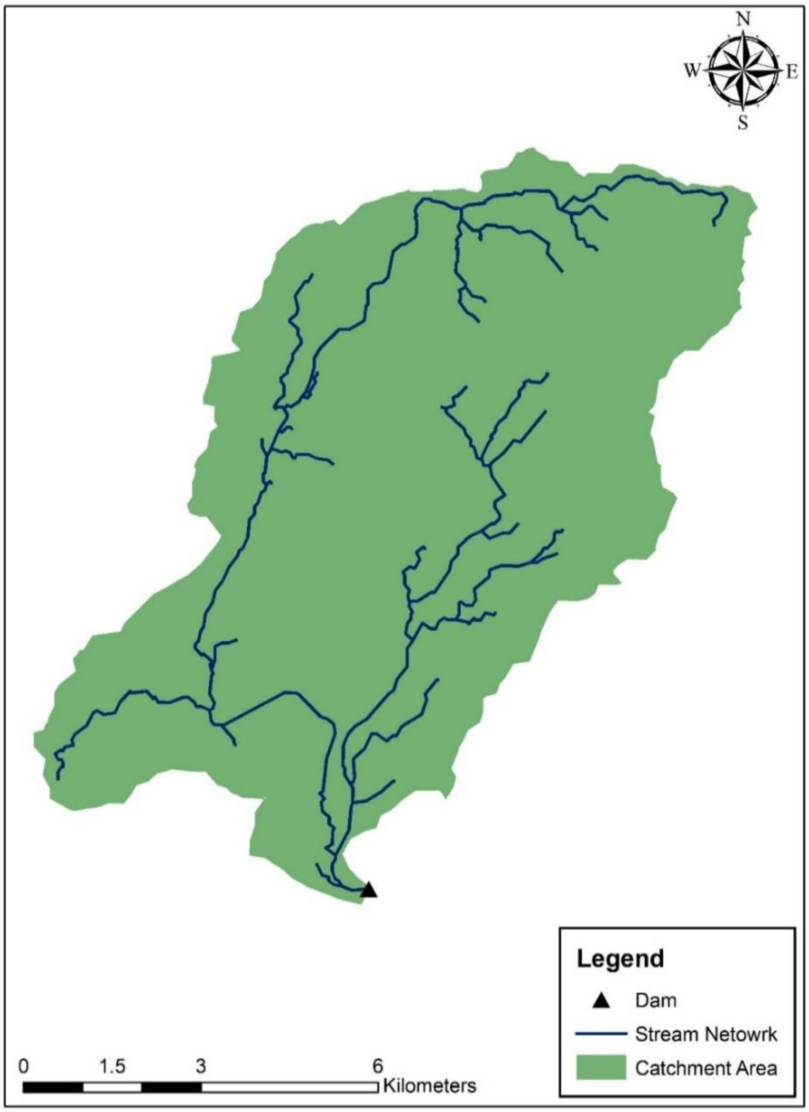


Figure 51: Catchment area of Jungshahi Dam.

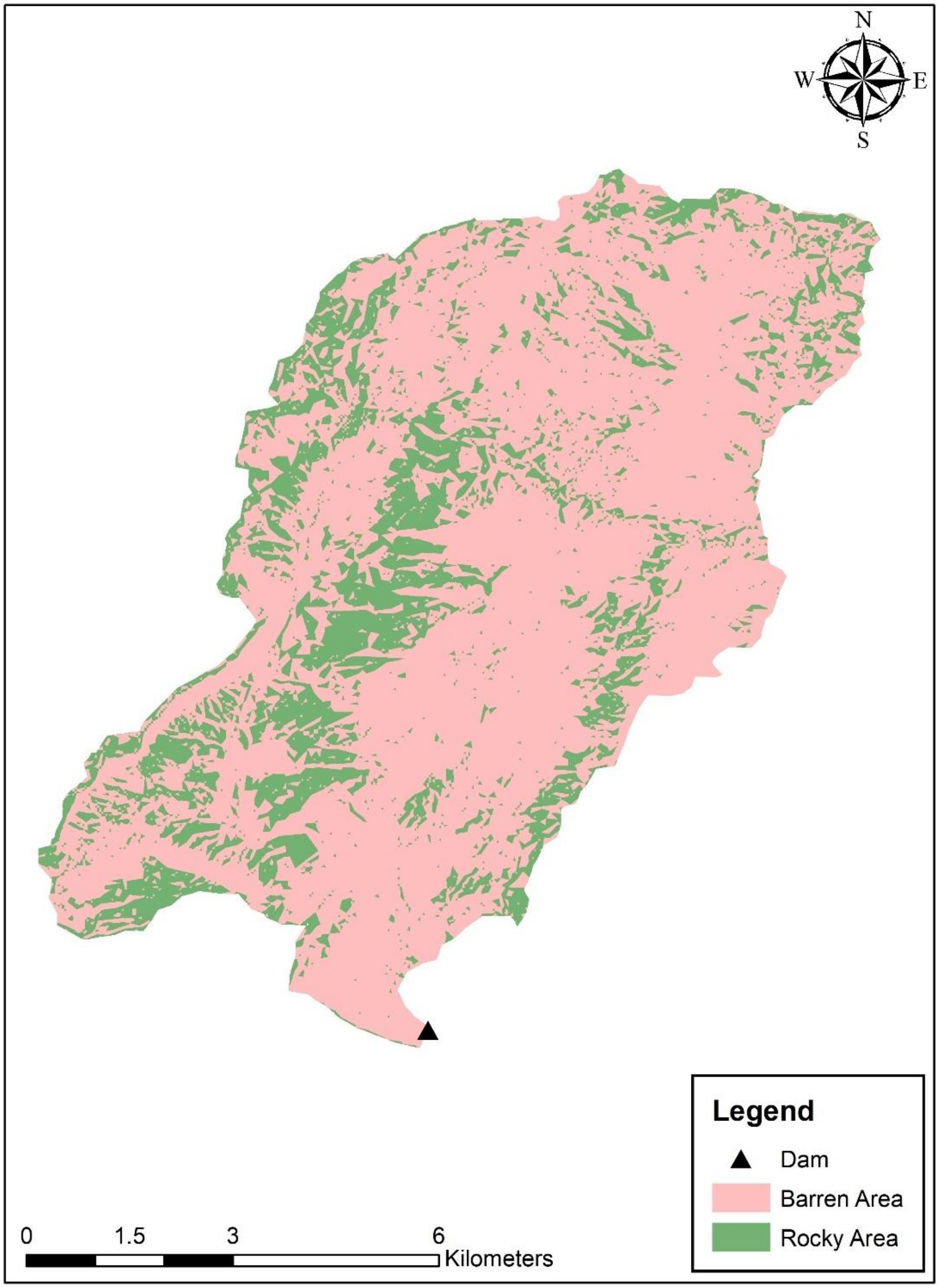


Figure 52: Land use land cover (LULC) in catchment area of Jungshahi dam.

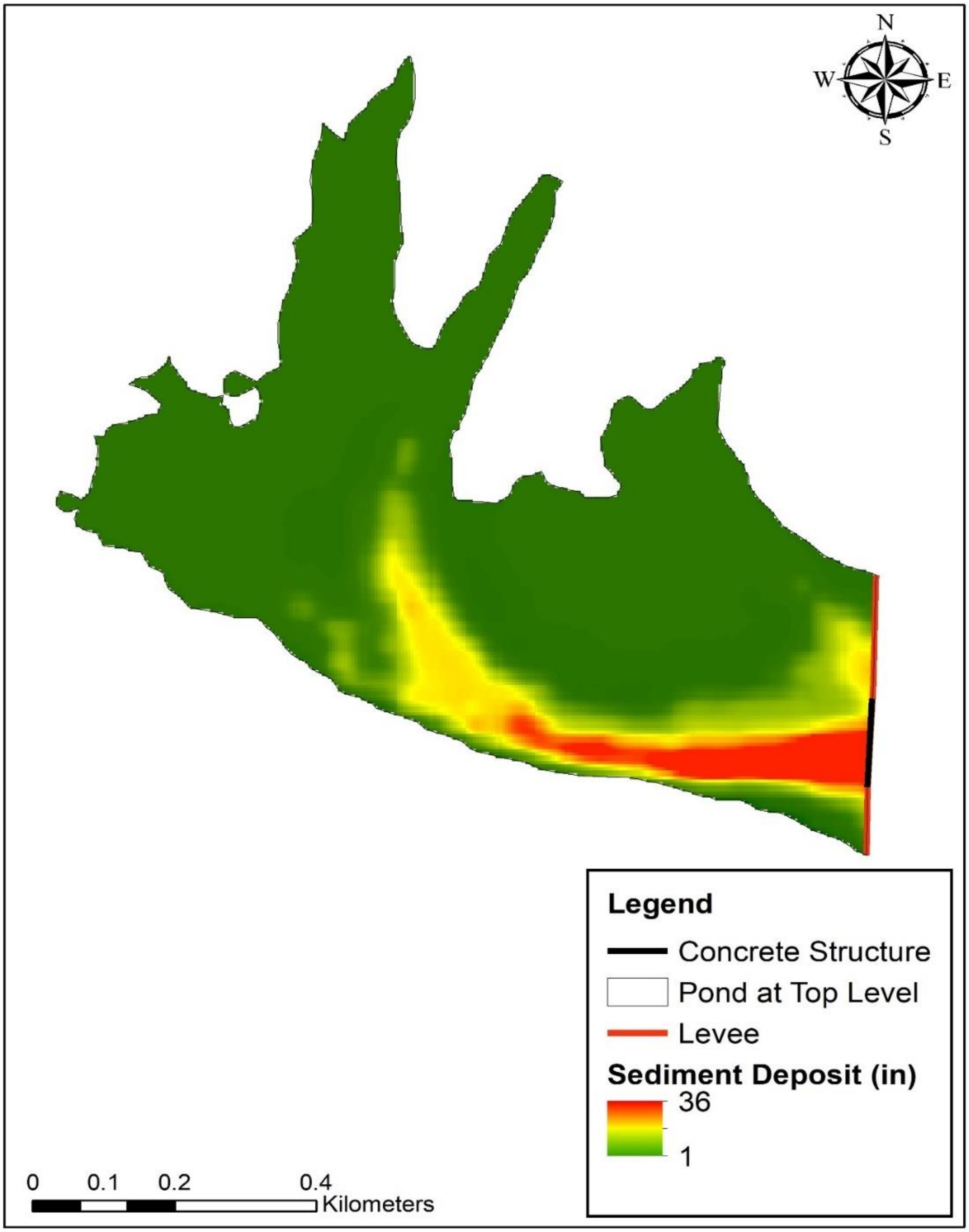


Figure 53: Sediment deposition in two years in the storage area of Jungshahi dam.

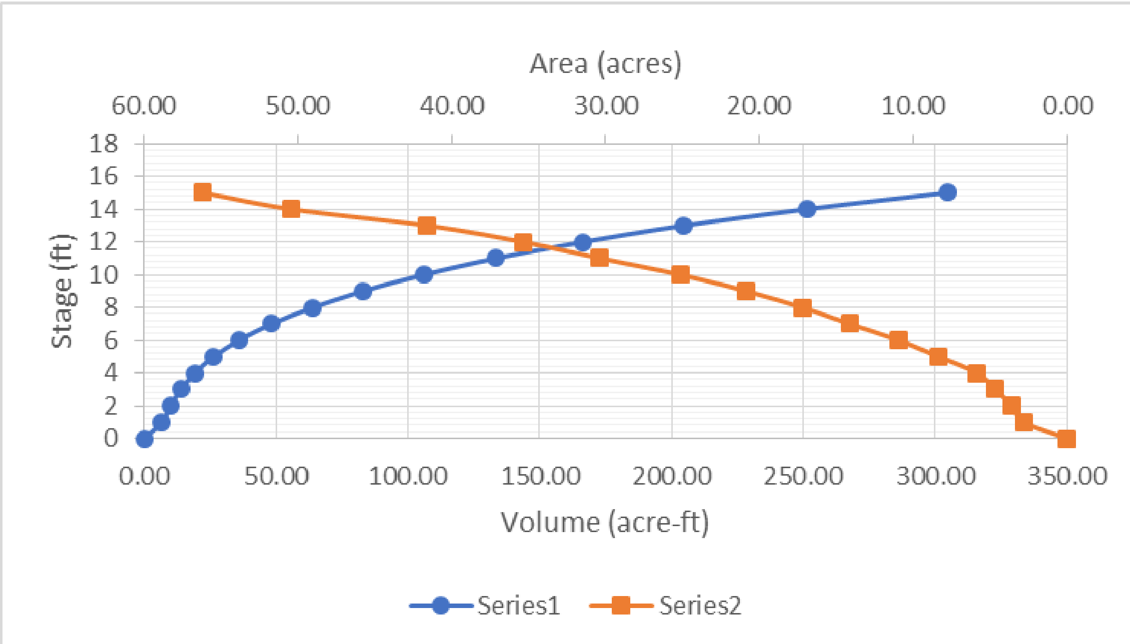


Figure 54: Stage-Area and Stage-capacity curves of Jungshahi dam.

4.2.6.10 Konkar Dam

Konkar dam is located at 25° 3'9.00"N, 67°15'26.00"E in Lower Kohistan Region. Catchment area of the Dam is 61.2 square miles (Table 24), out of which 61.3% is Barren soil and rest 38.7 % is Rocky Area (Table 25). The total capacity of the dam is 61.5 ac-ft (Table 29). Maximum silt deposit is about 2 inches near the base of dam, which has reduced the capacity of dam by 1.3 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, sediment deposited so far are given below in Figure 55 to Figure 57. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below Figure 58.

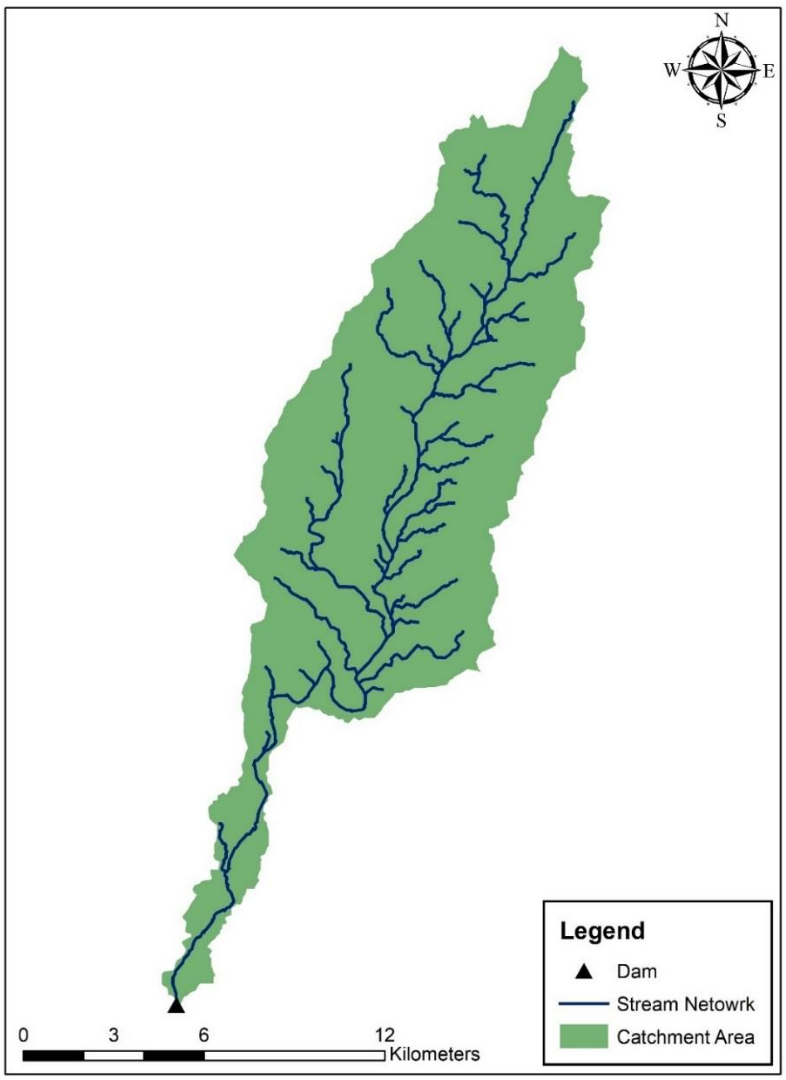


Figure 55: Catchment area of Konkar Dam.

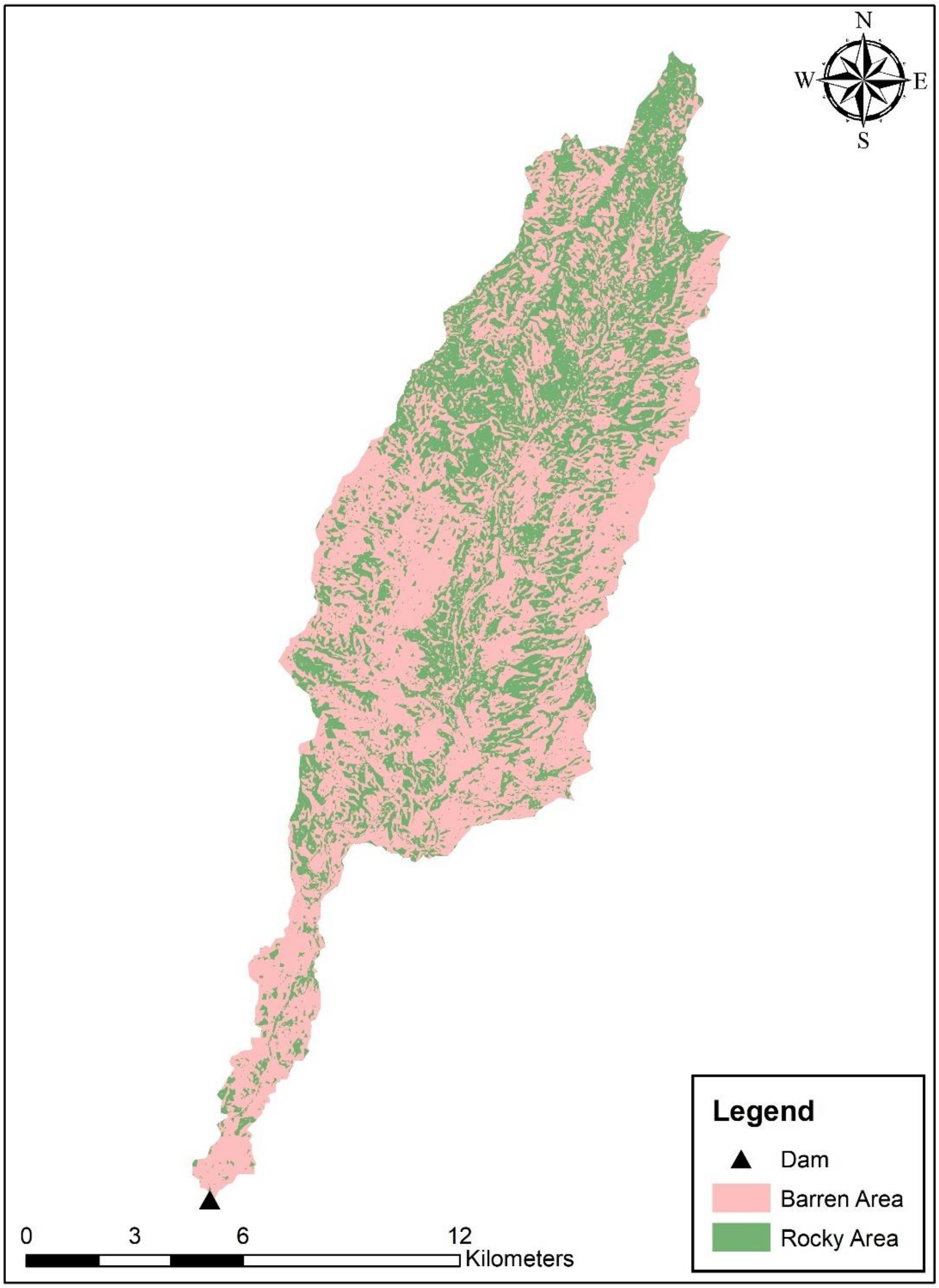


Figure 56: Land use land cover (LULC) in catchment area of Konkar dam.

