# Evaluating the Impact of Mini Dams on Agricultural Production and Socio-economic Conditions: A Case Study of Latamber's Dam District Karak (Pakistan)

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**Abstract**

*Water scarcity is an escalating global concern, and Pakistan is no exception, facing increasing water crises and growing demand. Effective water supply is crucial for the development of any area. Mini dams not only provide water for irrigation but also support domestic uses. This study evaluates the impact of mini dams on agricultural productivity in Latamber village, focusing on crop yield, land use and land cover (LULC) changes, and socio-economic conditions. A multifaceted methodology, including field surveys, departmental data collection, questionnaires, and remote sensing, was employed. Data collected through questionnaires and farmer interviews highlighted the economic and environmental benefits of mini dams. Statistical analysis and image processing revealed significant expansions in cultivation areas for crops like maize and rice, alongside increases in wheat yield and the adoption of new vegetable crops during the Rabi season. Additionally, socioeconomic benefits, such as enhanced agricultural incomes and employment opportunities, were observed due to improved water availability and irrigation technologies. The study emphasizes the importance of evaluating the impact of mini dams on agricultural production and socio-economic conditions to inform sustainable water resource management strategies, which are vital for the long-term development of similar regions.*

**Keywords:** Mini Dam, Agricultural Productivity, Socio-economic, Land Use Land Cover.

## Introduction

Freshwater is indispensable for the biosphere and the socioeconomic development of a country (Kumar & Jhariya, 2017). However, a significant increase in the demand for freshwater for domestic, industrial, and agricultural purposes exhausted the freshwater reservoirs. The quantum of rainfall and surface water availability is almost in balance, thus resulting in over-exploitation of groundwater reservoirs causing declination of the water table and deterioration of water quality (Kumar & Jhariya, 2017). Increase in production of major crops can be achieved through intensive and extensive practices. Intensive agriculture is the use of high yielding seed varieties and recommended fertilizers doses of fertilizers and chemicals for increasing crops yield. Extensive

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agriculture means expansion in cultivated area under major crops, and this can be achieved through provision of irrigation facility in rain-fed areas. Construction of small, medium and large dams and water canals for irrigation can help in utilizing uncultivated land for crops production (Khan & Shah, 2012; Khan et al., 2011; Majeed et al., 2010; Sarwar & Bastiaanssen, 2001).

Pakistan has an arid or sub-arid climate having an average rainfall of 240 millimeters (mm), mainly during the monsoon season (July-September) (Briscoe et al., 2006; Farooq et al., 2007). Water is an important mineral that occurs in nature and its regulation requires additional observation in the rain-fed region (Ali et al,. 2011).

The small dams are cheaper and easily manageable for the local community and government as compared with large dams. Pakistan loses most of the water as surface runoff and thus facing acute water shortage (Shahid et al., 2020). Pakistan rank 36$^{th}$ (3$^{rd}$ in the list by International Monetary Fund) in most water stress countries in the world (Kochhar et al., 2015; Shahid & Rahman, 2020). Water demand in Pakistan in the year 2025 is expected to be 274 million acre-feet (MAF), while the water recharge/supply remains dormant at 191 MAP (Kochhar et al., 2015). The province Khyber Pakhtunkhwa (KP) in Pakistan is also suffering from water shortages, and some of the agricultural lands and orchards are being affected due to water scarcity. Due to lack of small and large dams, it cannot store sufficient water during the floods events and monsoon seasons. Therefore, the construction of dams is indispensable in the country and even at province/regional scales

Pakistan's economy depends on agriculture, which contributes 24% of gross domestic product (GDP). Apart from producing food for the population, it provides raw material for agro-based industry. Agriculture, which is the back bone of the Pakistan’s economy, has a declining share in the Gross Domestic Production for the past years. Also, agriculture is a main source of employment, and it feeds the whole rural and urban population of the country, sustains approximately 45% of the nation’s employment (Usman, 2016).

The Southern districts of Khyber Pakhtunkhwa have potential for extensive crops production; however, due to unavailability of irrigation water, agricultural productivity is low and most of the area is barren. The rainfall in these regions is highly erratic in both space and time, Due to the uncertainty of rainfall, farmers in these areas typically minimize inputs to reduce the risk of loss in the event of drought, primarily depending on off-farm incomes for sustenance.