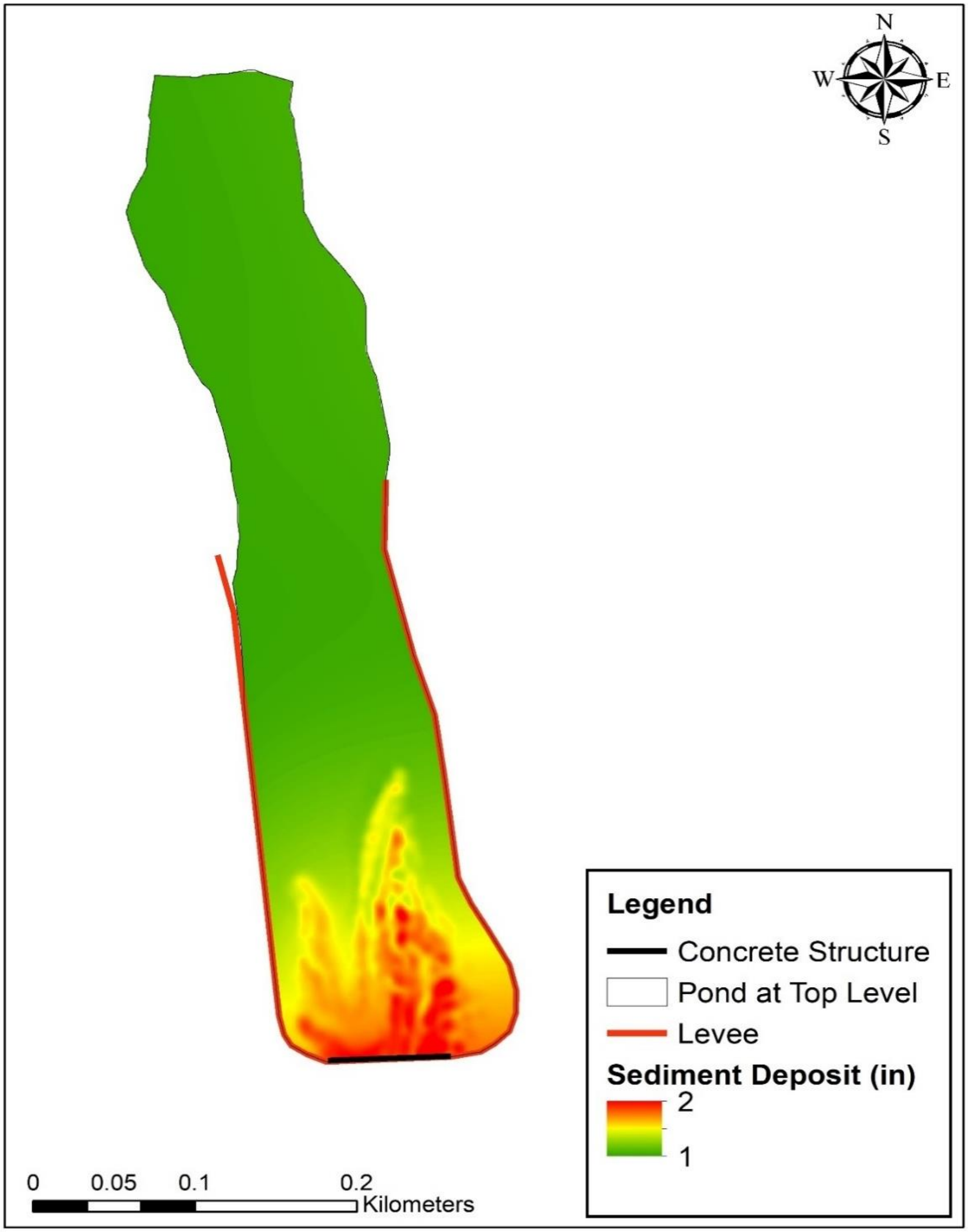


Figure 57: Sediment deposition in two years in the storage area of Konkar dam

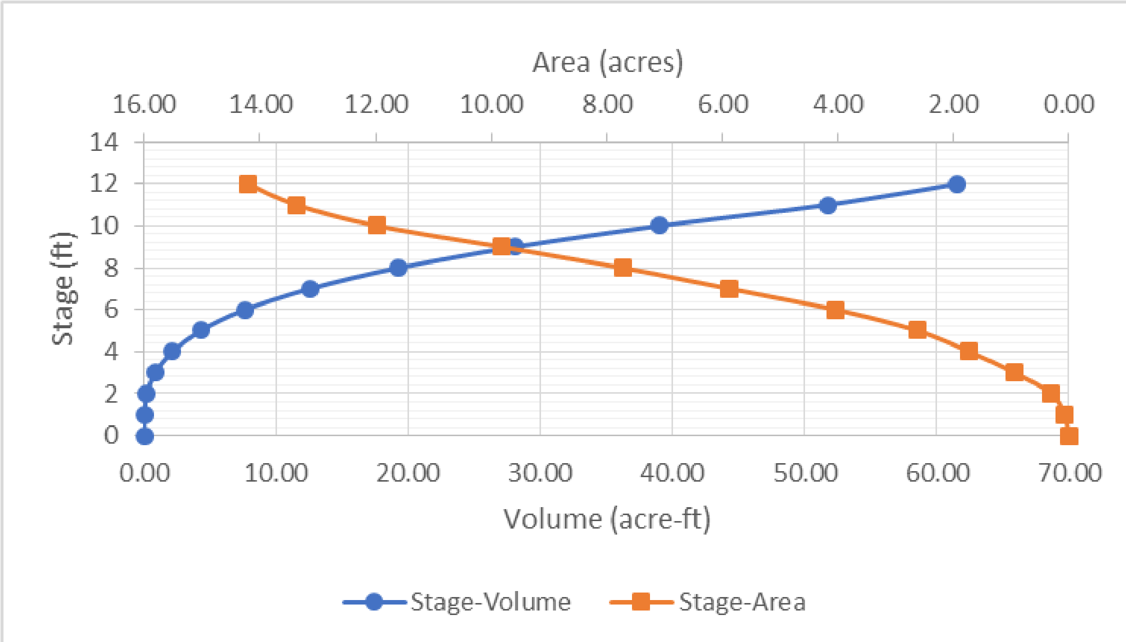


Figure 58: Stage-Area and Stage-capacity curves of Konkar dam.

4.2.6.11 Karamtiani Dam

Karamtiani dam is located at 25°10'28.27"N, 67°13'33.82"E in Lower Kohistan Region. Catchment area of the Dam is 16.3 square miles (Table 24), out of which 53.5% is Barren soil and rest 46.5 % is Rocky Area (Table 25). The total capacity of the dam is 58.3 ac-ft (Table 29). Maximum silt deposit is about 3 inches near the base of dam, which has reduced the capacity of dam by 1.6 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, sediment deposited so far are given below in Figure 59 to Figure 61. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 62.

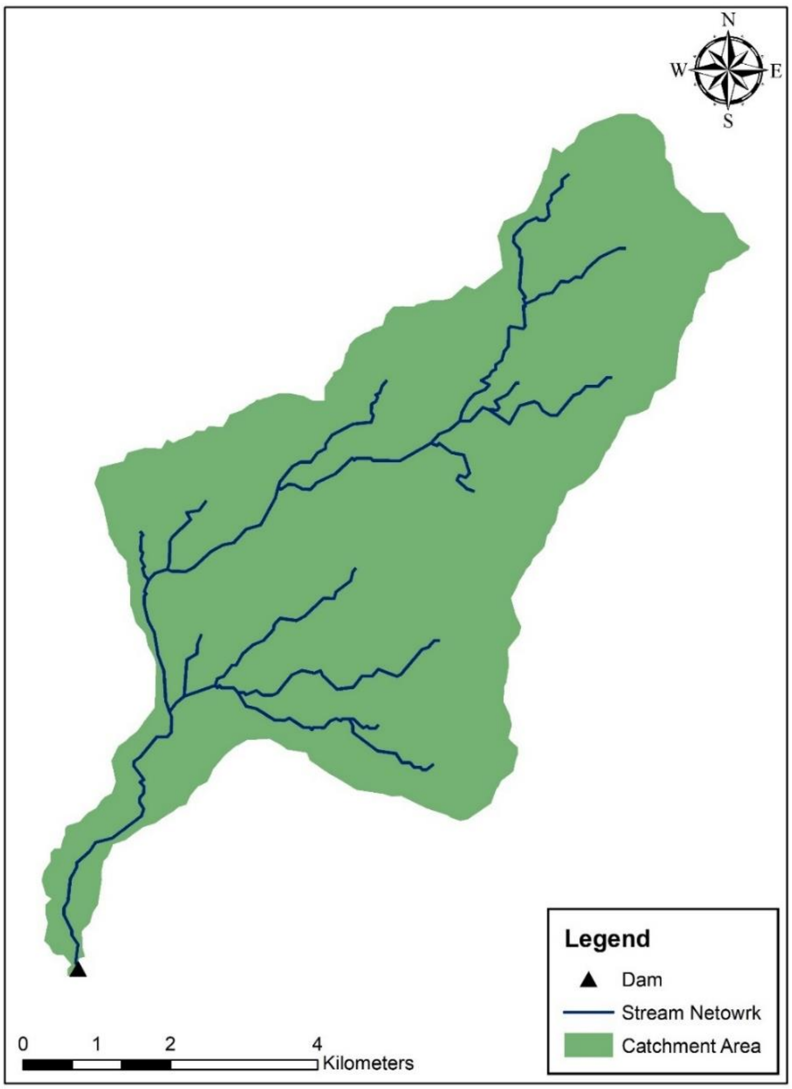


Figure 59: Catchment area of Karamtiani Dam.

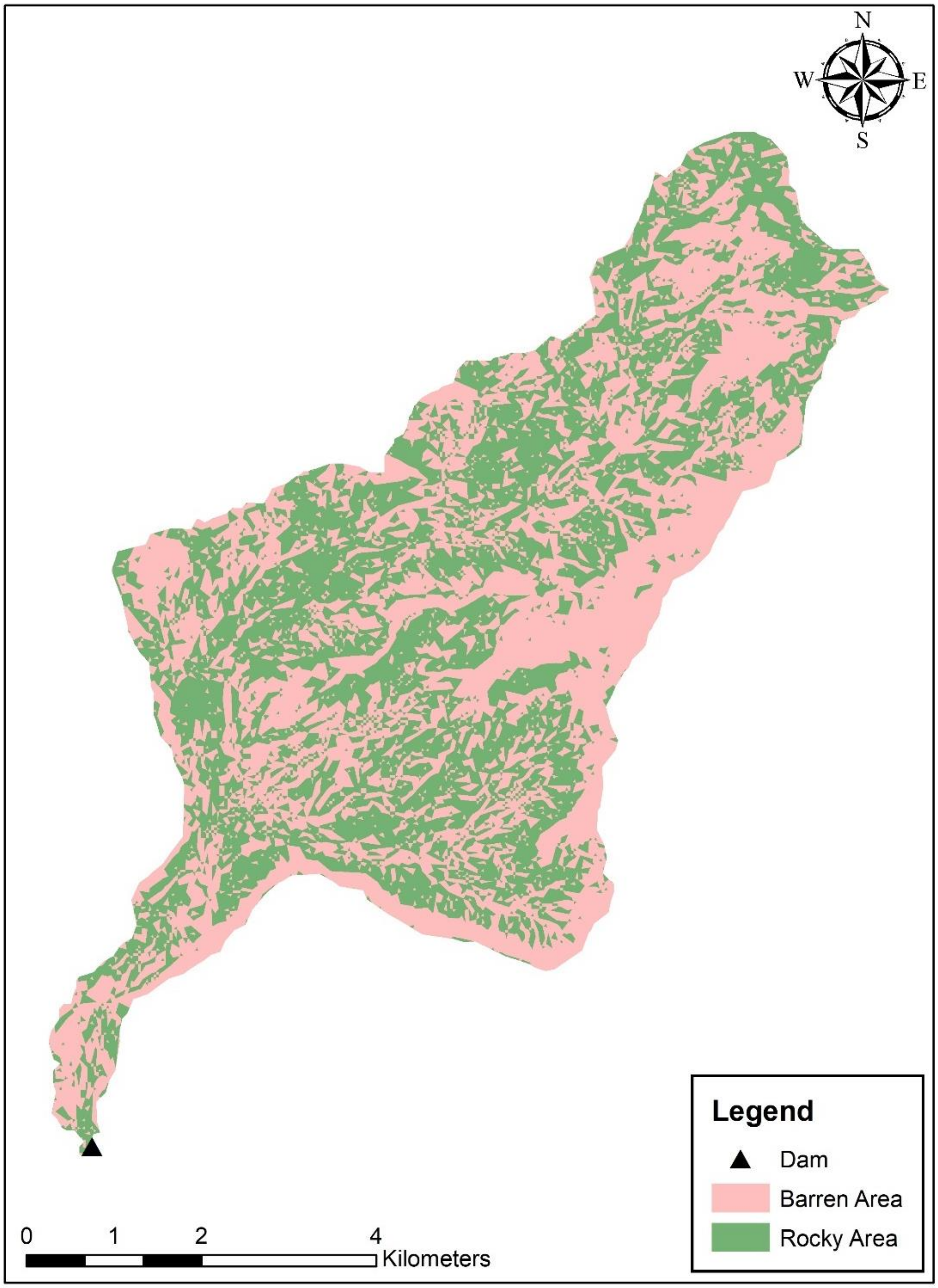


Figure 60: Land use land cover (LULC) in catchment area of Karamtiani dam.

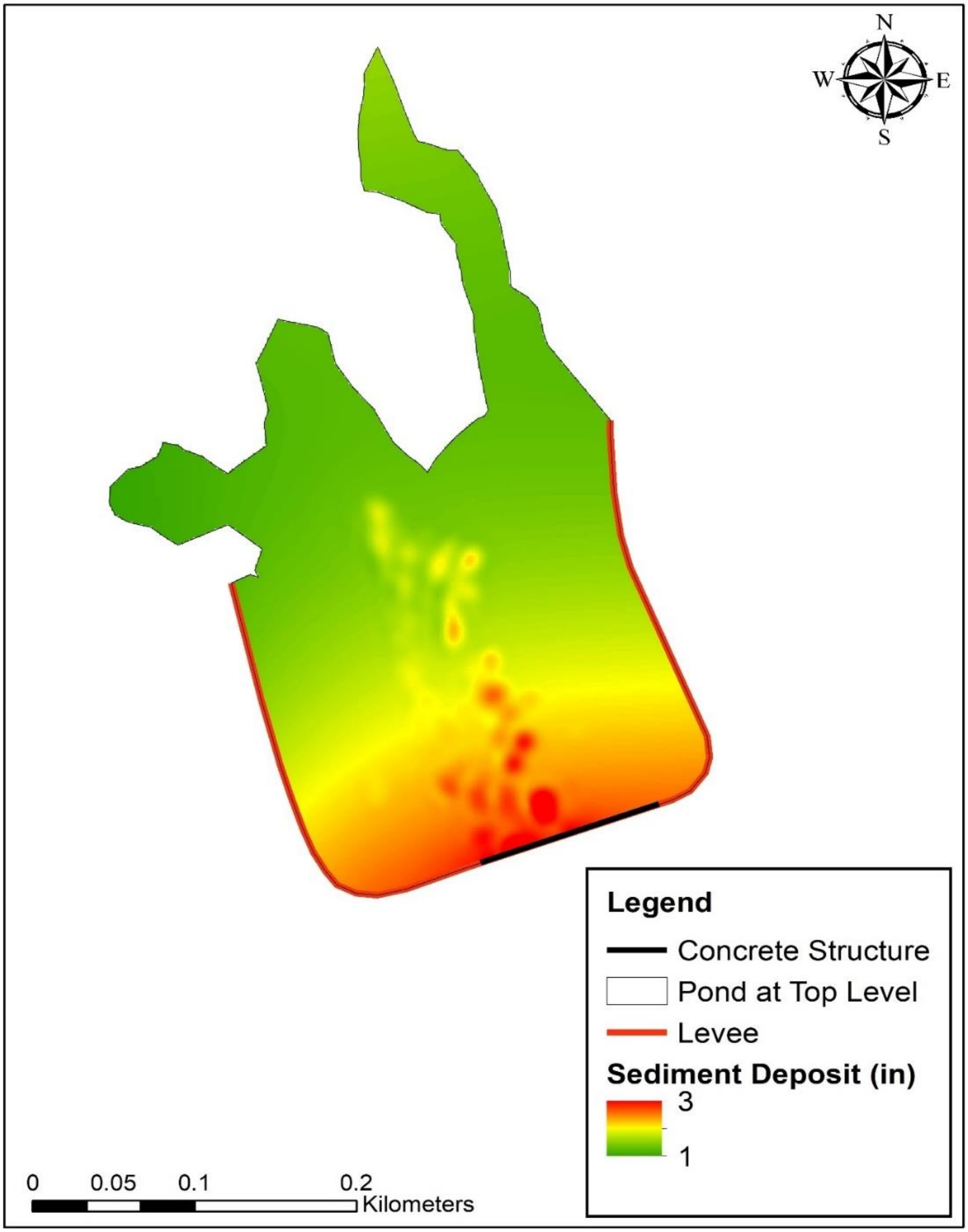


Figure 61: Sediment deposition in two years in the storage area of Karamtiani dam.

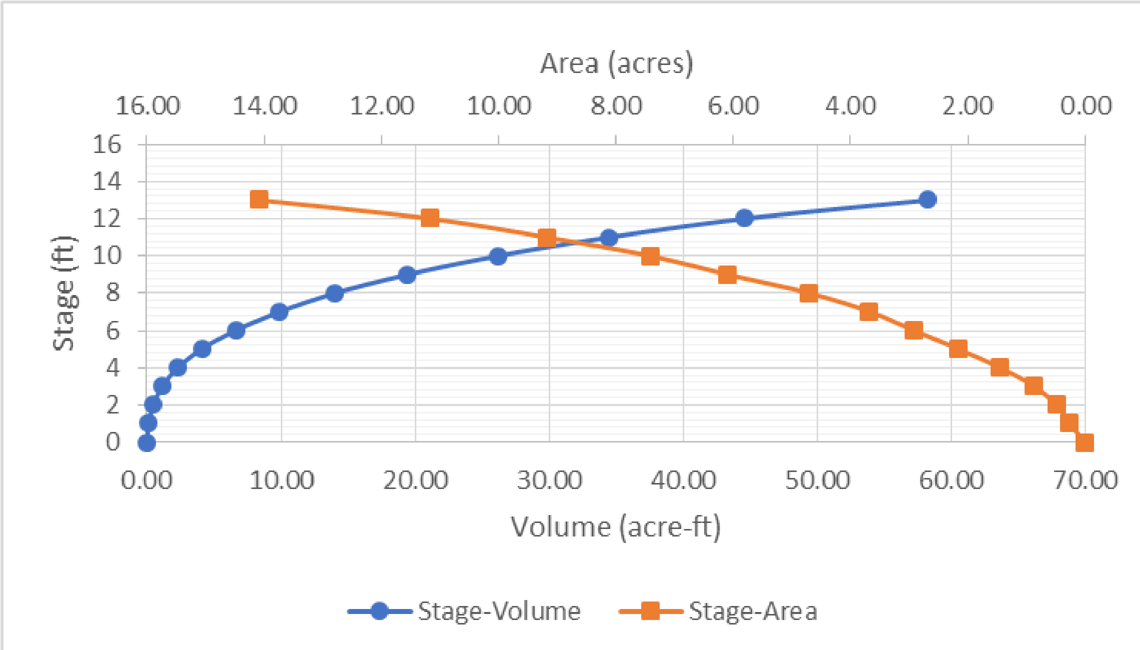


Figure 62: Stage-Area and Stage-capacity curves of Karamtiani dam.

4.2.6.12 Sabusan Dam

Sabusan Dam is located at 67°13'33.82"E, 70°41'31.95"E in Nangarparkar Region. The catchment area of the Dam is 4.5 square miles (Table 24), out of which 94.8% is Barren soil and the rest 5.2 % is Rocky Area (Table 25). The total capacity of the dam is 426.1 ac-ft (Table 29). The maximum silt deposit is about 4 inches near the base of the dam, which has reduced the capacity of the dam by 11.8 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, and sediment deposited so far are given below in Figure 63 to Figure 65. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 66.

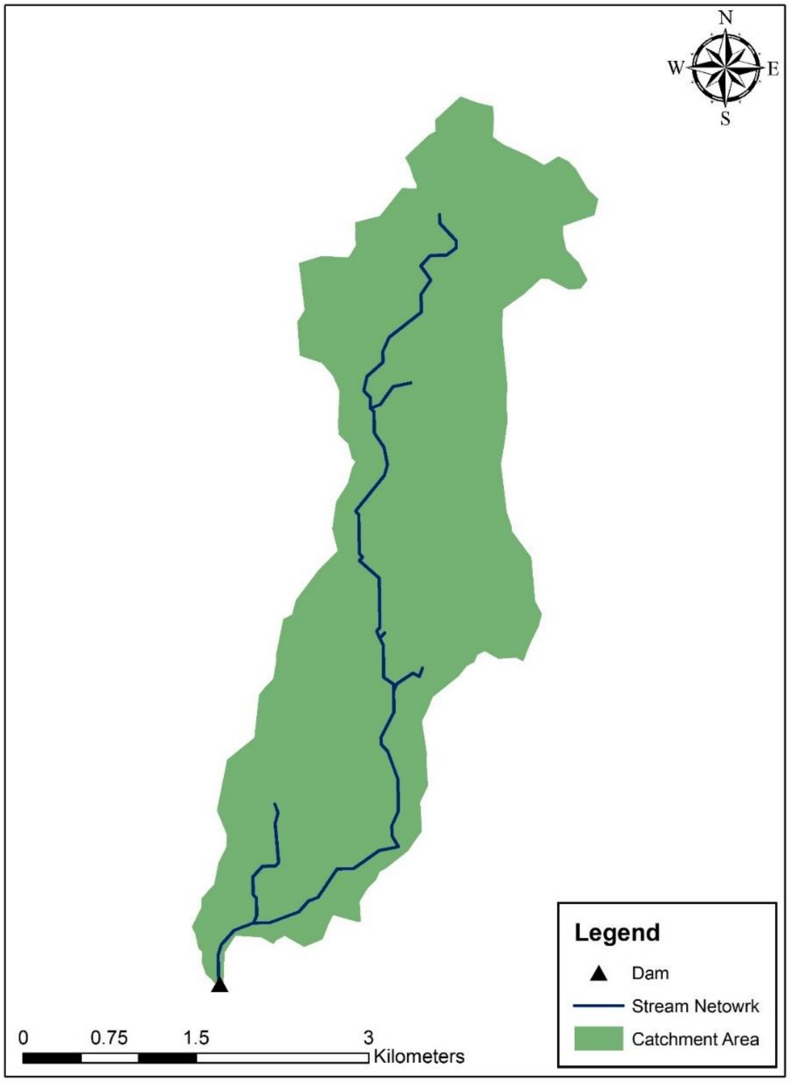


Figure 63: Catchment area of Sabusan Dam

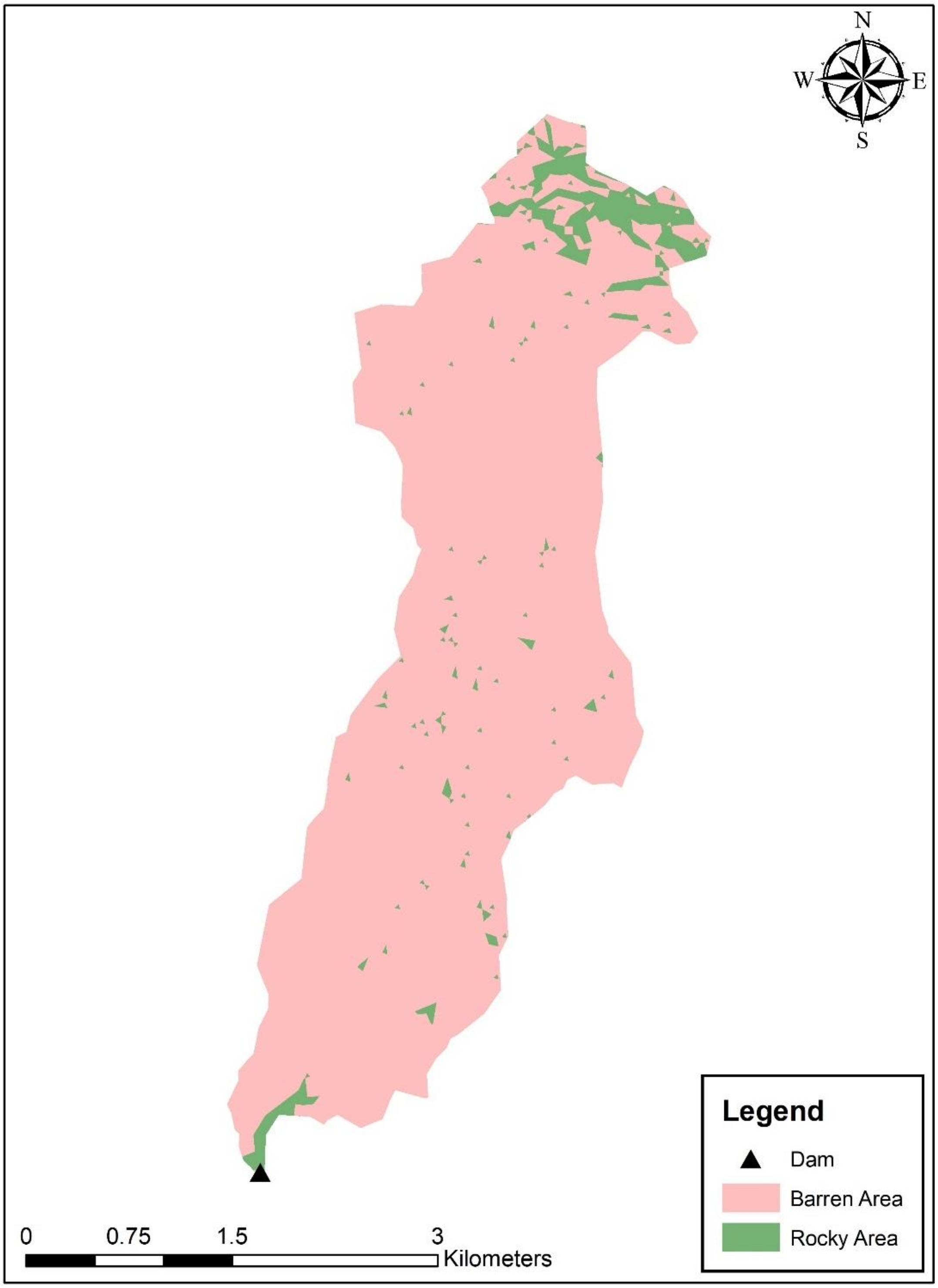


Figure 64: Land use land cover (LULC) in catchment area of Sabusan dam.

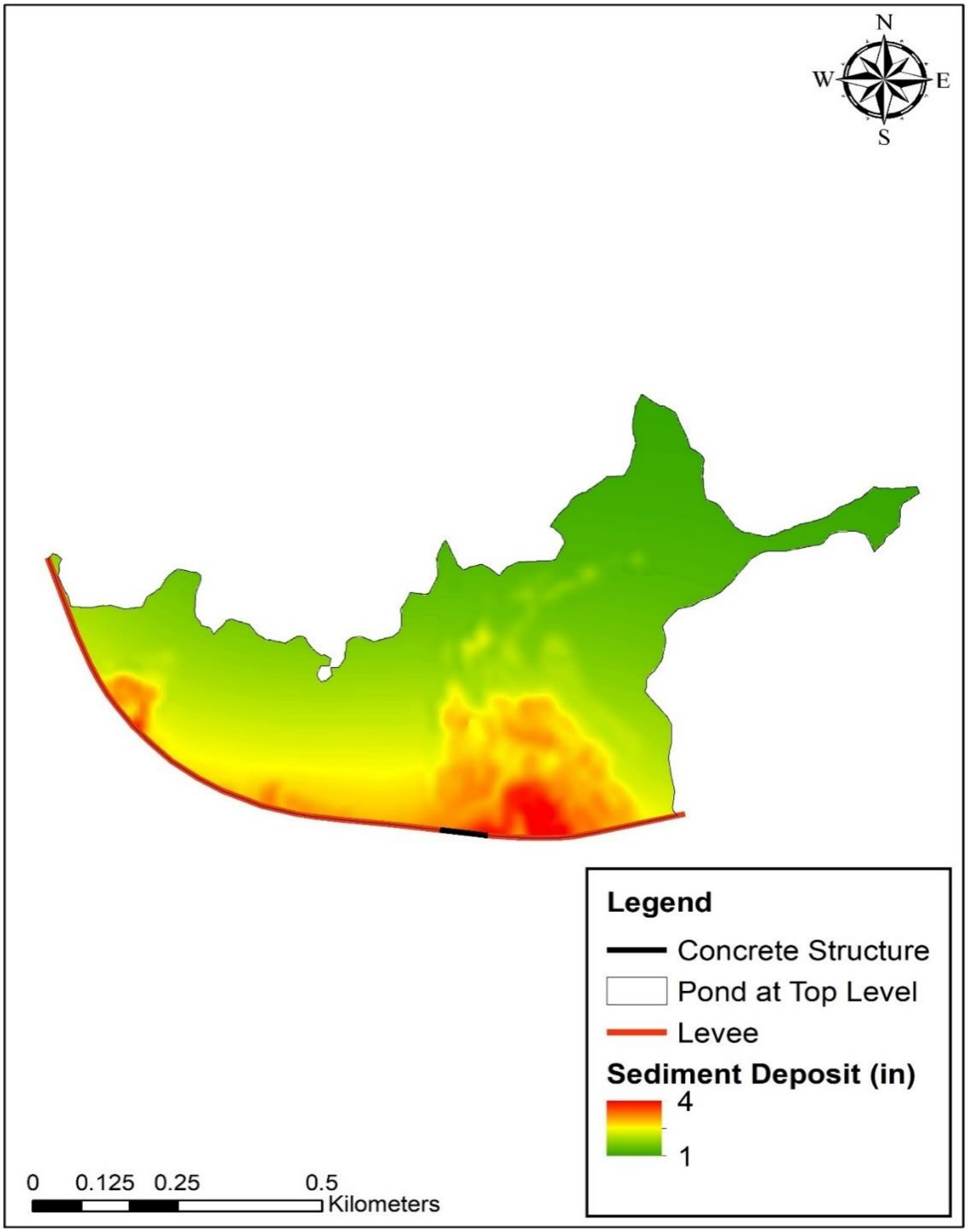


Figure 65: Sediment deposition in two years in the storage area of Sabusan dam.

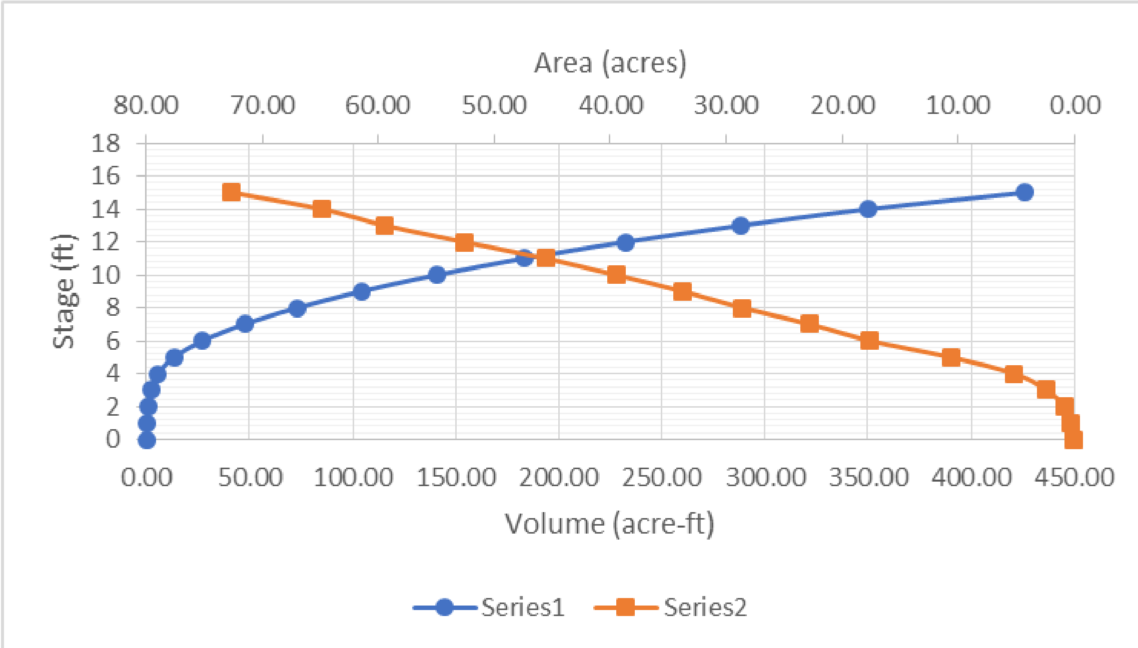


Figure 66: Stage-Area and Stage-capacity curves of Sabusan dam.

4.2.6.13 Sankar Dam

Sankar Dam is located at 24°32'35.80"N, 70°49'56.99"E in Nangarparkar Region. Catchment area of the Dam is 9.7 square miles (Table 24), of which 100.0 % is Barren soil (Table 25). The total capacity of the dam is 979.3 ac-ft (Table 29). Maximum silt deposit is about 4 inches near the base of dam, which has reduced the capacity of dam by 26.5 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, and sediment deposited so far are given below in Figure 67 to Figure 69. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 70.

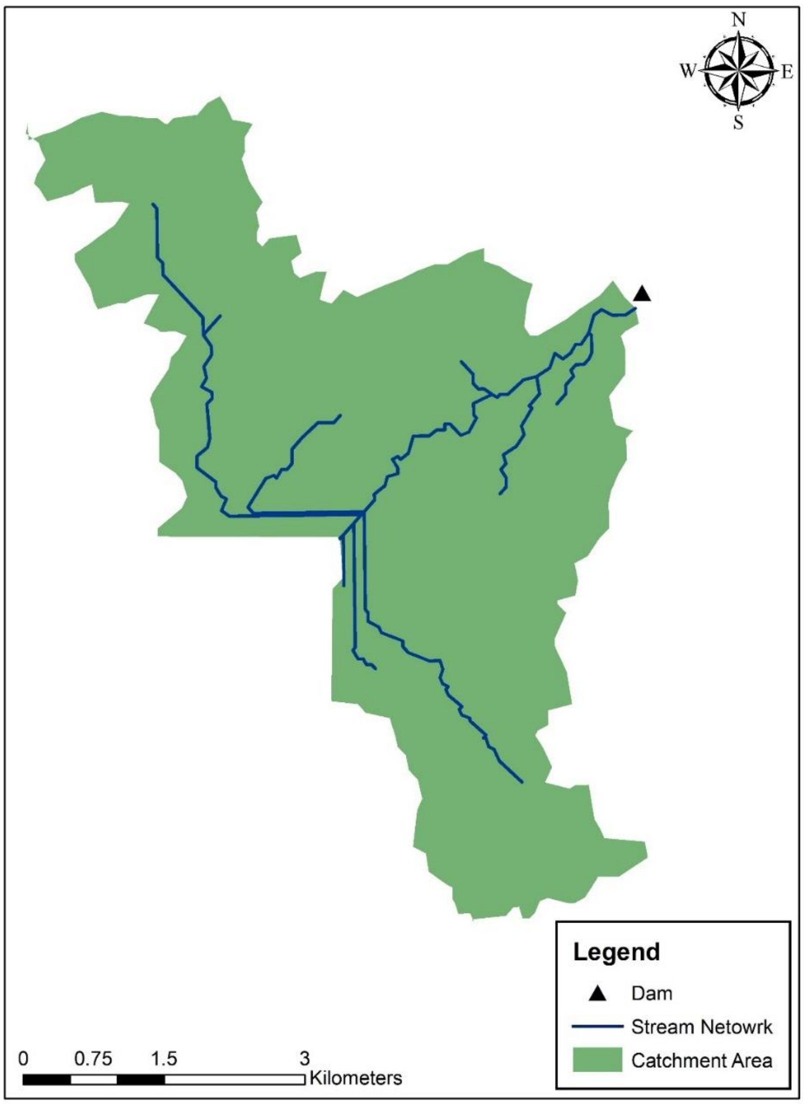


Figure 67: Catchment area of Sankar Dam.

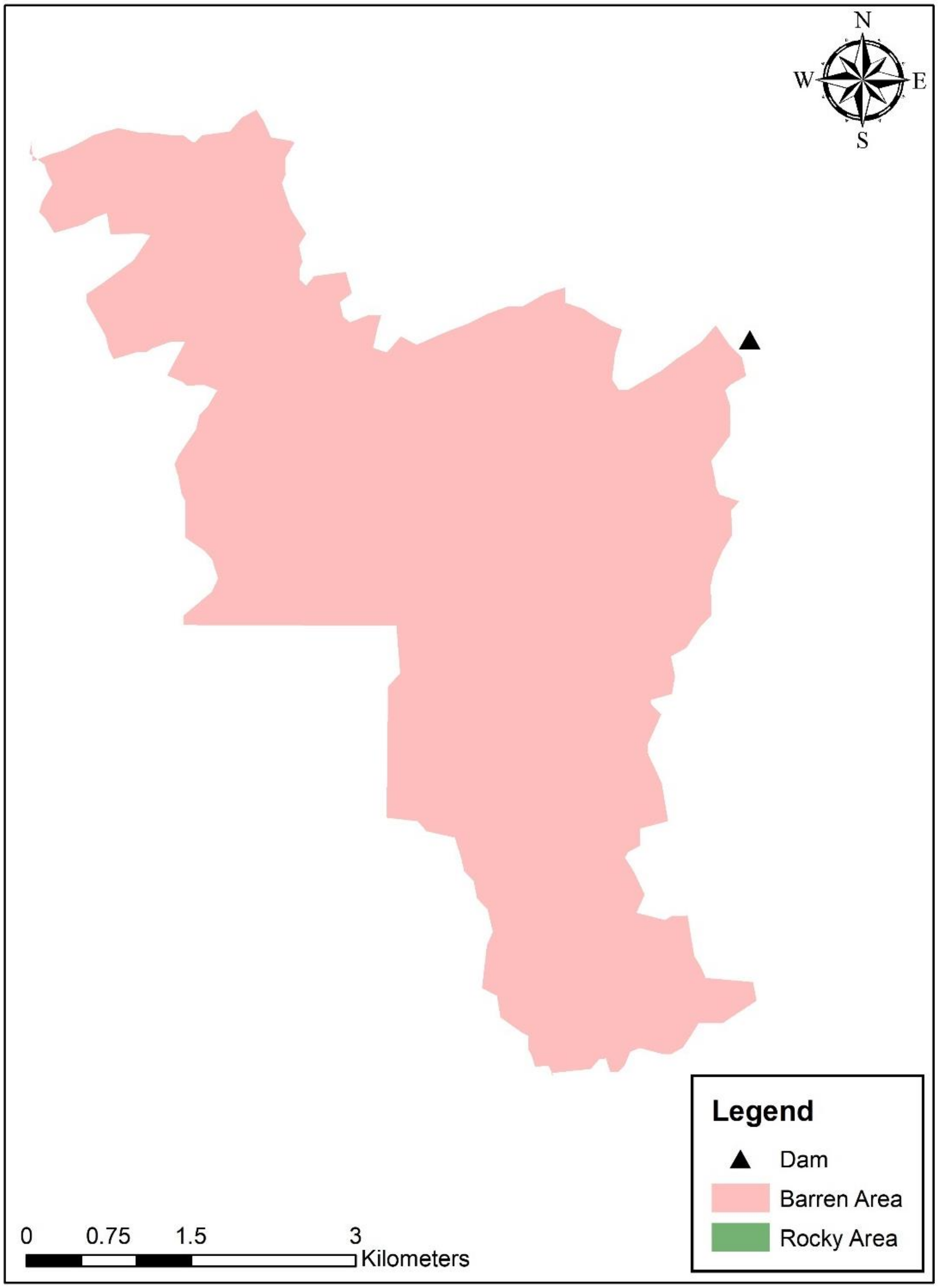


Figure 68: Land use land cover (LULC) in catchment area of Sankar dam.

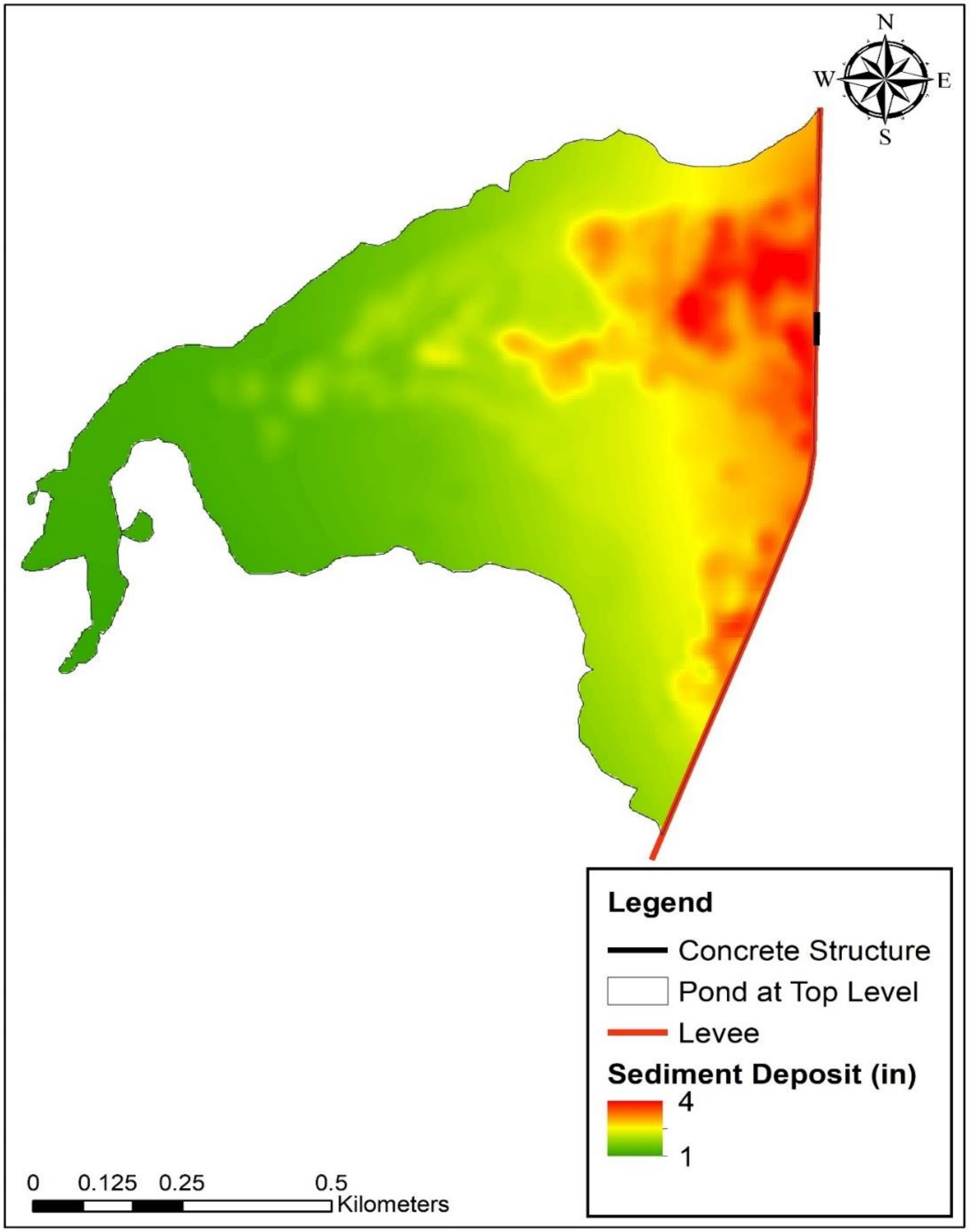


Figure 69: Sediment deposition in two years in the storage area of Sankar dam.

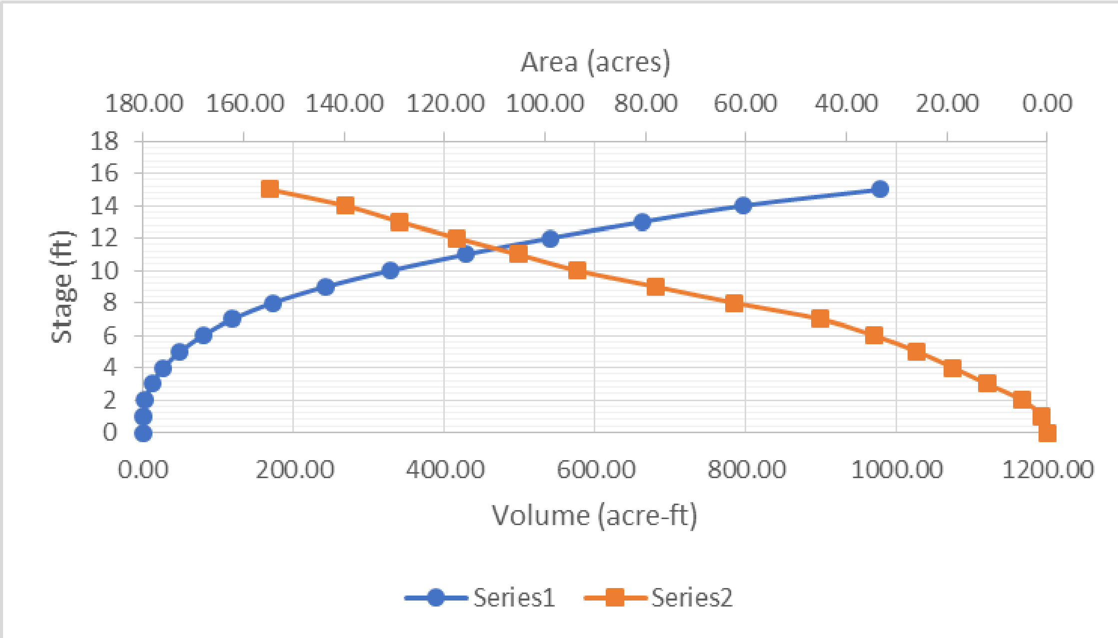


Figure 70: Stage-Area and Stage-capacity curves of Sankar dam.