The purpose of this study is to evaluate the impact of mini dams on agricultural productivity and sustainability by analyzing crop yield, assessing changes in cropping patterns, and examining alterations in agricultural practices due to the availability of water from mini dams. Additionally, the study aims to understand the economic benefits to local communities, assess the environmental sustainability of mini dams, and explore their broader social impacts. This comprehensive evaluation will provide valuable insights for policymakers, farmers, and stakeholders involved in water resource management and agricultural development.

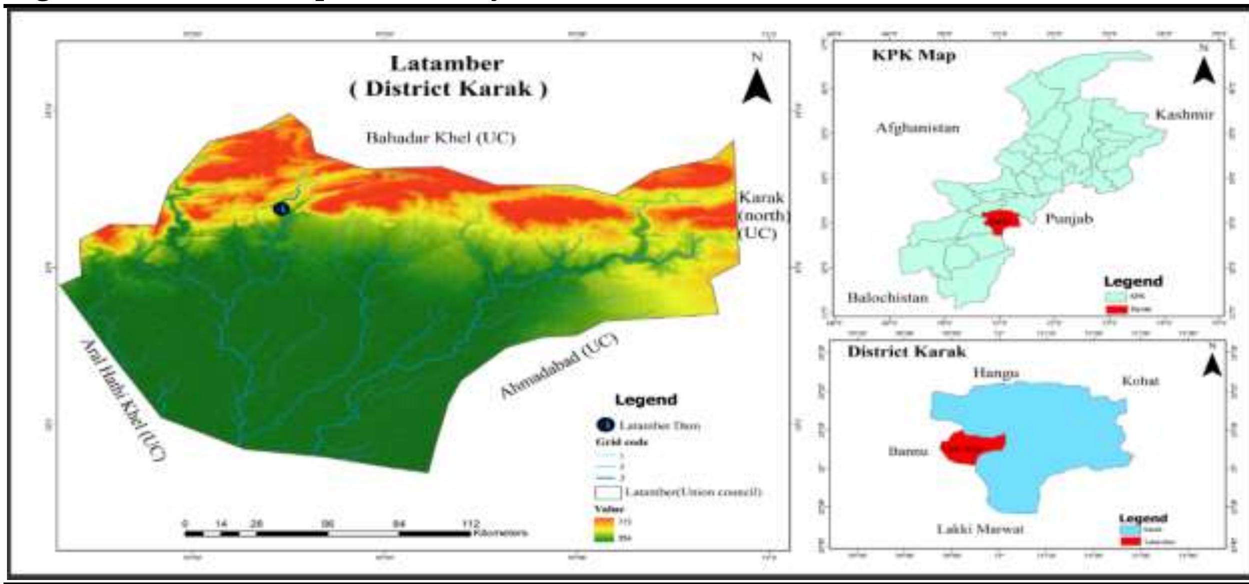
## The Study Area (Latamber Village)

The study area Latamber, is located in the Karak district of Khyber Pakhtunkhwa, Pakistan, Latamber is a union council town that is home to the Barak sub-tribe of Khattaks and other communities.

The study area agricultural landscape, shaped by the presence of mini dams, presents a microcosm for examining the broader implications of water resource management on agricultural land. However, there is a lack of comprehensive studies evaluating the specific impacts of these mini dam projects on the local agricultural environment and socio-economic conditions of Latamber.

Latamber Boundary is latitudinal extent from 33° 3′ 11.57″ to 33° 8′ 7.34″ North of equator and longitudinal extent from 70° 50′ 48.98″ to 70° 56′ 7.17″ East of Prime Meridian. Relatively the study area lie to the East UC Karak, to it's West is Aral Hathi Khel UC . To the North is Bahadar Khel UC and to its South is Ahmadabad UC.

**Figure 1: Location Map of the Study Area**




According to the 2023 Census, the population of the study area were 100,000. This population is primarily engaged in agricultural activities, which underscores the importance of effective water management systems like mini dams the study area Latamber's have an overall geographic area of 306 $km^2$, with a population density of 314 people per square kilometer.

Latamber's terrain is a mix of arid and semi-arid landscapes, characteristic of much of Khyber Pakhtunkhwa. The region's topography includes rolling hills and flat plains, which significantly influence it's agricultural potential and water management strategies.

## Materials and Methods

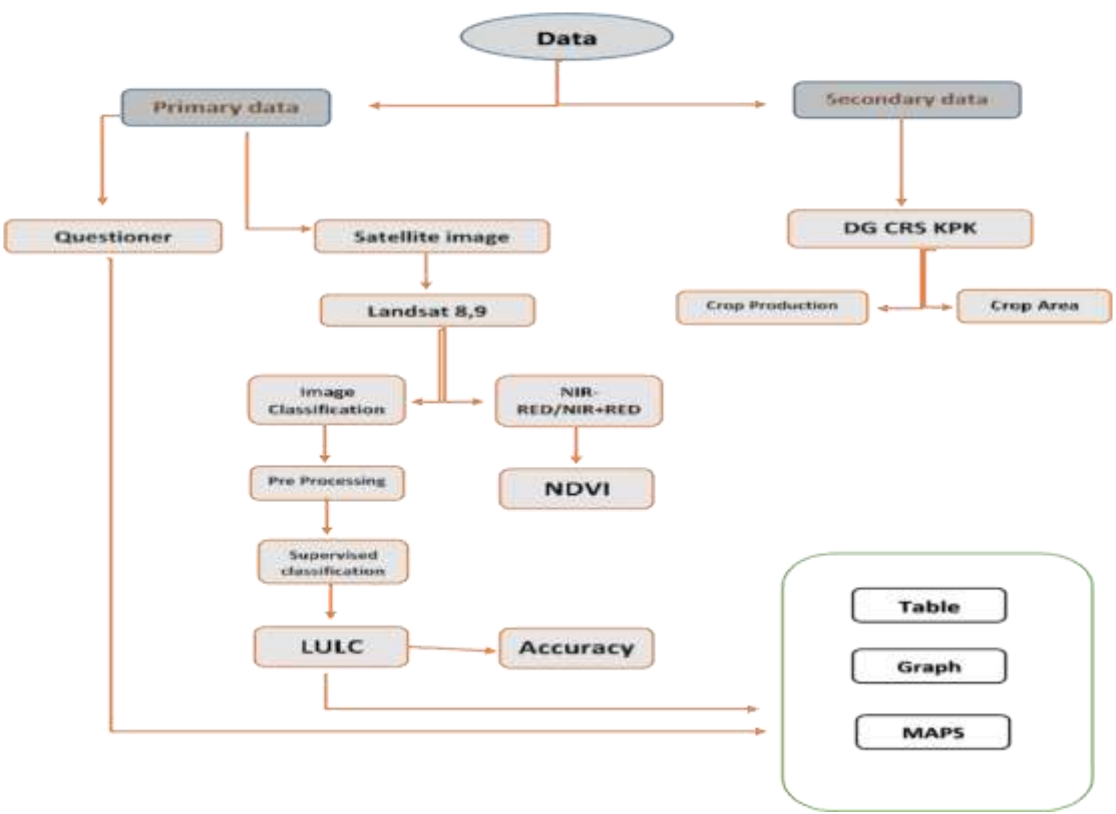
The study employs a mix of field surveys, departmental data collection, questionnaires, and case studies to gather comprehensive and reliable data.

### Field Visits and Surveys

Field visits were conducted to collect preliminary data on the catchment area, dam specifications, and agricultural practices, living trends of residents, crop patterns, climate conditions, and recreational activities. Discussions with local people provided insights into the impacts on Latamber's dam and community life. Included observing the study area's physical and environmental features and holding informal discussions with local farmers and residents to understand the practical impacts of mini dams. Data related to crop Production, outflow, reservoir levels, and discharge in irrigation canals were obtained from Director General Agriculture Crop Reporting Service KPK. The local dam office provided data on water management and dam operations, while the rainfall and climate data were obtained from the Pakistan Meteorological Department. Additionally.