4.2.6.14 Bhansar Rathi Dam

Bhansar Rathi Dam is located at 24°34'49.40"N, 70°50'28.63"E in Nangarparkar Region. Catchment area of the Dam is 19.6 square miles (Table 24), of which 100.0% is Barren soil (Table 25). The total capacity of the dam is 2373.1 ac-ft (Table 29). Maximum silt deposit is about 2 inches near the base of dam, which has reduced the capacity of dam by 42.6 ac-ft (Table 29). The GIS maps for the catchment area, land use land cover, sediment deposited so far are given below in Figure 71 to Figure 73. The stage-area and stage-capacity curves have also been developed so as to monitor the remaining capacity of the dam over subsequent years by just monitoring the stage of the silt deposited. The stage-area and stage-capacity curves are also given below in Figure 74.

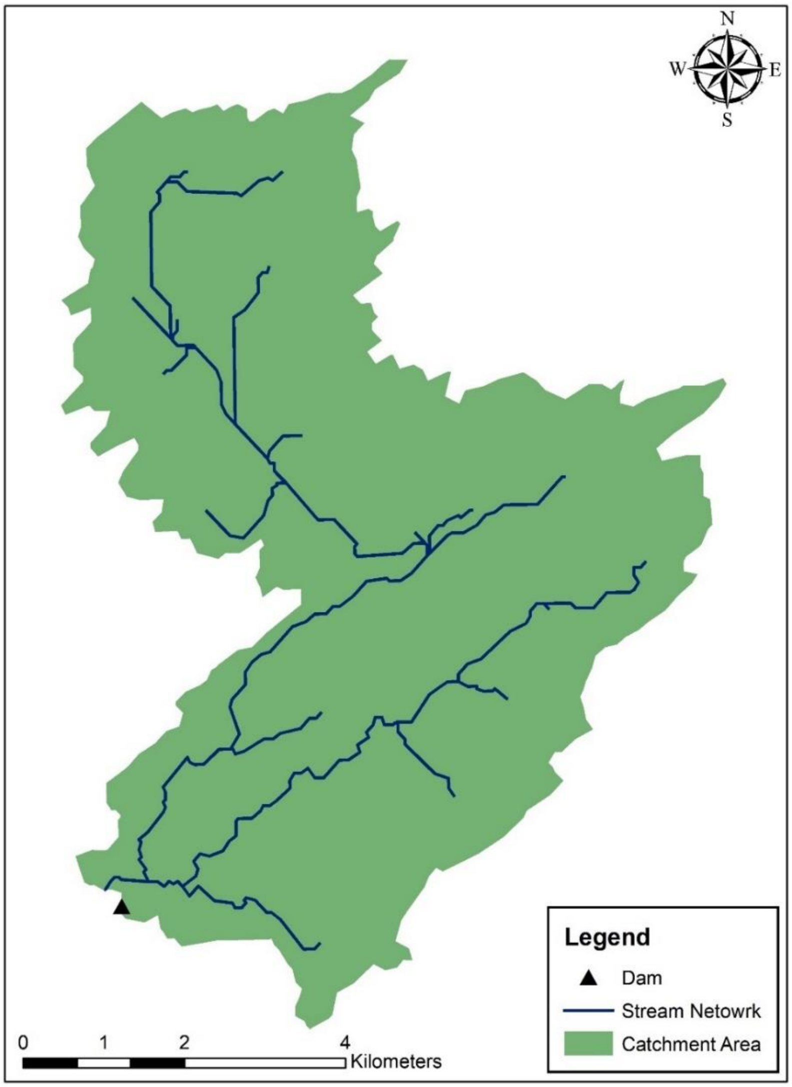


Figure 71: Catchment area of Bhansar Rathi Dam.

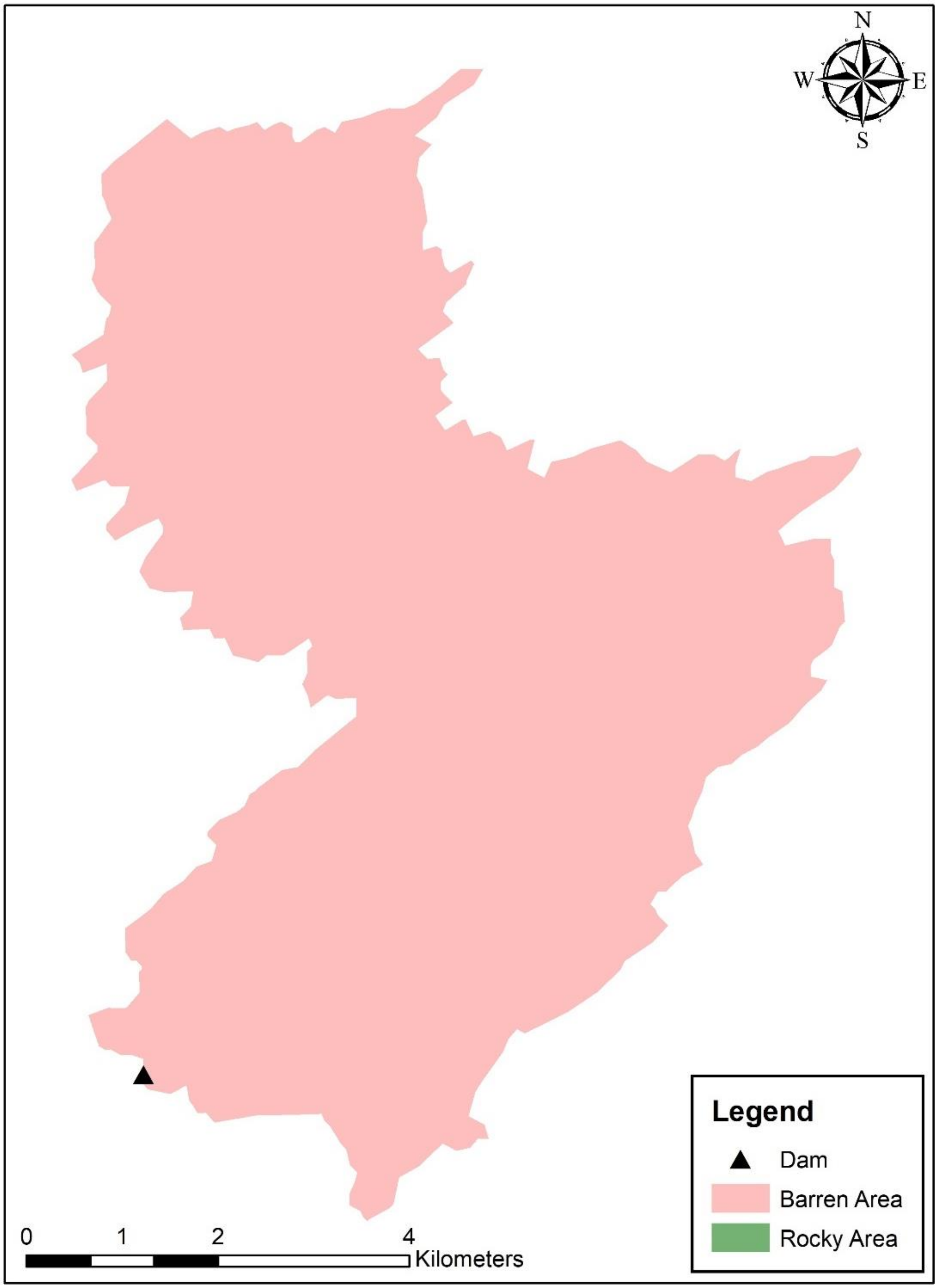


Figure 72: Land use land cover (LULC) in catchment area of Bhansar Rathi dam.

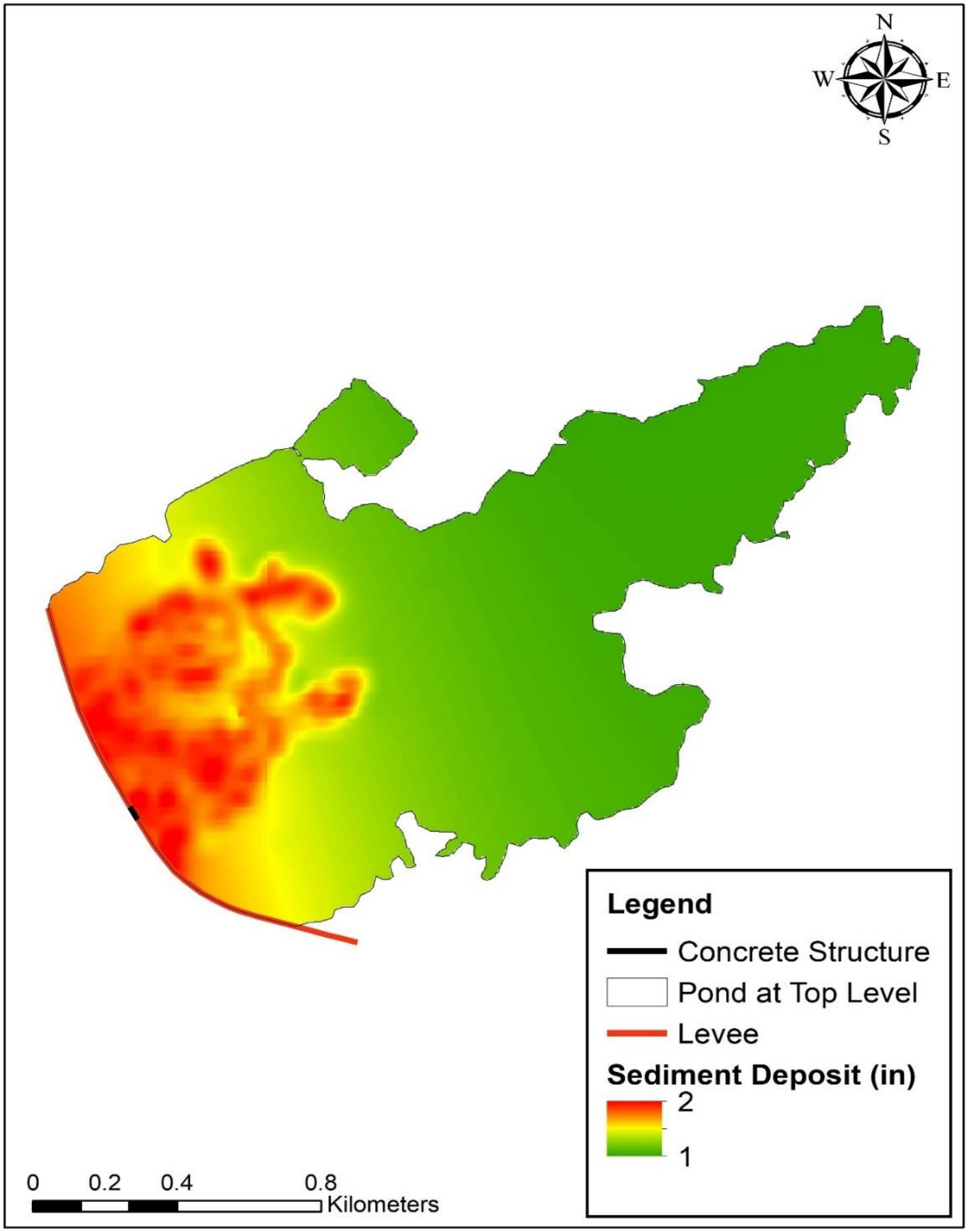


Figure 73: Sediment deposition in two years in the storage area of Bhansar Rathi dam.

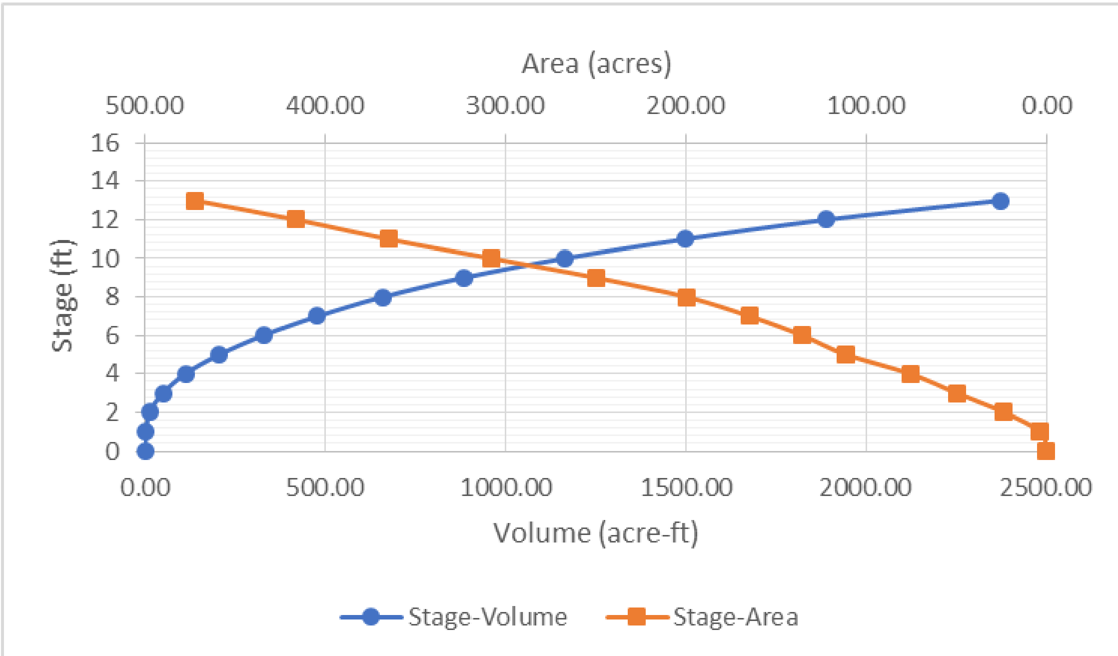


Figure 74: Stage-Area and Stage-capacity curves of Bhansar Rathi dam.

5 CONCLUSION

The evaluation of the impacts associated with the socio-economic well-being of 14 small dams constructed in the Nagarparkar and Kohistan region has been carried out in this study. The main purpose of these dams was to recharge the groundwater, reduce the drought-related risks and improve the community's socio-economic well-being through improved water availability for different uses in rural settings, including domestic, irrigation, and livestock. The overall aim of the impact study is to assess whether the post-dam construction significantly impacts the socio-economic well-being of the community of the study area and to determine the sedimentation and expected life of the dam.

In terms of satisfaction, the majority of respondents were satisfied with the construction of the dams. 100% satisfaction was shown at Dhal Dhoro, Gabol, Naing-II, Qasim Tok, and Aripir. Whereas, more than 80% satisfaction was shown at Tikho-II (85%), Upper Mole-II (93%), Junghshahi (80%), Sankar (95%), and Bhansar Rathi (93%). However, at Sureshi Dam though all respondents were satisfied with the development initiative, around 60% of the respondents were in favor of a larger dam.

The key potential benefits of the dams have been reported as an increase in availability and quality of water for domestic, drinking, livestock, agriculture, and groundwater recharge. It reflects that all of the dams are providing a larger spectrum of benefits, whatever has been targeted before the execution of the project. However, it reflects that in the long run, the community will get more benefit in the future, when these dams are repeatedly filled, as a result of the rise of the groundwater table through recharge. Moreover, the development of new niches of businesses is naturally a slow process, especially in these areas, due to geographical conditions and the socio-economic settings of the communities.

Traditionally, these areas have grown rain-fed crops, including millet, sorghum, guar, sesame, mung, moth, and castor bean. However, it was found that people of the area are now introducing new crops as well and the new emerging crops are of high value, including onion, wheat, chili, cotton, and tomato. The overall area under cultivation has also increased around all dams. It is evident from the fact that all dam respondents reported that the water table has improved after the dam construction.

The majority of respondents across all dams shared that their incomes have also increased by 33% after the construction of the dams and will hopefully further increase in the future. It was learned that the economic activity in agriculture, livestock, and agri-labor is taking momentum after enhanced water availability for a longer period of a year. Nevertheless, some dams have recently been completed, and their long-term impacts on the income of the communities are yet to come in the coming years. These findings reflect that in the near future, the ripple effect will be observed in the communities in the form of improved food security, education, and better health.

Livestock is also reported as one of the main sources of income and food security. Respondents across all dams shared the positive impact of increased water availability on livestock. The increased water quality has a positive impact on the health of livestock, and resultantly not only has milk production increased but the health of the animal and capacity to keep the larger number of livestock for a more extended period due to the availability of water and fodder has enhanced.

People living in the dam areas used to migrate temporarily or permanently to other areas for their livelihood. Post-dam construction development of new sources of livelihood, the temporary outward migration is almost negligible as people started rearing animals and growing high-value crops.

The study conducted on the sediments being deposited in the reservoir showed encouraging results. It has been observed that in its two years of operation no significant amount of sedimentation has been observed in the majority of the reservoirs. In most of the reservoirs, the sedimentation has been less than 5% of the total capacity of the reservoir. There are two reservoirs namely Tikho II and Jungshahi where sedimentation is observed to be around 10% of their capacity.

The useful life of these dams thus calculated is also very inspiring with most of them having a life of more than 20 years. In some of these dams where there is a dam on its upper catchment, the life may increase to more than 40 years.

In summary, the finding of the study reveals that the small dams have a significant impact on the socio-economic well-being of the communities living in the vicinity of the different dams. The existing farming system has been improved significantly, and the people in the area have started growing non-traditional high-value crops and increasing the heads of animals. The overall family income has been improved. Specific types of rural business niches such as vegetable production in Nagarparkar and livestock production in Kohistan will not only improve the food security situation of the area but will soon contribute to the economic growth of the area, the province of Sindh, and the country. The sediment deposits in the reservoir are observed to be not much, which is an encouraging sign. Hence the life expectancy is also good, which makes these dams very feasible.

6 RECOMMENDATIONS

- A mechanism based on community representation, NGOs, and Small Dams Organization should be formed for smooth post-construction dam operation and management.
- Considering the benefits of dams, it is recommended that more small/recharge dams need to be constructed. The folk wisdom of the community needs to be considered before the selection of the dams site and execution of the project.
- It is suggested to introduce the concept of more crops per drop through high-efficiency irrigation systems for efficient water use and to gain maximum benefit of increased water availability.
- It is suggested to construct small drinking water storage near dams and connected with solar tube wells for the drinking water and livestock.
- It is suggested that the agriculture extension department should be engaged in introducing new high-yield crops with the lowest water consumption.
- It is suggested that microfinance institutes and NGOs should be engaged in these areas to meet communities' financial requirements to invest in more productive activities.
- Existing Tarais (water ponds) may be lined to conserve water for a longer time, especially in areas where small dams are not yet constructed.
- New dams may be constructed on the upper catchments of existing dams where the sedimentation rate is observed to be on the higher side.
- A mechanism for desilting the reservoir may also be developed to help increase the life of these dams.

7 PICTURE GALLERY

Training of Survey Enumerators

Kitchen Garden at Bhansar Rathi

Millet and Sorgham at Aripir

Irrigated Crop

Irrigating Crops

Solar Installation at Aripir

Females Fetching Water from Well

Fetching water from a dam on Donkey Cart

Bhansari Rathi Dam

Excavated Pond Inside Sankar Dam

Focus Group Discussion (Female and Male)

Gauge and sediment deposit at Karmatiani Dam

Dry pond (Taraee) at Sabusan Dam

Sediment sample collection from Dam site

Hydrometer Analysis

LIST OF ANNEXURES

Annex-1 Dam Wise Village Profiles

Village Profile Survey Tool

U.S.- Pakistan Center for Advanced Studies in Water (USPCASW),
Mehran University of Engineering and Technology (MUET), Jamshoro
Sindh, Pakistan

Village Profile

Impact Assessment and Performance Evaluation of 14 Small Dams in the Sindh Province

Thank you very much for your coordination. Your participation is heartily appreciated. All the information given in this questionnaire will strictly be used only for socio-economic impact report of Small Dams project.

Name of Village	Name of Surveyor	Date

1. General Information	
1..1 Village Name: ___________________	1.2 Name of Dam: _____________________
1.3 Deh: _________________________	1.4 UC:_________________________
1.5 Tehsil: _________________________	1.6 District: _________________________
1.7 GPS Coordinates:	E:
	N:
1.8 No. of households in village: ____________	
1.9 Average family size in village: ____	1.10 Estimated population of village: ____
1.11 Male/Female Ratio/Number in village: Male _______ Female ________	
1.12 What is the estimated area of your village? ____________ (Unit:_______)	

2. Access to Civic Facilities						
2.1 Drinking water source (Mention Number)	**Tube Well**	**Dug Well**	**Hand Pump**	**Reservoir**	**Water Tanker**	
2.2 Distance traveled to fetch water (km)	**Before Dam:**		**After Dam:**			
2.3 **Sanitation** Tick Appropriate Box	**Open Space**	**Common Washroom**	**Separate Washroom**			
2.4 **Health Facilities** Mention Number	**Dispensary**	**Basic Health Unit**	**Maternity Home**			
2.5 **Education** Mention Number	**BPS***	**GPS***	**BMS***	**GMS***	**BHS***	**GHS***
2.6 Enrollment						
2.7 Distance of village from road ___________ km						
2.8 Telecommunication	Landline ( )	Mobile ( )				
2.9 Energy	Gas ( )	Biofuel ( )	Firewood ( )			
2.10 Priority needs of Community (1 to 6) **Irrigation water ( ) Link Road ( ) Health ( ) Education ( ) Drinking Water ( )**						

3. Future Interventions	
3.1 Priorities 1 to 4:	Piped water ( ) Irrigation network ( ) Agricultural extension ( ) Livestock extension ( )

Dam Wise Villages

Name of Dam	Village Name	GPS Coordinates	
		Latitude (N)	Longitude (E)
Dhal Doro	Kalari (Haji Suleman)	26° 04' 48.5"	67° 46' 47.1"
Gabol	Kevro Goth	26° 04' 27.0"	67° 44' 36.0'
	Ghulam Muhammad Gabol	25° 03' 57.1"	67° 45' 07.5'
	Ibrahim Goth	26° 03' 39.9"	67° 45' 42.0'
Naing-II	Nighawal	26° 23' 49.3"	67° 50' 51.3"
Qasim Tok	Imam Bux Jamali	26° 57' 30.1'	67° 36' 67.4"
Aripir	Photo Khan	25° 30' 50.5"	67° 28' 07.1"
	Saifal Fakir	25° 31' 33.6"	67° 28' 10.8"
	Mubarak	25° 30' 22.8"	67° 28' 24.1"
	Haji Sher Muhammad		
	Yaqoob	25° 30' 02.2"	67° 28' 11.3"
Sureshi	Suleman Barejo	25° 30' 21.7"	67° 38' 14.3"
	Nabi Bux Barejo	25° 32' 54.5"	67° 37' 28.1"
	Umer Barejo	25° 32' 46.9"	67° 37' 02.1"
	Wasiriyo Barejo	25° 31' 30.4'	67° 35' 59.3"
	Ghulam Muhammad Khaskheli	25° 31' 24.0"	67° 36' 41.0"
Tikho-II	Safar Barejo	25° 37' 21.3"	67° 36' 27.6"
	Ali Muhammad Barejo	25° 37' 39.9"	67° 37' 09.0"
	Faiz Muhammad	25° 36' 52.6"	67° 36' 04.4"
Upper Mole-II	Moton Khan		
	Saeendad	25° 25' 21.2"	67° 27' 57.5"
	Teroo Khaskheli	25° 24' 58.2"	67° 28' 00.8"
	Yaqoob Khan	25° 24' 30.9"	67° 27' 50.8"
Jungshahi	Mal Mari	24° 58' 34.2"	67° 37' 5.1"
	Jalal Ji	24° 59' 31.1"	67° 35' 59.6"
	Kund Makan	24° 59' 3.1"	67° 35' 41.3"
	Dhori Goth	24° 57' 16.8"	67° 34' 21.1"
Konkar	Chensar Jokhio	25° 3' 14.45"	67° 15' 7.2"

	Yaar Muhammad Wadhelo		
	Khan Muhammad Wadhelo		
	Khamiso Jokhio		
	Konkar Stop	25° 3' 48.8"	67° 16' 7.8"
Karamtiani	Haji Jokhio	25° 08' 21.9"	67° 13' 59.8"
	Malang Goth		
	Wadan Jo Wandhio	24° 15' 5.6"	70° 41' 14.9"
Sabusan	Sabusan	24° 15' 53.9"	70° 40' 47.0"
	Sootilai	24° 16' 10.4"	70° 38' 23.9"
	Malaro	24 14 15.6	70 41 37.9
Sankar	Sankar	24° 31' 56.3"	70° 49' 44.7"
	Sehriyoun	24° 31' 06.2"	70° 51' 29.5"
Bhansar Rathi & Sankar	Kharsar	24° 34' 33.4"	70° 48' 18.9"
	Pabasiro	24° 33' 50.8"	70° 51' 36.4"
Bhansar Rathi	Rathi	24° 35' 36.7"	70° 51' 25.9"
	Bataari	24° 35' 50.9"	70° 53' 58.2"
	Ittado	24° 36' 45.9"	70° 50' 45.2"
	Haji Ahmed	24° 36' 28.5"	70° 50' 49.9"

Dam-Wise List of Villages and Estimated Direct Beneficiary Population

Name of Dam	Village Name	Village Profile Survey	
		No. of HH in Village	Estimated Population of Village
Dhal Doro	Kalari (Haji Suleman)	40	300
	Juman Gabol	160	1,200
Gabol	Kevro Goth	30	300
	Ghulam Muhammad Gabol	25	300
	Ibrahim Goth	40	400
	Khairdin Gabol	200	1,600
Naing-II	Nighawal	100	700
Qasim Tok	Imam Bux Jamali	8	50
	Misri Khan Jamali	35	300
	Murad Khan Jamali	70	600
	Khandani	120	1000
Aripir	Photo Khan	50	400
	Saifal Fakir	50	400
	Mubarak	60	700
	Haji Sher Muhammad	180	1300
	Yaqoob	30	200
	Allah Juriyo	80	600
	Jan Muhammad/ Darwesh	50	400
Sureshi	Suleman Barejo	50	600
	Nabi Bux Barejo	120	1500
	Umer Barejo	30	600
	Wasiriyo Barejo	80	700
	Ghulam Muhammad Khaskheli	10	80
	Naseer Barejo	15	120
	Karo Kheskhali	50	400
	Rabnawaz Barejo	10	80
	Ghulam Rasool Barejo	15	120
	Yar Muhammad Barejo	15	120
	Juman Barejo	20	160
Tikho-II	Safar Barejo	20	160
	Ali Muhammad Barejo	15	150
	Faiz Muhammad	10	80
	Zafar Barejo	50	400
	Haji Qasim Barejo	50	400
	Wadero Azam Barejo	70	560

Upper Mole-II	Moton Khan	250	1,500
	Saeendad	30	250
	Teroo Khaskheli	30	250
	Yaqoob Khan	50	400
	Waiyal	25	200
	Ismial	200	1,600
	Bachal	30	240
	Mole Town	1000	8,000
Jungshahi	Mal Mari	300	2,400
	Jalal Ji	100	850
	Kund Makan	50	500
	Dhori Goth	100	700
Konkar	Chensar Jokhio	400	3,500
	Yaar Muhammad Wadhelo	100	800
	Khan Muhammad Wadhelo	40	300
	Khamiso Jokhio	550	4,000
	Konkar Village	200	2,000
	Konkar Stop	2500	20,000
Karamtiani	Haji Jokhio	150	1,500
	Malang Goth	30	250
Sabusan	Wadan Jo Wandhio	200	1,500
	Sabusan	400	2,880
	Sootilai	400	3,000
	Malaro	50	400
	Dev Jo Wandhio	20	200
	Pane Jo Wandhio	30	250
	Boran Jo Wandhio	30	250
	Gul Hassan Ji Dhani	30	250
	Scatered Sattlements	50	250
Sankar	Sankar	500	3500
	Sehriyoun	40	300
	Scatered Sattlements	30	250
Sankar & Bhansar Rathi	Kharsar	800	7,500
	Pabasiro	800	7,000
Bhansar Rathi	Rathi	400	3,000
	Bataari	80	500
	Ittado	80	700
	Haji Ahmed	80	700
	Maya Ji Ghani	250	2,000

Dam Wise Educational Facilities[3]

Name of Dam	Number of Schools		
	Primary	Middle	High
Dhal Dhoro	0	0	0
Gabol	0	0	0
Naing-II	1	0	0
Qasim Tok	0	0	0
Aripir	2	0	0
Sureshi	2	0	0
Tikho-II	2	0	0
Upper Mole-II	2	0	0
Junghshahi	7	0	1
Konkar	8	3	1
Karamtiani	1	0	0
Sabusan	4	1	0
Sankar	0	0	0
Bhansar Rathi	6	0	0

[3] As narrated by Survey Respondents

Annex-2: Survey Questionnaire

.

U.S.- Pakistan Center for Advanced Studies in Water (USPCASW), Mehran University of Engineering and Technology (MUET), Jamshoro Sindh, Pakistan

Household questionnaire survey on

Impact Assessment/ Performance Evaluation of 14 Small Dams in the Sindh Province

I am ______________________, student of USPCAS-W, Mehran University of Engineering and Technology. We are conducting the research study on socio-economic impact of small dams. The obtain information will be used only for our research purpose. All the personal information will be confidential and will not be shared with anyone. We appreciate your time and request you to participate in this study. If you agree, can we start

☐ Yes ☐ No

Thank you very much for your coordination. Your participation is heartily appreciated. All the information given in this questionnaire will strictly be used only for socio-economic impact report of Small Dams project.

Name of Village	Name of Dam	Date of Completion	Date
Respondent ID	**Name of Surveyor**	**Form #**	**Time**

1. Personal Information	
1.1 Name of Respondent (Optional):	**1.2** Contact (Optional):
1.3 Gender: ☐ Male ☐ Female ☐ Trans	**1.4** Age: ________
1.5 Family Members: Total ________________ Male _______ Female ________	

2. Income and Expenditure		
2.1 Household Expenditure in Year **(PKR)** __________________________		
2.2 Do you take loan? ☐ Yes ☐ No		
2.2.1 If yes, what was purpose of loan?		
2.2.2 If yes, how often do you take loan?	**After Dam:**	**Before Dam:**
2.2.3 If yes, formal or informal loan? **(✓)**	**Formal:**	**Informal:**
2.2.4 If yes, is there any change in duration of taking loan after construction of dam ☐ Yes ☐ No		
2.3 Has your family income increased after construction of dam? ☐ Yes ☐ No ☐ Don't Know		
2.3.1 If yes, please mention (Choose Multiple Options, wherever applicable)	Please insert notes if there is any	

☐ Agriculture (growing of crops) ☐ Livestock - selling of animals and their products (e.g. milk, meat, wool, and dung etc.) ☐ Agriculture labor ☐ Business ☐ Job (Govt. and Private)	
2.3.2 Main Source of Income (Please Specify from above options) ________________	

3. Satisfaction from Construction of Dam
3.1 Since when water storage into the dam has begun?
3.2 Is construction of small dam beneficial for you? ☐ Yes ☐ No ☐ Don't Know
3.2.1 If yes, how? (Multiple Options) ☐ Improvement in water availability for domestic consumption and drinking ☐ Improvement in water availability for livestock ☐ Improvement in water availability for agriculture ☐ Groundwater recharge ☐ Others (Please Mention) ____

4. Access to Drinking Water Facilities					
4.1 Drinking Water Source **(✓)**	**Tube Well**	**Dug Well**	**Hand Pump**	**Reservoir**	**Water Tanker**
4.2 Water Quality (Sweet/ Brackish) **After Dam**					
Before Dam					
4.3 Has groundwater level increased after construction of dam? ☐ Yes ☐ No ☐ Don't Know					

4.4 Water table depth **(ft)** **After Dam** ( ) **Before Dam** ( )	

5. Agriculture	
5.1 Land under cultivation in this area (Acres)	Total ( ) Owned ( ) Leased ( ) Yak Salla ( )

5.2 Type of Crops you Grow (Acres)	**Millet**	**Sorghum**	**Guar**	**Mustard**	**Onion**	**Wheat**						
After Dam												
Before Dam												
5.3 Average crop yield (Mound/Acre)	**Millet**	**Sorghum**	**Guar**	**Mustard**	**Onion**	**Wheat**						
After Dam												
Before Dam												

	After Dam	**Before Dam**
5.4 Source(s) of Irrigation		
5.5 Months of adequate water for irrigation	**After Dam**	**Before Dam**

6. Livestock							
6.1 Type of livestock you have (no)	**Buffalo**	**Cow**	**Goat**	**Sheep**	**Camel**	**Donkey**	**Chicken**
After Dam							
Before Dam							
6.2 Has there any improvement in animal health due to water availability	☐ Yes ☐ No ☐ Don't Know						

6.3 Have you experienced any improvement in animal milk production	☐ Yes ☐ No ☐ Don't Know						
6.3.1 If yes, please mention (Liters/day)	**Buffalo**	**Cow**	**Goat**	**Sheep**	**Camel**		
6.4 Have you experienced any improvement in number of animal sell	☐ Yes ☐ No ☐ Don't Know						
6.5 Selling price variation of animals due to improved health	☐ Yes ☐ No ☐ Don't Know						
6.6 Is there change in pastureland area after construction of dam? ☐ Yes ☐ No ☐ Don't Know							
6.6.1 If yes, mention type of change.							

7. Migration		
7.1 Is there migration trend in your area? ☐ Yes ☐ No ☐ Don't Know		
7.1.1 If yes: **(✓)** Migration-In ( ) Migration-Out ( ) Both ( )		
7.2 Migration trend **(%)**	**Migration-In**	**Migration-Out**
After Dam		
Before Dam		
7.3 Type of migration **(%)**	**Temporary**	**Permanent**
After Dam		
Before Dam		
8. Kitchen Gardening		
8.1 Do you perform kitchen gardening? ☐ Yes ☐ No		
8.1.1 If, yes since when? **(✓)** **After Dam ( )** **Before Dam ( )**		
8.1.2 If not before dam, please mention the reason ____		

9. Water Use related Conflicts
9.1 Type of water use related conflicts in your area before and after construction of dam? **(✓)**
After Dam: Drinking Water ( ) Irrigation Water ( ) Livestock Drinking Water ( )
Before Dam: Drinking Water ( ) Irrigation Water ( ) Livestock Drinking Water ( )

10. Cross Cutting Themes		
10.1 Months of water scarcity (Mention names of months)	**After Dam:**	**Before Dam:**
10.2 Time required to fetch drinking water. **(Hours)**	**After Dam:**	**Before Dam:**
10.3 Time required to take livestock for water. **(Hours)**	**After Dam:**	**Before Dam:**
10.3.1 If time is saved, how it is utilized?		

10.4 Did you observe any change in occurrence of diseases due to dam?	☐ Yes ☐ No ☐ Don't Know
10.5 What type of diseases usually occur? ____	

11. Future Interventions
11.1 Type of future intervention you want in your area

Annex-3 Focus Group Discussion Guide

U.S.- Pakistan Center for Advanced Studies in Water (USPCASW),
Mehran University of Engineering and Technology (MUET), Jamshoro
Sindh, Pakistan

Impact Assessment and Performance Evaluation of 14 Small Dams in Sindh Province

(Focus Group Discussion Guideline)

CONSENT DOCUMENT

BACKGROUND

We are conducting a research study to evaluate the performance of small dams. Before you decide whether you would like to participate, we must provide you with more information about the purpose of the study, who is conducting it, and what your participation will involve.

We are members of a research team from USPCASW, Mehran University of Engineering and Technology, Jamshoro.

STUDY PROCEDURE

The focus group discussion will last about one hour. The discussion will be around following themes:

- Socio-economic impacts of small dams in the project area,
- Improvement in water availability, agriculture, and livestock,
- Improvement in a drought situation
- Protection from floods
- Inward migration
- Change in use of solar energy and status of schooling

CONSENT

We confirm that we have read/heard this consent and authorization document and have had the opportunity to ask questions.

I agree to participate in this research study Yes No

Village/community name: ___________________________________

FGD Type: Male ( ) Female ( ) Mix ( )

No of FGD Participants: ______________________________________

Age Range: _____________________ Education Range:________________________

Place of FGD:_______________________ Time Duration:__________________

Water Availability

Q.1: What you think how water availability has changed before and after the construction of the dam?

Possible Probing

- If yes how do you know that water availability has changed? And for how long water availability has changed? Please also mention the name of months?
- What is the source of drinking water in your area?
- Has water quality also improved due to construction of the dam?
- If yes how do you know that it has improved?
- If water availability has increased, what do think the time for water fetching has also decreased? If yes, how much time and distance is reduced for water fetching for domestic use?

Agriculture

Q.2: It is said that after the construction of the dam people are having good agriculture in the area. What is your opinion on the above statement?

Possible Probing

- If yes, can you describe the key changes in cultivation after construction of dam?
- Any new crops been introduced in your area after construction of dam?
- Any one of you planning for introducing new crops after the construction of the dam?
- Which crops are traditionally cultivated in your area?
- How the construction of the dam has impacted the impacted the crop yield?
- If yes, can you tell us the crops and how much crop yield has been impacted after construction of dam?

Livestock

Q.5: It is said that livestock is the prime beneficiary of the dam construction. Do you agree or with this statement and can you describe why you have this opinion?

Possible Probing

- How the construction of the dam has impacted the impacted the livestock?
- If dam has positive impact on livestock, how much income is increased from livestock?

Flood and Drought Protection

Q.6: What do you think about change in drought situation after construction of dam in your area?

Possible Probing

- Can you differentiate the intensity (impact) of drought before and after construction of dam?

Q.7: What do you think about the change in flooding events after the construction of a dam in your area?

Possible Probing

- Can you differentiate the intensity (impact) of flooding before and after construction of dam?

Migration

Q.8: In this area, people used to migrate due to the unavailability of water but now the situation has changed after the construction of dam… What is your opinion on the above statement?

Change in Use of Solar Energy

Q.9: Can you describe the change in the use of solar energy in your area after the construction of dam, specially for fetching ground water?

Cross-cutting themes

Q.10: As water availability and quality has increased and it has impacted the health and no of days of kids schooling as well… What is your opinion on the above statement?

Q.11: As water availability and quality has increased and it has greatly impacted lives females… What is your opinion on the above statement? And if you agree or disagree, please tell why you say this?

Annex-4 Key Informant Interview Guideline

US. Pakistan Center for Advanced Studies in Water (USPCASW),
Mehran University of Engineering and Technology (MUET), Jamshoro
Sindh, Pakistan

Impact Assessment and Performance Evaluation of 14 Small Dams in Sindh Province

(Key Informant Interview Guideline)

CONSENT DOCUMENT

BACKGROUND

We are conducting a research study to evaluate performance of small dams. Before you decide whether you would like to participate, it is important that we provide you with more information about the purpose of the study, who is conducting it, and what your participation will involve.

We are members of a research team from USPCASW, Mehran University of Engineering and Technology, Jamshoro.

STUDY PROCEDURE

The key informant interview will last about one hour. The discussion will be around following themes:

- Socio-economic impacts of small dams in project area,
- Improvement in water availability, agriculture, and livestock,
- Improvement in drought situation
- Protection form floods
- Migration
- Change in use of solar energy and status of schooling

CONSENT

We confirm that we have read/heard this consent and authorization document and have had the opportunity to ask questions.

I agree to participate in this research study Yes No

Department: _____________________Designation: _________________________

KII : Male ( ) Female ( )

Place of KII:____________________ Time Duration:______________________

Water Availability

Q.1: What you think how water availability has changed before and after the construction of the dam?

Possible Probing

- If yes, how do you know that water availability has changed? And for how long water availability has changed? Please also mention the name of months.
- What is the source of drinking water in your area?
- Has water quality also improved due to construction of the dam?
- If yes, how do you know that it has improved?
- If water availability has increased, what do think the time for water fetching has also decreased? If yes, how much time and distance is reduced for water fetching for domestic use?

Agriculture

Q.2: How has the cropping pattern changed in project area after construction of dam?

Possible Probing

- What is change in land under cultivation after construction of dam?
- Change in land under cultivation in kharif season.
- Change in land under cultivation in rabi season.

Q.3: Which new crops are introduced in project area after construction of dam?

Possible Probing

- Which crops are traditionally cultivated in project area?
- What are the benefits of new crops?

Q.4: How much crop yield has increased after construction of dam?

Possible Probing

- What was the crop yield of traditional crops before construction of dam?
- What is the crop yield of traditional crops after construction of dam?

Livestock

Q.5: How much population of livestock in project area has changed after construction of dam?

Q.6: And what are reason of change in population of livestock?

Q.8: How has death number of livestock changed in project area after construction of dam?

Flood and Drought Protection

Q.9: How has droughts condition changed in project area after construction of dam?

Possible Probing

- Number of droughts occurred before construction of dam.
- What is the intensity (impact) of drought before construction of dam?
- Number of droughts occurred After construction of dam.
- What is the intensity (impact) of drought after construction of dam?

Q.10: How has floods condition changed in project area after construction of dam?

Possible Probing

- Number of floods occurred before construction of dam.
- What is the intensity (impact) of flood before construction of dam?
- Number of floods occurred After construction of dam.
- What is the intensity (impact) of flood after construction of dam?

Migration

Q.11: What do you think about change inward migration in project area after construction of dam?

Possible Probing

- Number of families came to permanently settle in project area.
- Change in number of families, who temporary moved to irrigated area due to shortage of water.

Change in Use of Solar Energy

Q.12: Can you describe the change in use of solar energy in project area after the construction of dam?

Possible Probing

- Number of solar energy operated tube well in project area before construction of dam?
- Number of solar energy operated tube well in project area after construction of dam?

Change in Status of Schooling

Q.13: Can you describe the change in status of schooling in project area after the construction of dam?

Possible Probing

- Number of children going to school in project area before construction of dam.
- Number of children going to school in project area after construction of dam.

Annex-5: Crop-wise data analysis

Millet

Millet is one of the major crops cultivated in rain-fed areas. According to the respondents the average cropping area of millet crop has increased in the Sankar and Bhansar Rathi dam areas and decreased in Sabusan dam area after construction of the dam. While no change was reported in millet cropping area in Junghshahi dam area.

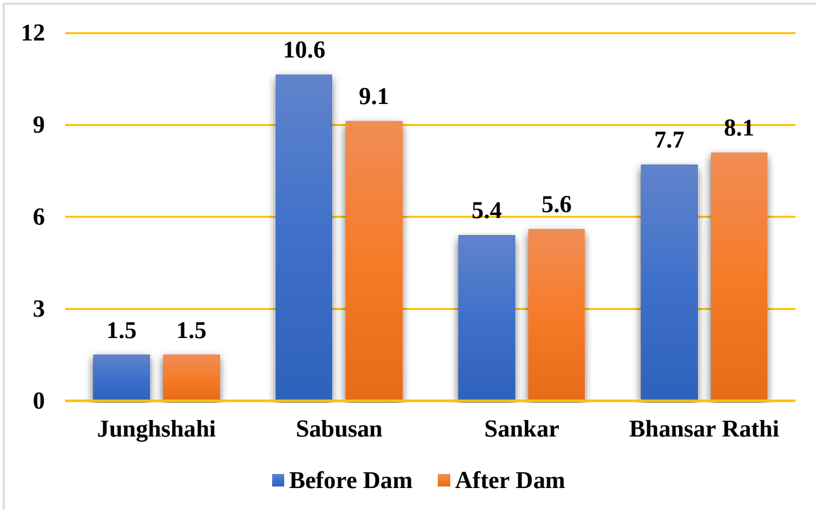


Figure A-5.1: Millet Average Cropped Area (Acre)

According to the respondents' average yield of the millet crop has increased in all dam area after the construction of the dam which is positive sign of the dam construction. The maximum increase in millet crop yield was reported in Sankar dam area from 11 to 16 mounds per acre.