A close-ended questionnaire was developed to capture the public behavior and trends related to the impacts of mini dams. The questionnaire included questions on land acquisition, crop and fruit yields, agricultural earnings, irrigation methods, water charges, and water table depth. Each question was rated on a scale from -4 (highly negative impact) to 4 (highly positive impact).
The questionnaire survey was conducted from 60 farmers and stakeholders from various categories. Random sampling was used to select farmers and stakeholders Data collected included household size, agricultural land holdings, types of cultivated crops and fruits, and monthly income from agriculture. Interviews were also conducted to gather qualitative data and validate the questionnaire responses.
To find out the land use land cover of the study area the Landsat image 8 and 9 were downloaded from USGS for the year 2014 and 2024. These images were classified in to different land use land cover classes. Each year's satellite image is classified using this supervised classification technique according to the following scheme: Vegetation encompasses all green areas, including cultivable land, while urban areas comprise buildings and permanent structures. Barren areas include fallow lands and uncultivable areas.
The final step involves calculating the area under each land use class. Quantified data for all land cover changes from 2014 to 2024 is compiled and tabulated. This allows for the generation of land use land cover maps for Study area, facilitating the comparison of changes in land cover and the increase of crop land after the latamber's dam over barren land. Similarly to find out the overall greenery in the study area the NDVI technique was used for the study time period and change map of NDVI was created.

**Figure 2: Research Flow Chart**



## Results and Discussion

Questionnaire Survey Results: The questionnaire aimed to understand the impact of the mini dam project on agricultural land, focusing on water availability, crop productivity, and socio-economic conditions. The survey gathered responses from farmers regarding changes in irrigation practices, crop yields, and the socio-economic benefits experienced after the dam's construction.

### Socioeconomic and Demographic Information

The demographic data revealed that the average age of the farmers was 49.48 years, with a significant portion (70%) falling between the ages of 30 and 60 years. The education levels were notably low, with 62% of respondents being illiterate.

**Table 1: Show the Demographic Characteristics of Respondents**

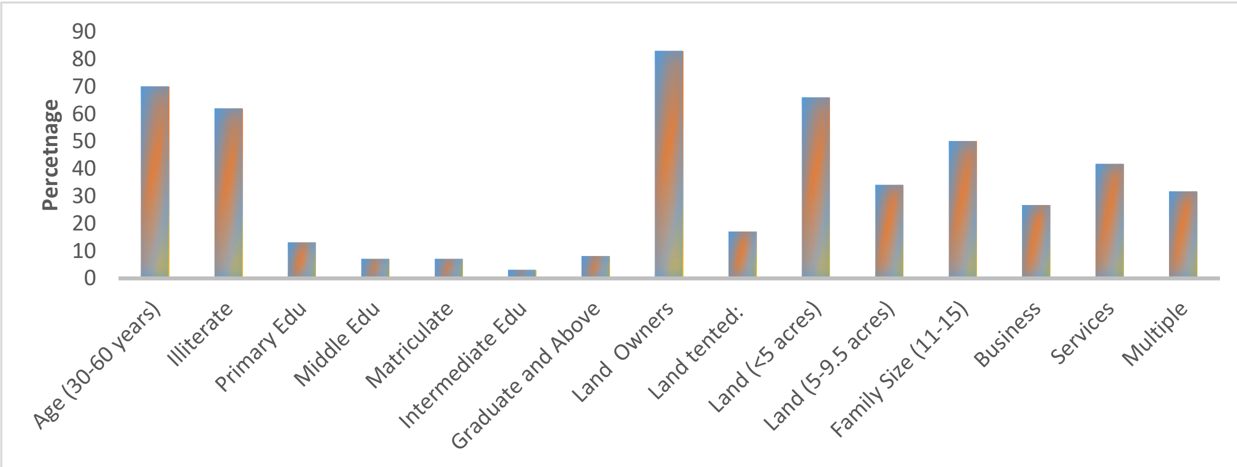
| Characteristic | (%)age |
|---|---|
| Landholdings < 5 acres | 66 |
| Landholdings > than 5 acres | 34 |
| Family Size (11-15 members) | 50 |
| Farming as Primary Occupation | 100 |
| Additional Occupation - Business | 26.66 |
| Additional Occupation - Services | 41.66 |
| Additional Occupation - Multiple Employment | 31.66 |

Of the literate respondents, the distribution of education levels 13% is Primary level, Middle level and Matriculate are 7% while Intermediate are 3% and 8% are Graduate level and above. The average family size was 13 members, with half of the respondents having a family size between 11 to 15 members. Farming was the primary occupation for all respondents, supplemented by other activities such as small business (26.66%), labor (41.66%), and others categories (31.66%).