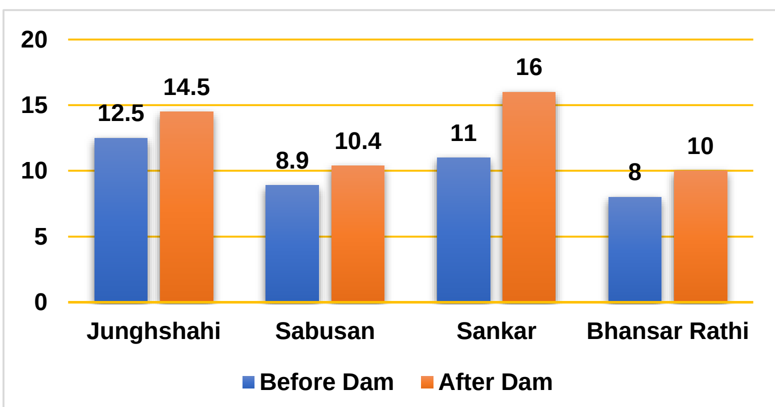


Figure A-5.2 Millet Average Yield (Mound/Acre)

Sorghum

Sorghum is also one of the major crops cultivated in rain-fed areas. According to the respondents the average cropping area of sorghum crop has increased in the Upper Mole-II and Junghshahi dam areas and decreased in Sabusan dam area after construction of the dam. While no change was reported in sorghum cropping area in Sureshi dam area.

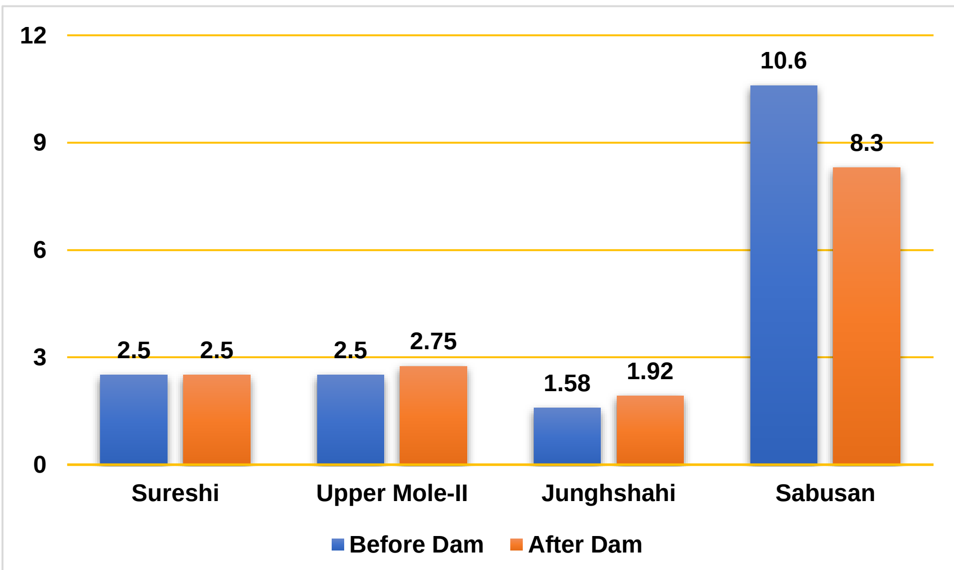


Figure A-5.3 Sorghum Average Cropped Area (Acre)

According to the respondents' average yield of the sorghum crop has increased in Sureshi, Upper Mole-II, Junghshahi, and Sabusan dam areas after the construction of the dam which is positive sign of the dam construction. The maximum increase in sorghum crop yield was reported in Sabusan dam area from 8.1 to 10.7 mounds per acre.

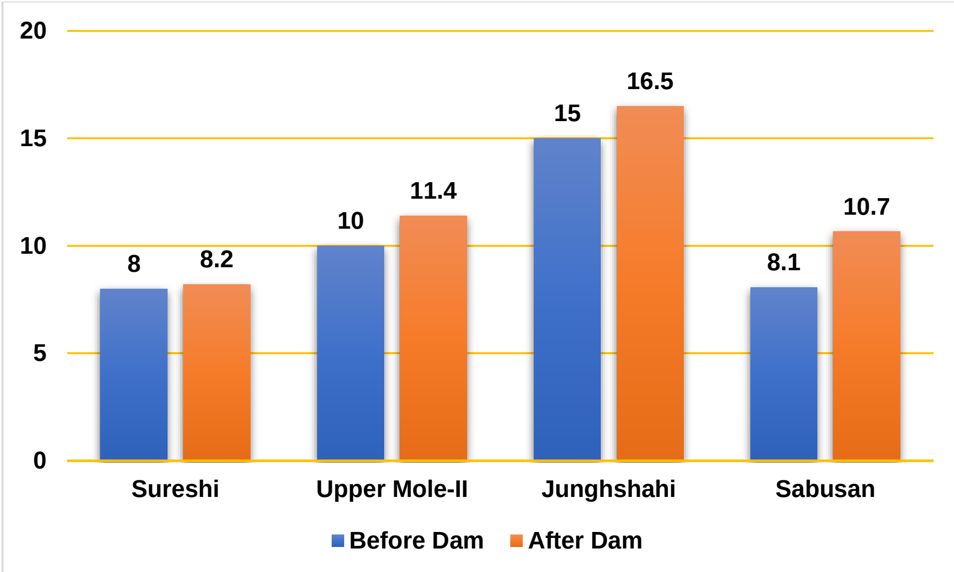


Figure A-5.4 Sorghum Average Yield (Mound/Acre)

Guar

Guar are also one of the major crops cultivated in rain-fed areas. According to the respondents the average cropping area of guar crop has increased in the Naing-II, Qasim Tok, Aripir, Upper Mole-II, Sankar and Bhansar Rathi dam areas and decreased in Sabusan dam area after construction of the dam. While no change was reported in guar cropping area in Sureshi and Junghshahi dam areas.

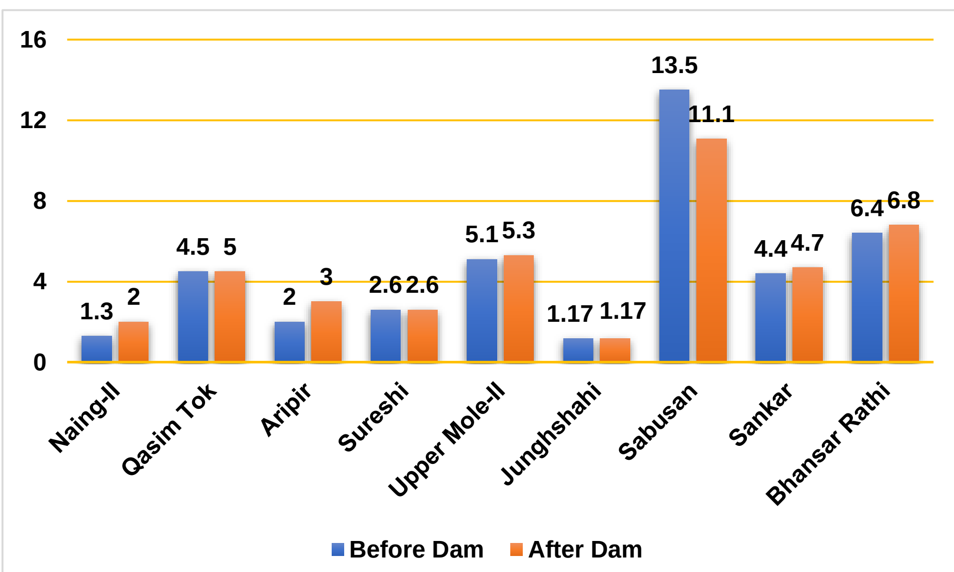


Figure A-5.5 Guar Cropped Area (Acre)

According to the respondents' average yield of the guar has increased in Qasim Tok, Aripir, Upper Mole-II, Junghshahi, Sabusan, Sankar, and Bhansar Rathi dam areas after the construction of the dam which is positive sign of the dam construction. The maximum increase in guar yield was reported in Qasim Tok dam area from 11 to 18 mounds per acre. While no change was reported in the guar yield in Naing-II and Sureshi dam areas.

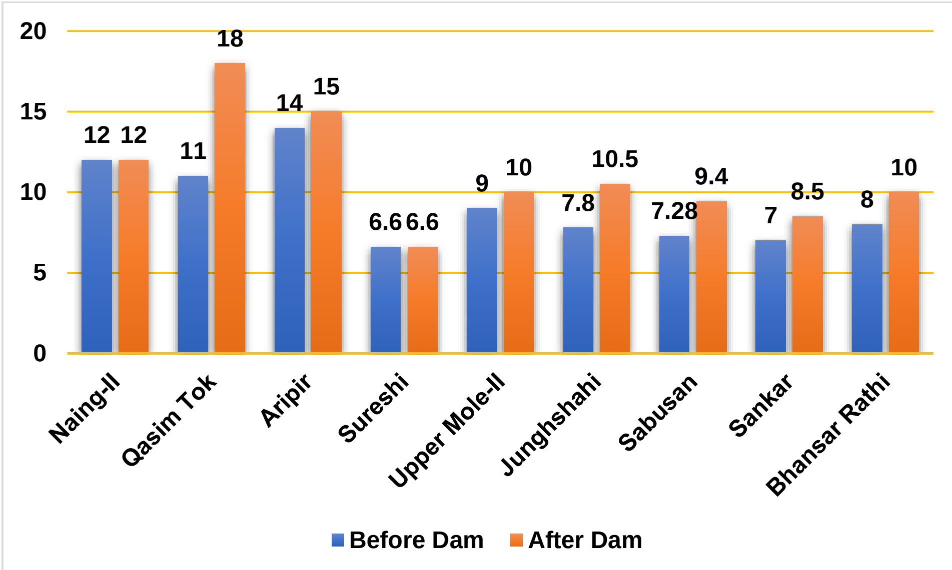


Figure A-5.6 Guar Average Yield (Mound/Acre)

Sesame

Sesame crop is also cultivated in rain-fed areas. According to the respondents the average cropping area of sesame crop has increased in Sankar and Bhansar Rathi dam areas after construction of the dam. While no change was reported in sesame cropping area in Sabusan dam area.

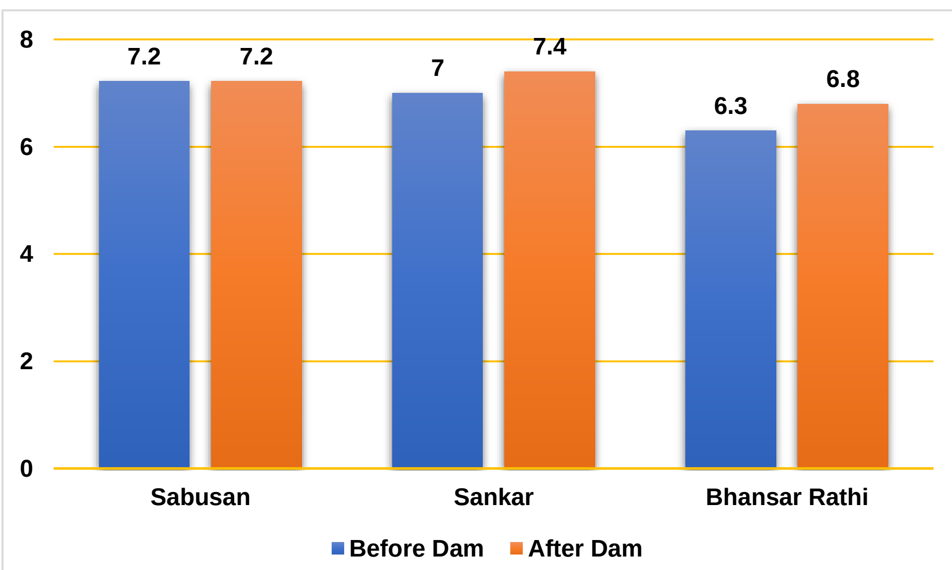


Figure A-5.7 Sesame Average Cropped Area (Acre)

According to the respondents' average yield of the sesame has increased in Sabusan, Sankar, and Bhansar Rathi dam areas after the construction of the dam which is positive sign of the dam construction. The maximum increase in sesame yield was reported in Sankar dam area from 1.6 to 2.3 mounds per acre after construction of the dam.

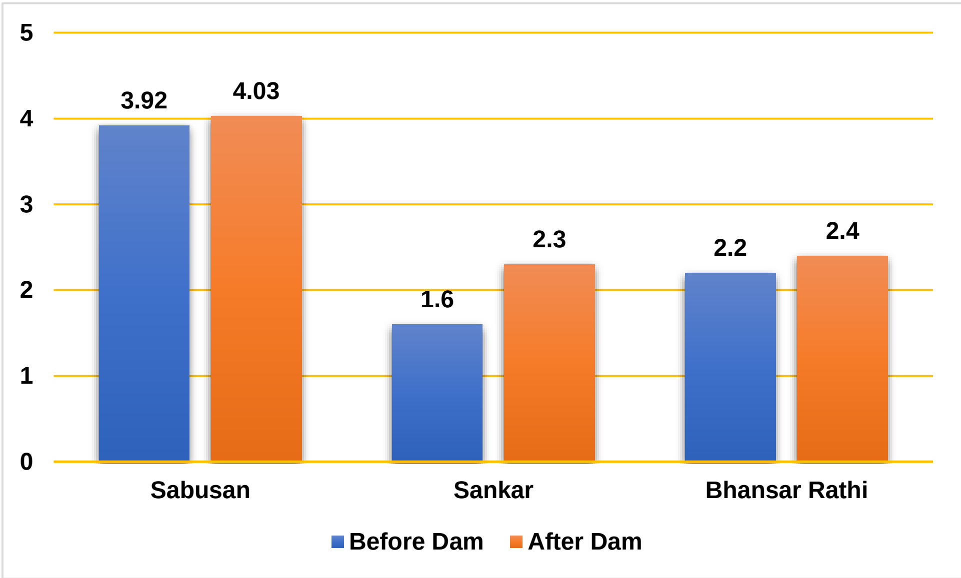


Figure A-5.8 Sesame Average Yield (Mound/Acre)

Mung

According to the respondents the average cropping area of mung has increased in Sankar and Bhansar Rathi dam areas after construction of the dam. While no change was reported in mung cropping area in Sabusan dam area.

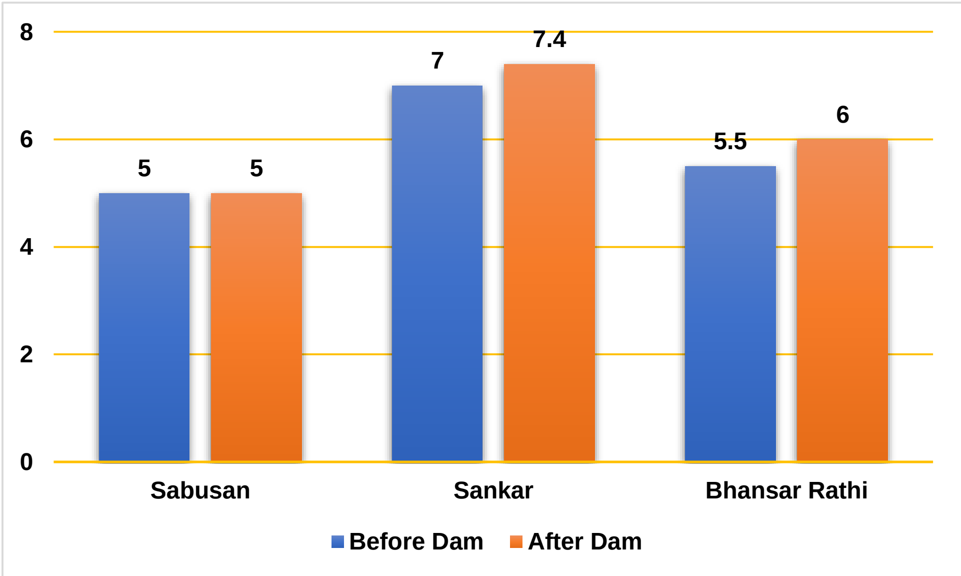


Figure A-5.9 Mung Average Cropped Area (Acre)

According to the respondents' average yield of the mung has increased in Sabusan, Sankar, and Bhansar Rathi dam areas after the construction of the dam which is positive sign of the dam construction. The maximum increase in mung yield was reported in Bhansar Rathi dam area from 2.6 to 3.4 mounds per acre after construction of the dam.

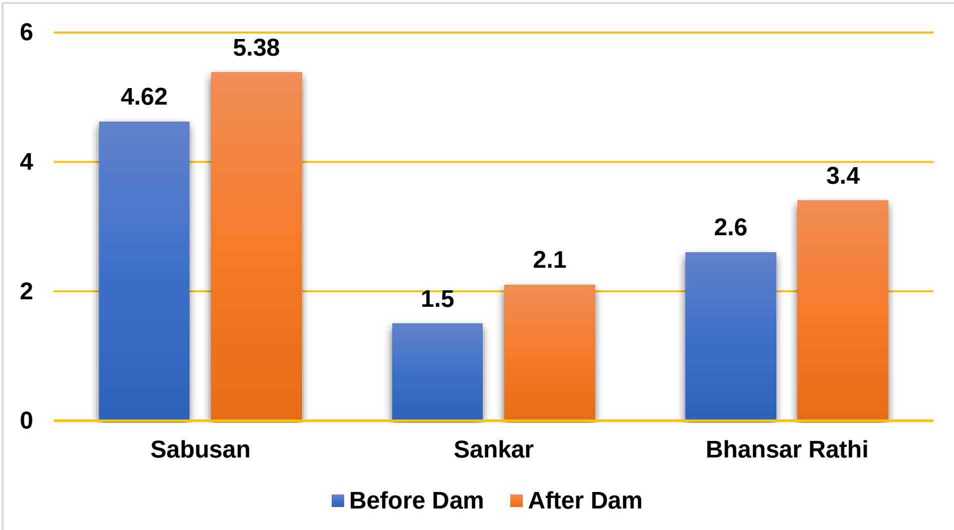


Figure A-5.10 Mung Average Yield (Mound/Acre)

Moth

According to the respondents the average cropping area of moth has increased in Sankar and Bhansar Rathi dam areas after construction of the dam. While no change was reported in moth cropping area in Sabusan dam area.

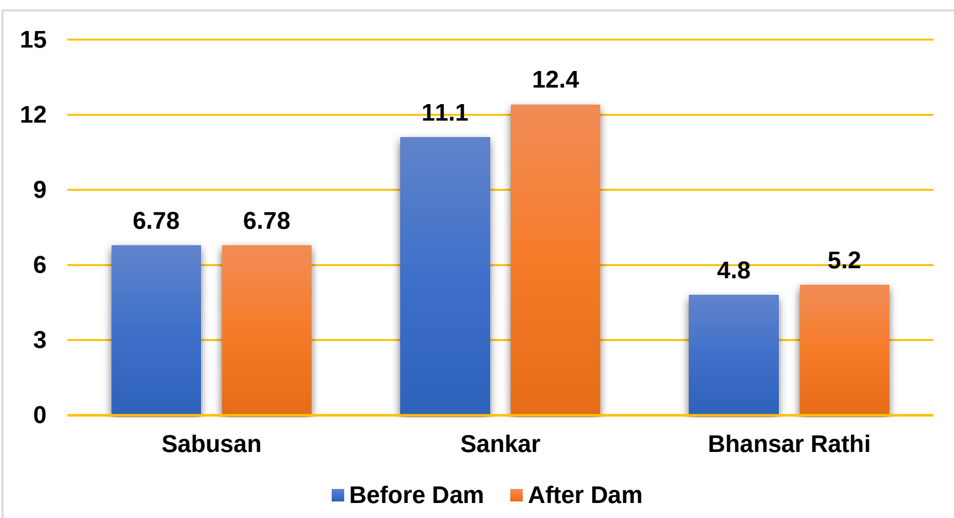


Figure A-5.11 Moth Average Cropped Area (Acre)

According to the respondents' average yield of the moth has increased in Sabusan, Sankar, and Bhansar Rathi dam areas after the construction of the dam which is positive sign of the dam construction. The maximum increase in moth yield was reported in Bhansar Rathi dam area from 4 to 5.2 mounds per acre after construction of the dam.

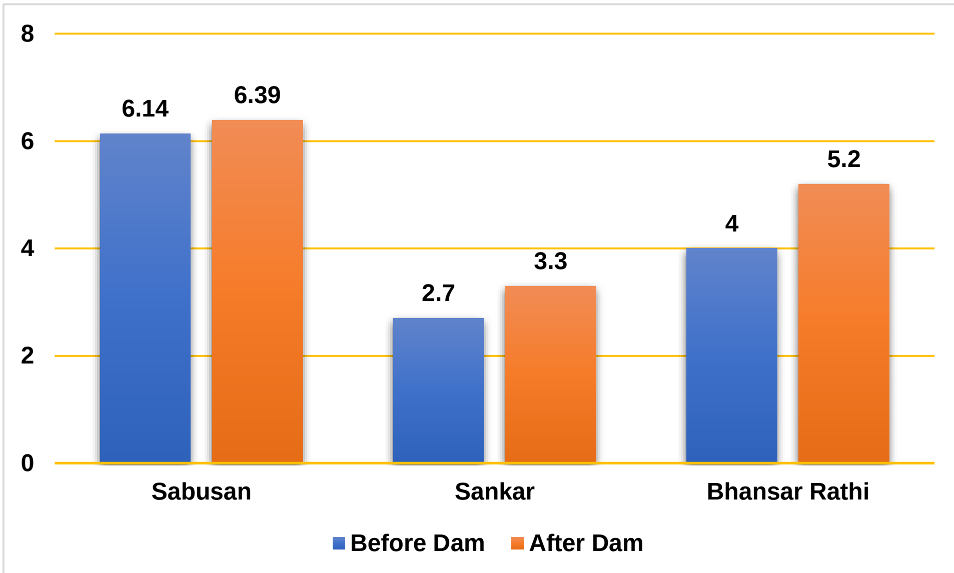


Figure A-5.12 Moth Average Yield (Mound/Acre)

Casterbean

Casterbean crop cultivation was only reported at Sabusan dam area. According to the respondents' average cropping area of casterbean has decreased after construction of the dam but the average yield has increased 6.5 to 8.5 mounds per acre.

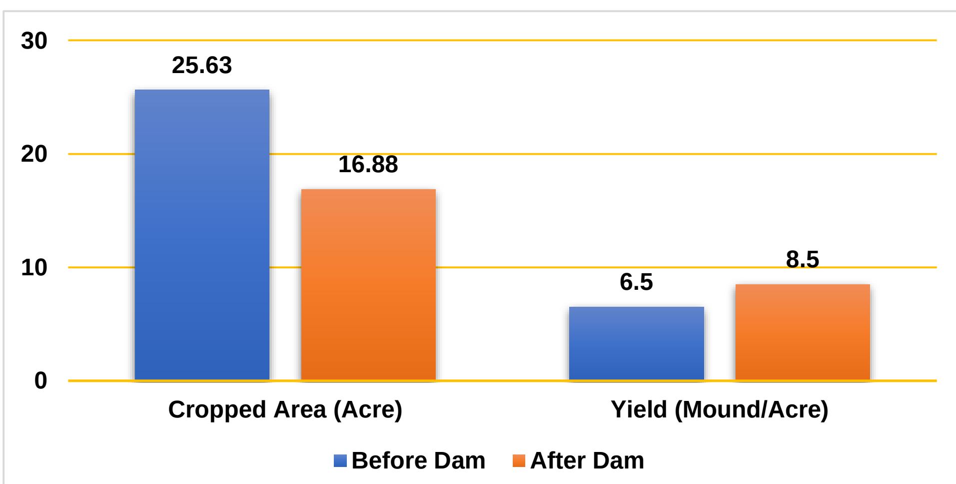


Figure A-5.13 Casterbean Average Cropped Area & Yield at Sabusan Dam

Onion

Onion is one of the major irrigated crops cultivated in rain-fed areas using modern irrigation technology. According to the respondents the average cropping area of onion crop has increased in the Dhal Dhoro, Gabol, Naing-II, Qasim Tok, Aripir, and Upper Mole-II dam areas. While no change was reported in onion cropping area in Tikho-II dam area.

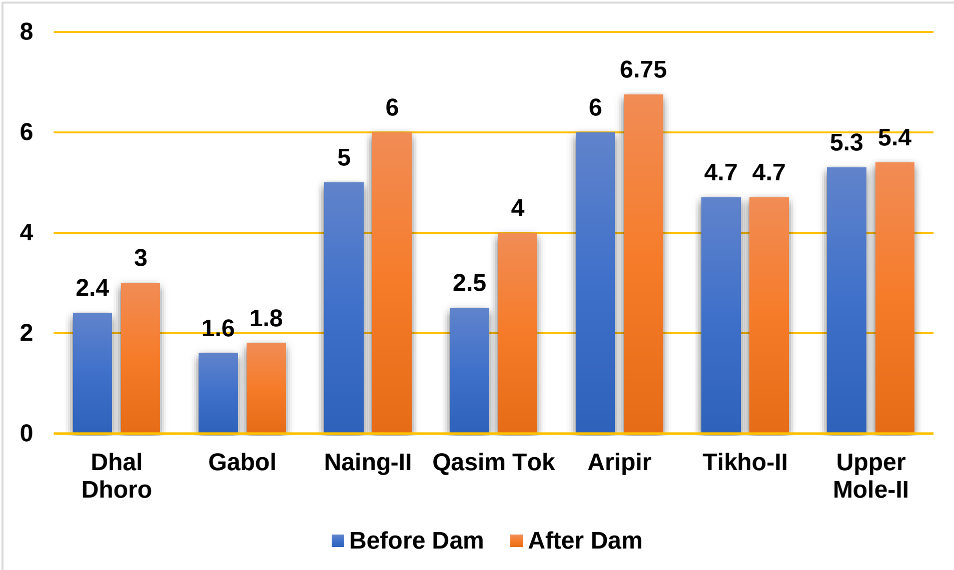


Figure A-5.14 Onion Average Cropped Area (Acre)

According to the respondents' average yield of the onion has increased in Dhal Dhoro, Gabol, Naing-II, Aripir, Tikho-II, and Upper Mole-II dam areas after the construction of the dam which is positive sign of the dam construction. The maximum increase in onion yield was reported in Dhal Dhoro dam area from 128 to 198 mounds per acre. While decrease in the onion yield was reported in Qasim Tok dam area.

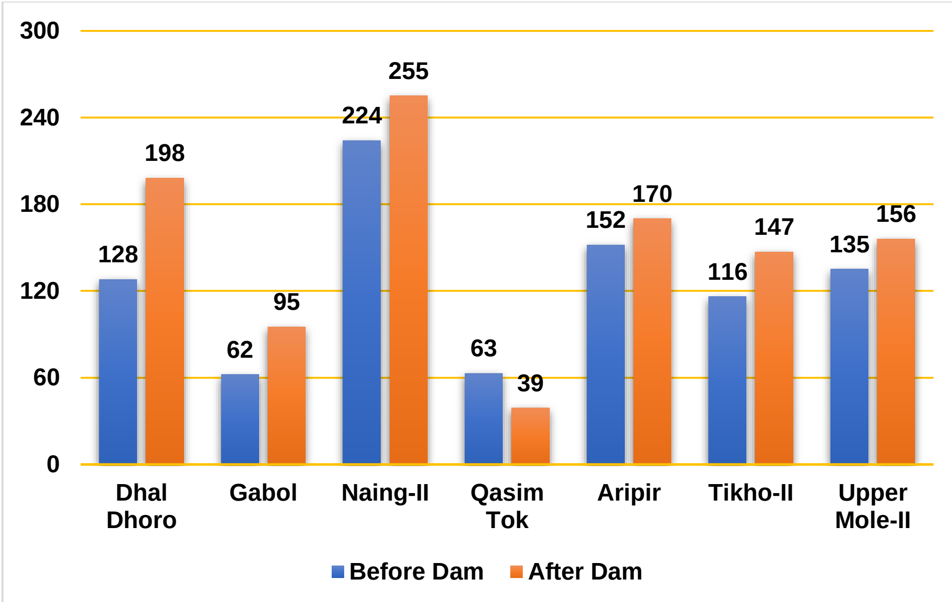


Figure A-5.15 Onion Average Yield (Mound/Acre)

Wheat

Wheat is also one of the major irrigated crops cultivated in rain-fed areas using modern irrigation technology. According to the respondents the average cropping area of wheat crop has increased in the Dhal Dhoro, Gabol, Naing-II, Qasim Tok, Aripir, Upper Mole-II, and Junghshahi dam areas. While no change was reported in wheat cropping area in Sureshi and Tikho-II dam areas.

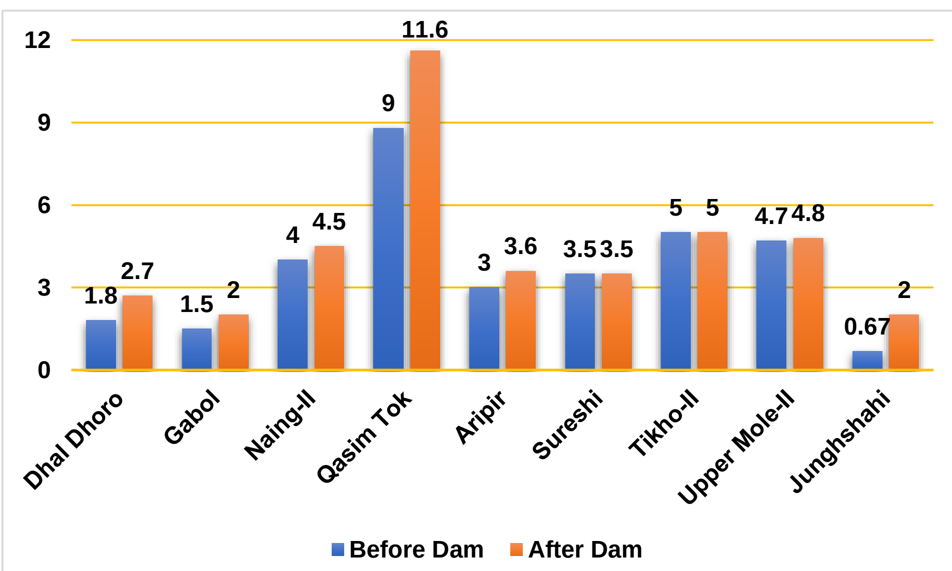


Figure A-5.16 Wheat Average Cropped Area (Acre)

According to the respondents' average yield of the wheat has increased in Dhal Dhoro, Gabol, Naing-II, Qasim Tok, Aripir, Sureshi, Tikho-II, Upper Mole-II, and Junghshahi dam areas after the construction of the dam which is positive sign of the dam construction. The maximum increase in wheat yield was reported in Junghshahi dam area from 16 to 40 mounds per acre.

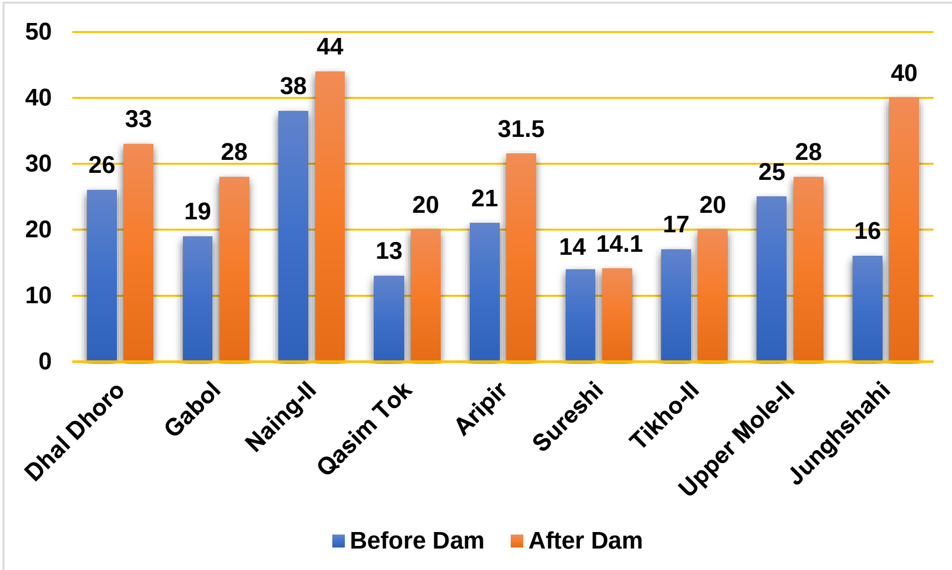


Figure A-5.17 Wheat Average Yield (Mound/Acre)

Chili

Chili is an irrigated crop, which is cultivated in rain-fed areas using modern irrigation technology. According to the respondents average cropping area of chili crop has increased in the Dhal Dhoro, Gabol, and Naing-II dam areas. While no change was reported in chili cropping area in Aripir dam area.

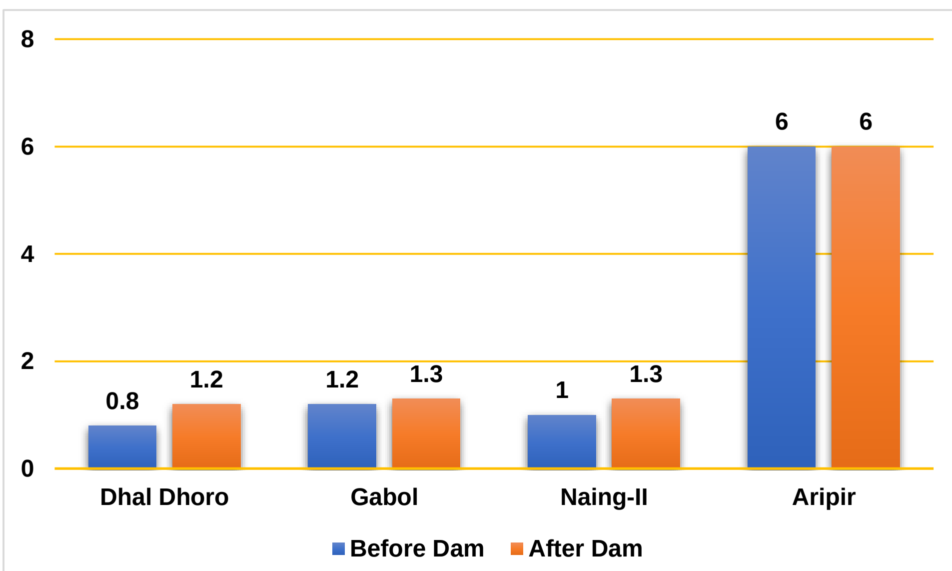


Figure A-5.18 Chili Average Cropped Area (Acre)

According to the respondents' average yield of the chili has increased in Dhal Dhoro, Gabol, Naing-II, and Aripir dam areas after the construction of the dam which is positive sign of the dam construction. The maximum increase in chili yield was reported in Dhal Dhoro dam area from 31.5 to 51.7 mounds per acre.

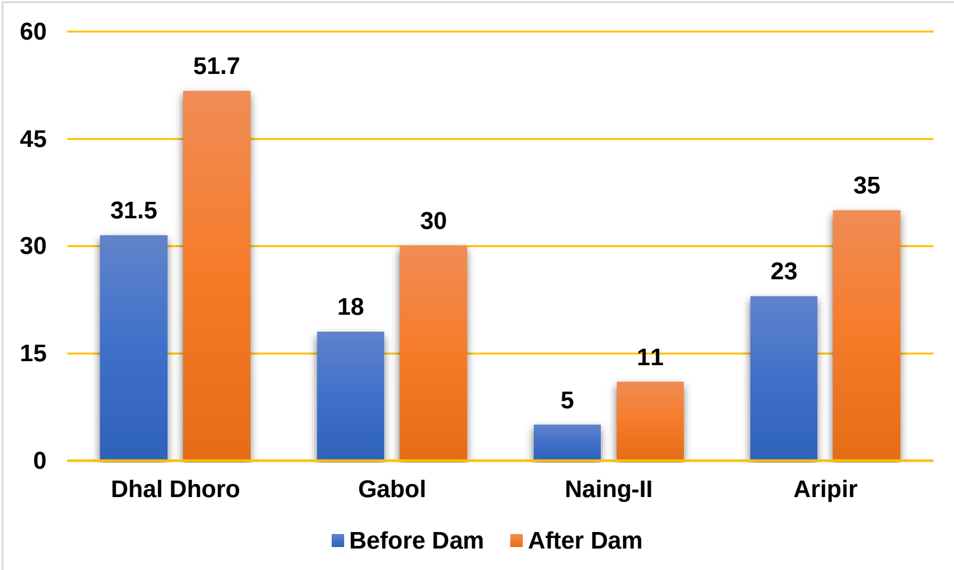


Figure A-5.19 Chili Average Yield (Mound/Acre)

Cotton

Cotton crop cultivation was only reported at Tikho-II dam area. According to the respondents' there was no change in average cropping area of cotton after construction of the dam, but the average yield has increased 20 to 30 mounds per acre.

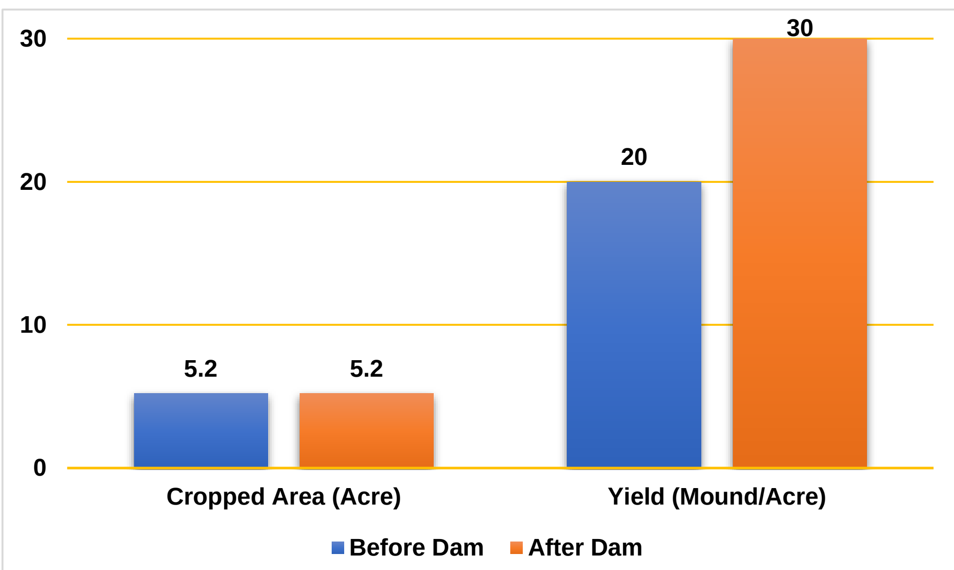


Figure A-5.20 Cotton Average Cropped Area & Yield at Tikho-II Dam

Tomato

Tomato crop cultivation was only reported at Junghshahi dam area. According to the respondents' cropping area of tomato has increased after construction of the dam and the average yield has also increased from 8 to 21 mounds per acre.

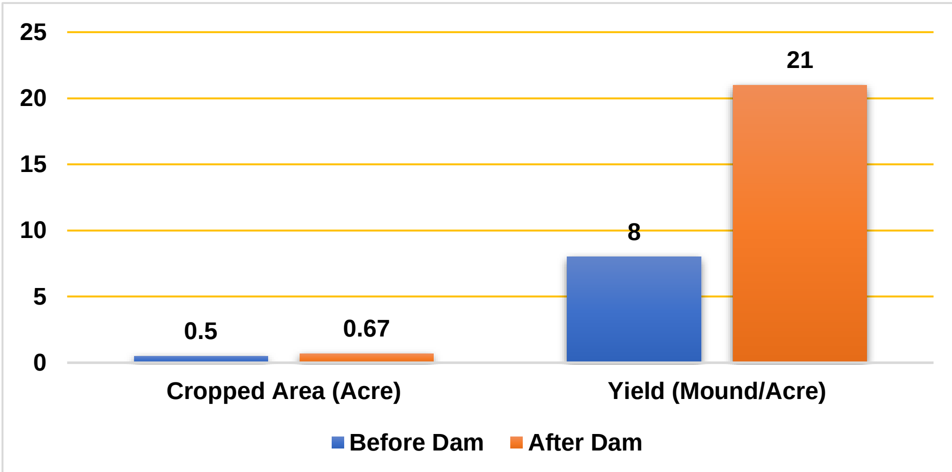


Figure A-5.21 Tomato Average Cropped Area & Yield at Junghshahi Dam

Annex-6: Detail of Landholding

Name of Dam	Total Land (Acres)			Owned Land (Acres)			Leased Land (Acres)		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Dhal Dhoro	100	1.5	11	15	1.5	5.7	7	1.5	3.4
Gabol	20	1	4.4	20	1	4.8	5	2	3.5
Naing-II	97	4	20	30	4	11	85	5	30.5
Qasim Tok	45	3	12.6	25	6	12	20	3	10.25
Aripir	22	2	9	22	1	7.5	20	2	7
Sureshi	30	1	5.8	30	0.5	5.1	0	0	0
Tikho-II	30	2	6.6	30	2	6.5	6	4	5.25
Upper Mole-II	200	1	16	26	2	10	174	1	25
Junghshahi	8	1	5	8	1	5	0	0	0
Konkar	24	2	6.5	24	2	9.5	5	2	3.5
Karamtiani	10	1	6	10	1	5	5	3	4
Sabusan	75	1	19	75	1	20	25	1	9
Sankar	150	2	17	150	2	21	10	2	5
Bhansar Rathi	70	1	18.5	70	1	17	60	5	15

Annex-7: Animal-wise data analysis

Cow

According to the respondents of Aripir, Tikho-II, Upper Mole-II, Junghshahi, Karamtiani, and Sankar dams the number of the cows has increased after construction of the dam. The maximum increase in number of cows was reported in Upper Mole-II dam area from 4 to 9. While the respondents of the Naing-II and Sureshi dams were of view that there is no change in number of cows after construction of dam. This is the positive impact of the small dams out of 11 dams where respondents reported they have cows, respondents of 6 dam said there is increase in number of the cows.

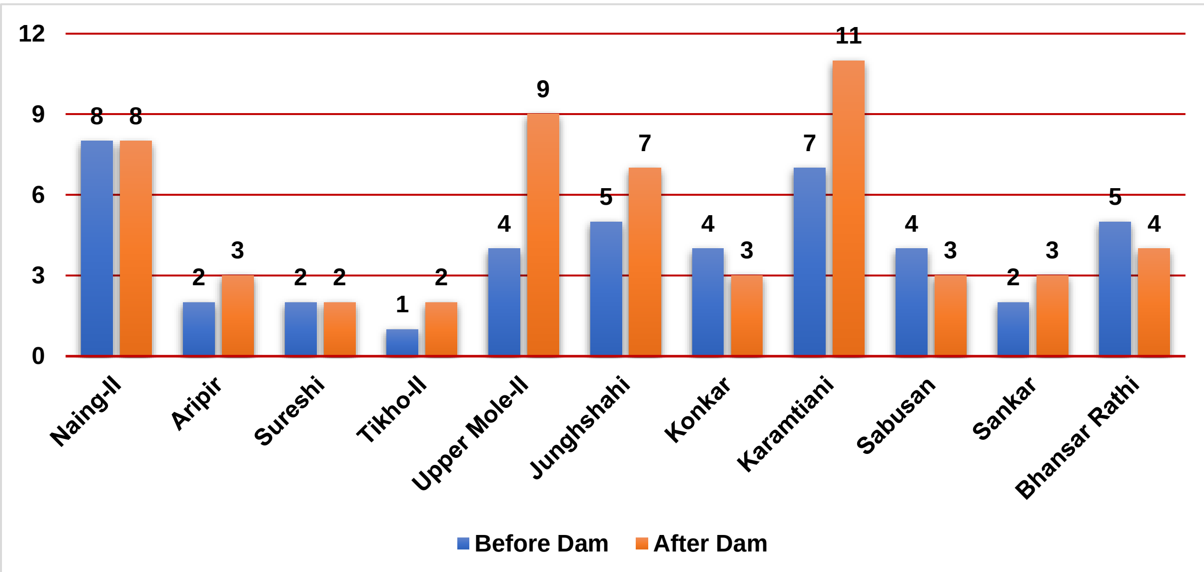


Figure A-7.1 Average Number of Cows

Goat

According to the respondents of Dhal Dhoro, Gabol, Aripir, Tikho-II, Upper Mole-II, Junghshahi, and Bhansar Rathi dams the number of the goats has increased after construction of the dam. The maximum increase in number of goats was reported in Upper Mole-II dam area from 17 to 29. This is the positive impact of the small dams out of 14 dams where respondents reported they have goats, respondents of 7 dam said there is increase in number of the goats.