**Table 2: Show the Socioeconomic Characteristics of Respondents**

| Characteristic | (%)age |
|---|---|
| Age (30-60 years) | 70 |
| Illiterate | 62 |
| Education Level: Primary | 13 |
| Education Level: Middle | 7 |
| Education Level: Matriculate | 7 |
| Education Level: Intermediate | 3 |
| Education Level: Graduate Above | 8 |

**Figure 3: Show the Demographic and Socioeconomic characteristics**



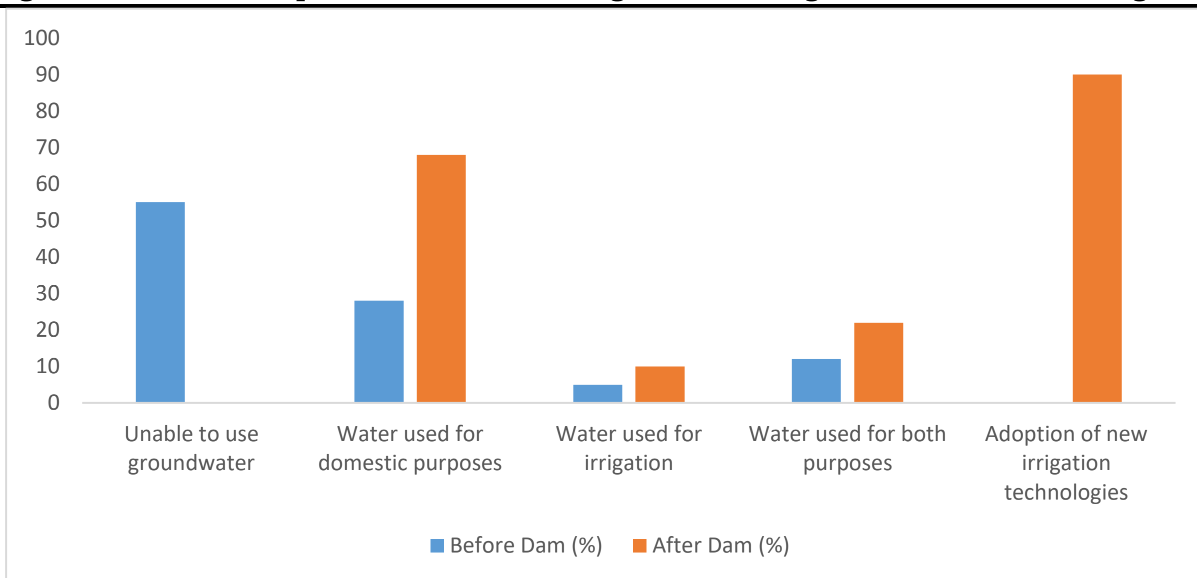

**Impact of Mini Dam on Agriculture Irrigation and Water Management**

The construction of the mini dam significantly impacted water availability and irrigation practices. Before the dam, the majority (55%) of respondents could not use groundwater for any purpose. After the dam, 68% of respondents reported using water for domestic purposes, 10% for irrigation, and 22% for both purposes. The introduction of new irrigation technologies, such as drip irrigation and sprinklers, was adopted by 90% of respondents.

**Table 3: Show the Impact of Mini Dam on Agriculture Irrigation and Water Management**

| Irrigation and Water Management | Before Dam (%) | After Dam (%) |
|---|---|---|
| Unable to use groundwater | 55 | 0 |
| Water used for domestic purposes | 28 | 68 |
| Water used for irrigation | 5 | 10 |
| Water used for both purposes | 12 | 22 |
| Adoption of new irrigation technologies | 0 | 90 |

**Figure 4: Show the Impact of Mini Dam on Agriculture Irrigation and Water Management**



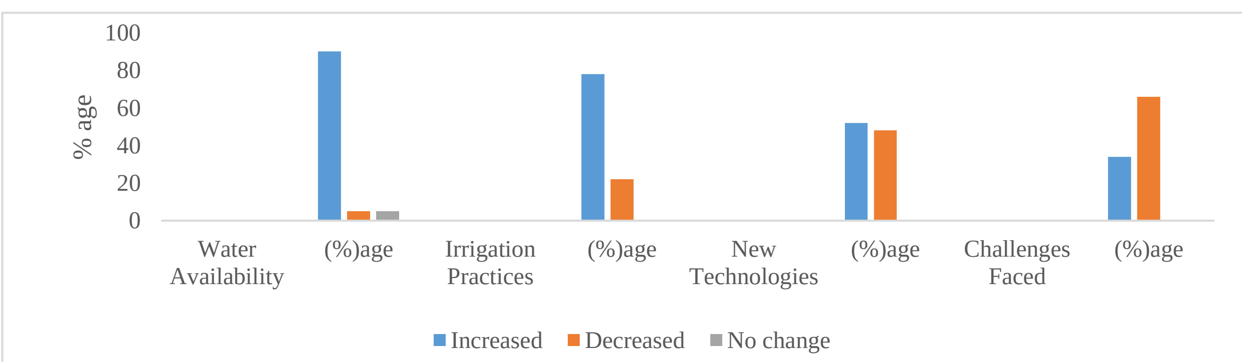

## Water Availability and Irrigation Practices

The construction of the mini dam significantly impacted water availability and irrigation practices. According to the survey, 90% of the farmers now use the dam water for irrigation, with a substantial increase in water availability. Additionally, 68% reported improved water quality.

**Table 4: Show the Water Availability and Irrigation Practices**

| Water Availability | (%)age | Irrigation Practices | (%)age | New Irrigation Technologies | (%)age | Challenges Faced | (%)age |
|---|---|---|---|---|---|---|---|
| Increased | 90 | Yes | 78 | Yes | 52 | Yes | 34 |
| Decreased | 5 | No | 22 | No | 48 | No | 66 |
| No Change | 5 | nil | - | -- | -- | -- | - |

**Figure 5: Show the Water Availability and Irrigation Practices**




## Impact on Crop Productivity and Land Use

The mini dam project has led to significant improvements in crop productivity and land use patterns among the respondents. A notable 90% reported an increase in crop yields, with 70% observing a yield increase between 20-60%. The majority (85%) attributed this improvement directly to the mini dam. Additionally, 60% of the farmers have started cultivating new crops, and 55% have observed changes in land use patterns. In terms of soil quality, 50% reported improved fertility, while 30% noted increased salinization. The construction of the dam increased crop yields, Wheat yield increased from 451.67 kg/acre to 997.22 kg/acre. There was a decrease in the cropping area for wheat and maize but an introduction of vegetables in the Rabi season. Additionally, the average farm size in the Rabi season increased from 23 to 34 acres, while the Kharif season farm size remained the same.

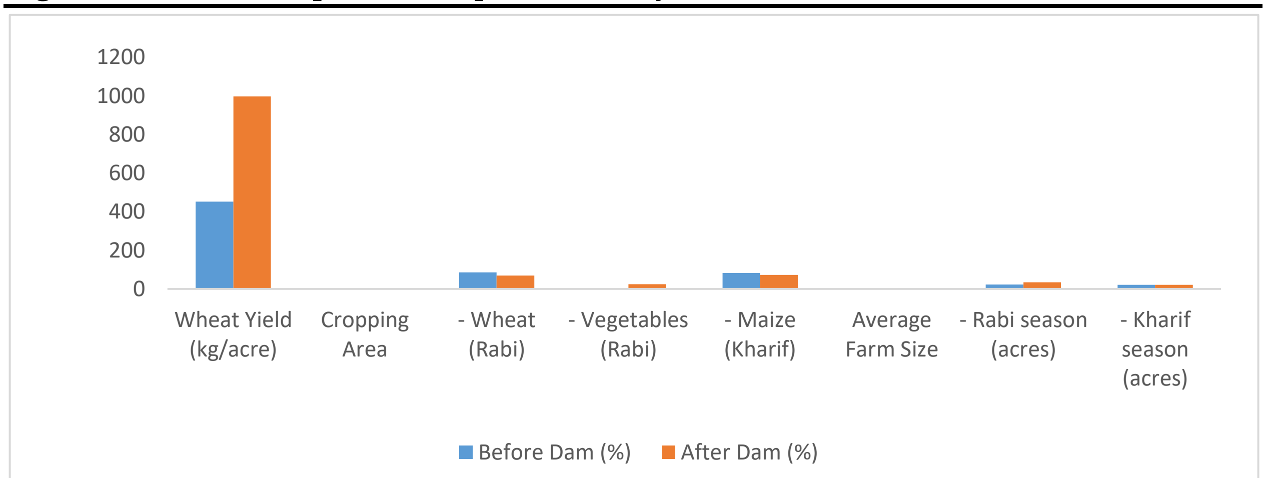
**Table 5: Impact on Crop Productivity and Land Use**