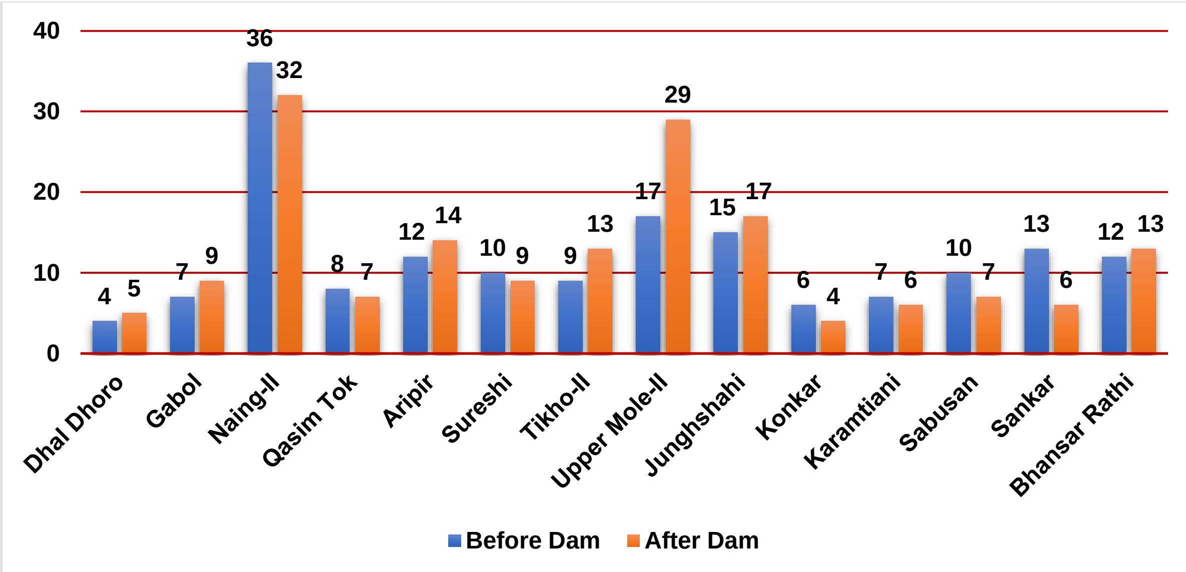


Figure A-7.2 Average Number of Goats

Sheep

Interestingly the sheep were reported only by respondents of the Tharparkar small dams' area. According to the respondents of Sabusan and Bhansar Rathi dams the number of the sheep has increased after construction of the dam. The maximum increase in number of sheep was reported in Sabusan dam area from 5 to 11. While the respondents of the Sankar dam were of view that there is no change in number of sheep after construction of dam. This is the positive impact of the small dams out of 3 dams where respondents reported they have sheep, respondents of 3 dams said there is increase in number of the sheep.

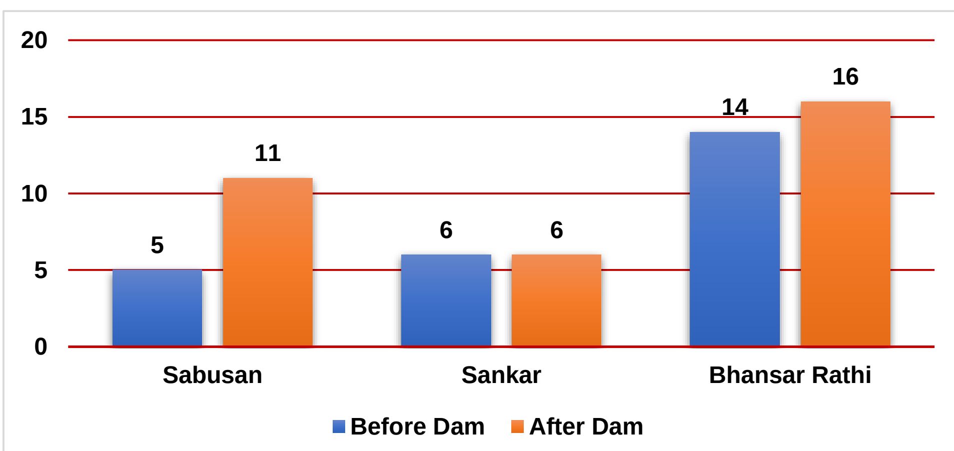


Figure A-7.3 Average Number of Sheep

Chicken

According to the respondents of Qasim Tok, Aripir, Sureshi, and Upper Mole-II dams the number of the chickens has increased after construction of the dam. The maximum increase in number of chickens was reported in Aripir dam area from 0 to 3. While the respondents of the Karamtiani dam were of view that there is no change in number of chickens after construction of dam. This is the positive impact of the small dams out of 6 dams where respondents reported they have chickens, respondents of 4 dams said there is increase in number of the chicken after construction of the dam.

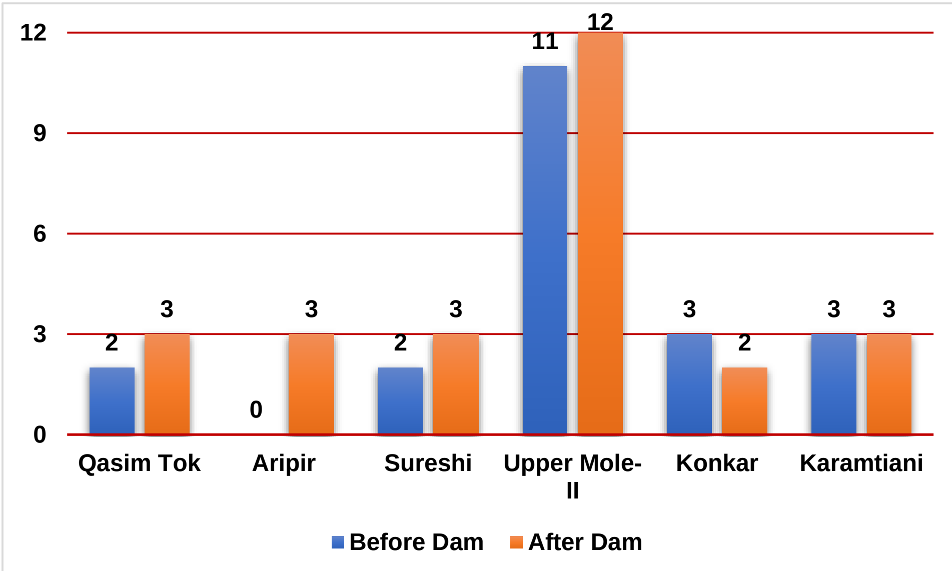


Figure A-7.4 Average Number of Chicken

Donkey

In rural areas, people usually keep donkeys for hauling purposes. According to the respondents of Sureshi, Karamtiani, and Bhansar Rathi dams the number of the donkeys has increased after construction of the dam. On average number of donkeys has increased by 1 in above mentioned dams' area. While the respondents of the Konkar dam were of view that there is no change in number of donkeys after construction of dam. This is the positive impact of the small dams out of 4 dams where respondents reported they have donkeys, respondents of 3 dams said there is increase in number of the donkey after construction of the dam.

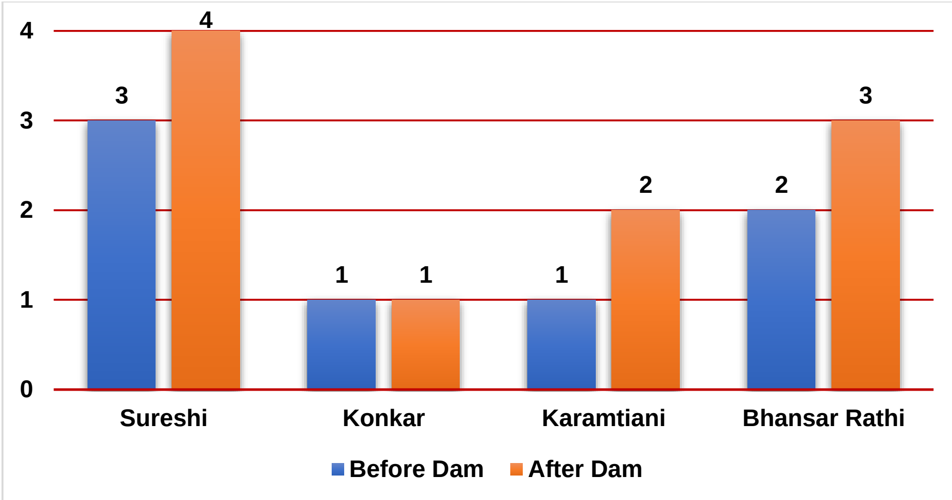


Figure A-7.5 Average Number of Donkey

Improvement in the Livestock Health

The respondents were asked "is there any improvement in animal health due to water availability?", majority of the respondents of the Dhal Dhoro, Gabol, Naing-II, Qasim Tok, Aripir, Tikho-II, Upper Mole-II, Junghshahi, Konkar, Karamtiani, Sabusan, Sankar, and Bhansar Rathi dams reported that there is improvement in animal health due to improvement in water availability after construction of small dams.

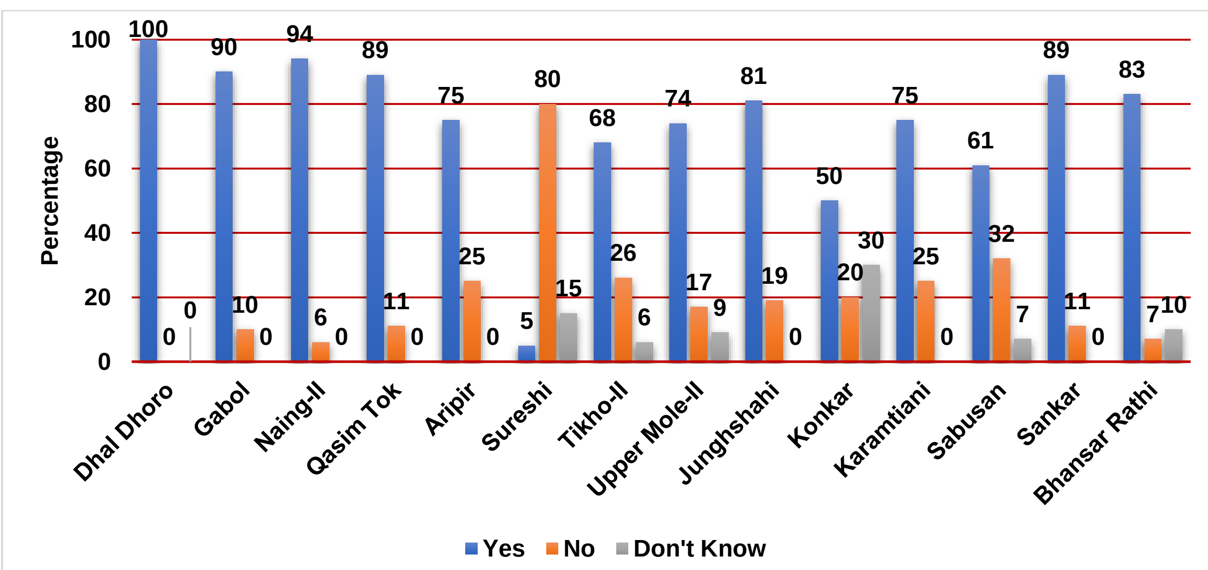


Figure A-7.6 Improvement in Livestock Health

Further, when respondents were asked "is there any variation in livestock selling price due to improved health?", majority of the respondents of the Dhal Dhoro, Gabol, Naing-II, Qasim Tok, Aripir, Tikho-II, Upper Mole-II, Junghshahi, Konkar, Karamtiani, Sabusan, Sankar, and Bhansar Rathi dams were of view that there is variation in selling price of livestock due to improved health after construction of small dams.

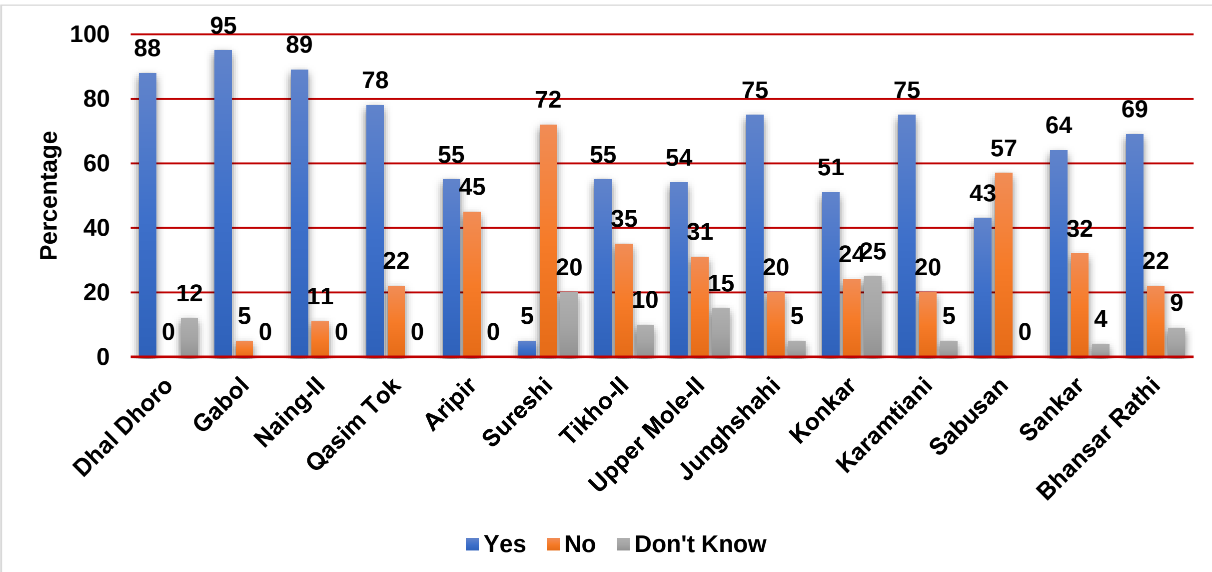


Figure A-7.7 Variation in Selling Price of Livestock due to Improved Health

Improvement in Livestock Milk Production

The respondents were asked "have you experienced any improvement in milk production of the livestock?", majority of the respondents of the Dhal Dhoro, Gabol, Naing-II, Aripir, Upper Mole-II, Junghshahi, Konkar, Karamtiani, Sabusan, Sankar, and Bhansar Rathi dams reported that there is improvement in milk production of the livestock after construction of small dams.

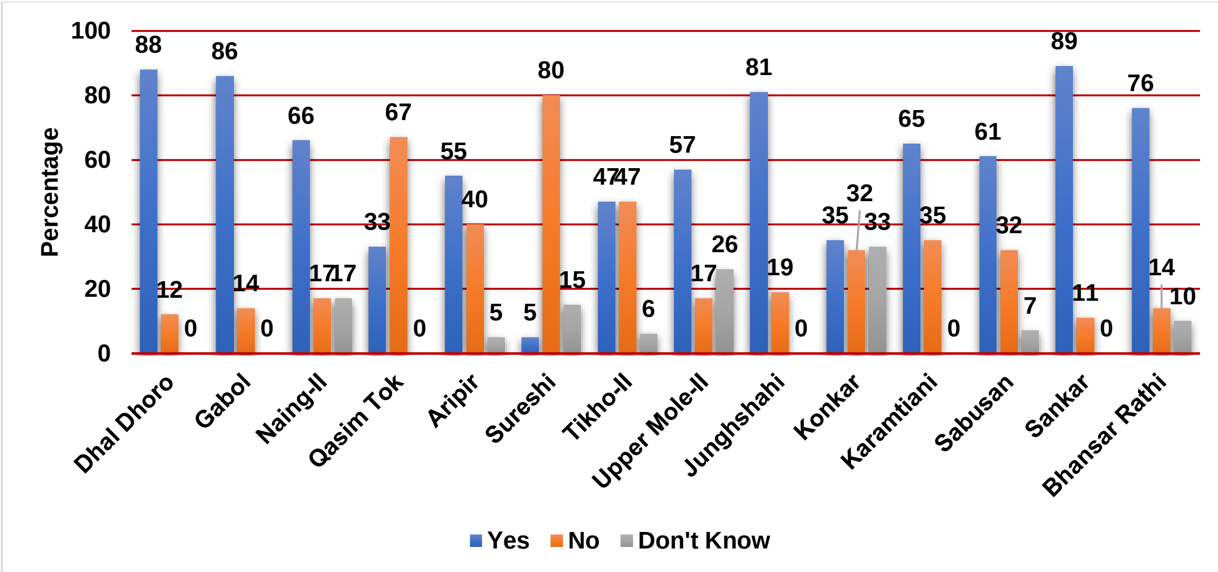


Figure A-7.8 Improvement in Livestock Milk Production

Improvement in Livestock Sell

The respondents were asked "have you experienced any improvement in number of livestock sell?", majority of the respondents of the Dhal Dhoro, Gabol, Naing-II, Qasim Tok, Aripir, Upper Mole-II, Junghshahi, Konkar, Karamtiani, Sabusan, Sankar, and Bhansar Rathi dams reported that there is improvement in sell of the livestock after construction of small dams.

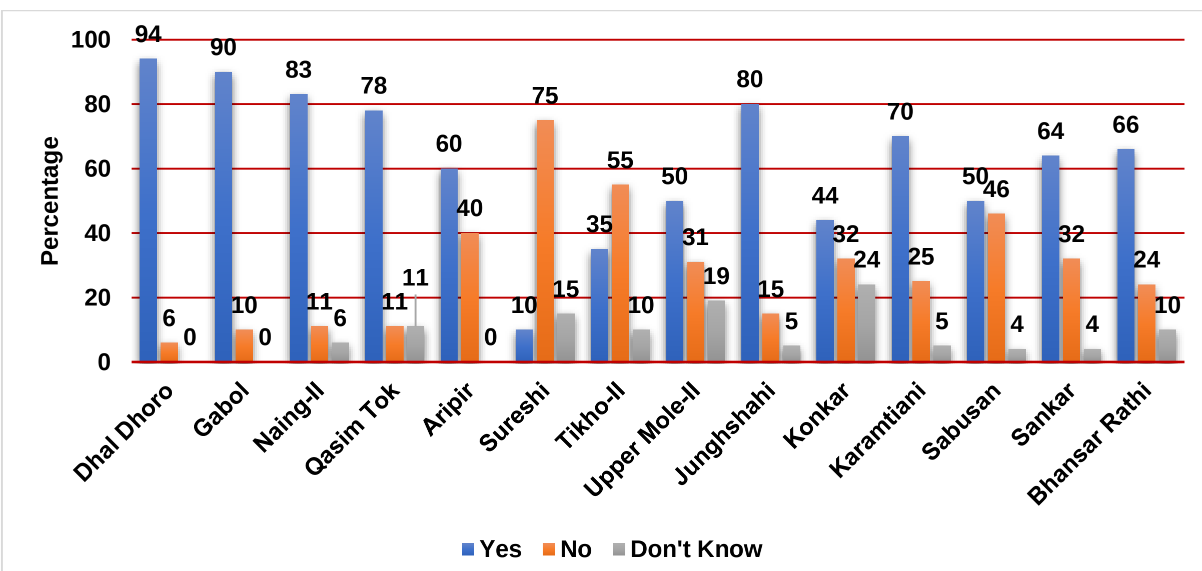


Figure A-7.9 Improvement in Livestock Sell

8 REFERENCES

1. Annandale, G. W., Morris, G. L., & Karki, P. (2016). *Extending the life of reservoirs: sustainable sediment management for dams and run-of-river hydropower*. The World Bank.
2. SRP. (2018b, December). *Environmental and Social Management Plan (ESMP) Dhall Dhoro, Gabol, Naing-II, Nali, Qasim Tok, Sureshi, Tikho-II, Upper Mole II, and Bhansar Rathi Small Dams* (No. 2). Sindh Resilience Project Irrigation Department, Government of Sindh.
3. SDO. (2015a, June). *Feasibility Study of Investigation, Designing and Initiating the Construction Work for Detention Weirs/Check Dams/Small Dams in Dadu and Larkana Districts Feasibility Study Report (Final) Part-I* (No. 1). Small Dams Organization Sindh Irrigation Department, Government of Sindh.
4. SDO. (2015b, June). *Feasibility Study of Investigation, Designing and Initiating the Construction Work for Detention Weirs/Check Dams/Small Dams in Dadu and Larkana Districts Feasibility Study Report (Final) Part-II* (No. 2). Small Dams Organization Sindh Irrigation Department, Government of Sindh.
5. SDO. (2020, April). *PERFORMANCE EVALUATION OF SMALL DAMS IN THE SINDH PROVINCE FINAL REPORT* (No. 1). Small Dams Organization Sindh Irrigation Department, Government of Sindh.
6. SRP. (2018a, August). *Environmental and social management plan (ESMP) of Sabusan, Sankar, Karmatiani, Konkar, Jhungshahi and Aripir small dams*. Sindh Resilience Project Irrigation Department, Government of Sindh.
7. SDO. (2010, July). *Comprehensive Feasibility Study for Design and Construction of Small Dams & Detention Weirs for Leftover Potential Sites in Nagarparkar Area Including Construction of Irrigation Bund along Chhrasar Nai* (No. 1). SMALL DAMS ORGANISATION, IRRIGATION AND POWER DEPARTMENT, GOVERNMENT OF SINDH.
8. United States Department of Interior, Bureau of Reclamation, "Design of Small Dams". Third Edition, 1987.

Community Voices

"...dams have not only increased water availability but also water quality, which is helpful in growing healthy livestock, as a resuly we are getting more milk and better prices as well".

"...earlier we used to move our animals in Sindh (canal command areas) during dry season, but during last year limited number of people moved their animals in Sindh".

"...before dam we used to sell our animals during dry season on low price and could not keep them for the right time to sell, now we are in position to keep more number of animals for longer period in a year and moreover our bargaining position for selling animals has also improved"

"...before construction of dam there was no water available in last months of the year (March to June), but after the dam water table has increased and water is available throughout the year"

"...if dam is filled only for few months even then it leaves great impact on groundwater quality, earlier it used to be brackish but now it is sweat and we feel that because of good quality of water, the instance of diseases has reduced during the year".

"...earlier (before dam) we used to fetch water from common well of the village but now we have borehole at our home and we use that water for domestic, drinking and livestock and now I find some time to relax"