| Category | Response | Percentage (%) |
|---|---|---|
| Change in Crop Yields | Increased | 90% |
| Percentage Increase in Crop Yields | 20-60% | 70% |
| Attribution to Mini Dam | Yes | 85% |
| Changes in Crop Types | New Crops Cultivated | 60% |
| Changes in Land Use Patterns | Yes | 55% |
| Changes in Soil Quality | Improved Fertility | 50% |
| | Increased Salinization | 30% |

**Table 6: Impact on Crop Productivity and Land Use**

| Crop/Productivity Indicator | Before Dam (%) | After Dam (%) |
|---|---|---|
| Wheat Yield (kg/acre) | 451.67 | 997.22 |
| Cropping Area | | |
| - Wheat (Rabi) | 86 | 69 |
| - Vegetables (Rabi) | 0 | 25 |
| - Maize (Kharif) | 82 | 72 |
| Average Farm Size | | |
| - Rabi season (acres) | 23 | 34 |
| - Kharif season (acres) | 22 | 22 |

**Figure 6: Show the Impact on Crop Productivity and Landuse**



**LULC Analysis 2014 and 2024**

The change detection analysis from Landsat satellite Image for the year 2014 and 2024 reveals notable Changes in the LULC of the study area. The built-up area increased significantly by 8.9 sq km (4.13%) from 2014 to 2024. Agricultural land also saw a major increase, which is 14.33 sq km (6.66%), reflecting intensified farming activities. Range land showed a slight increase of 1.68 hectares (0.78%), maintaining its dominance in the landscape. Conversely, wetlands decreased by 5.06 sqkm (2.35%), and barren land saw a dramatic reduction of 19.85 sqkm (9.23%), highlighting a shift towards more productive land use. These changes point to a trend of increasing urbanization and agricultural intensification, along with improved land management practices reducing non-productive land.

**Figure 7: LULC 2014**

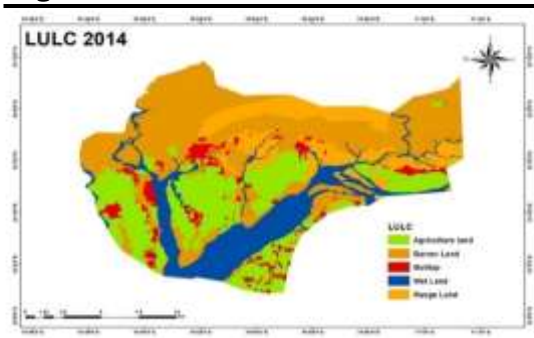



**Figure-8: LULC 2024**

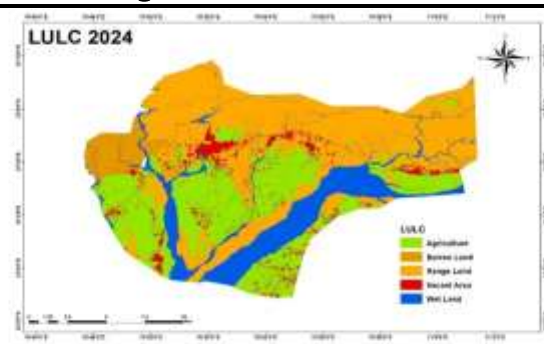
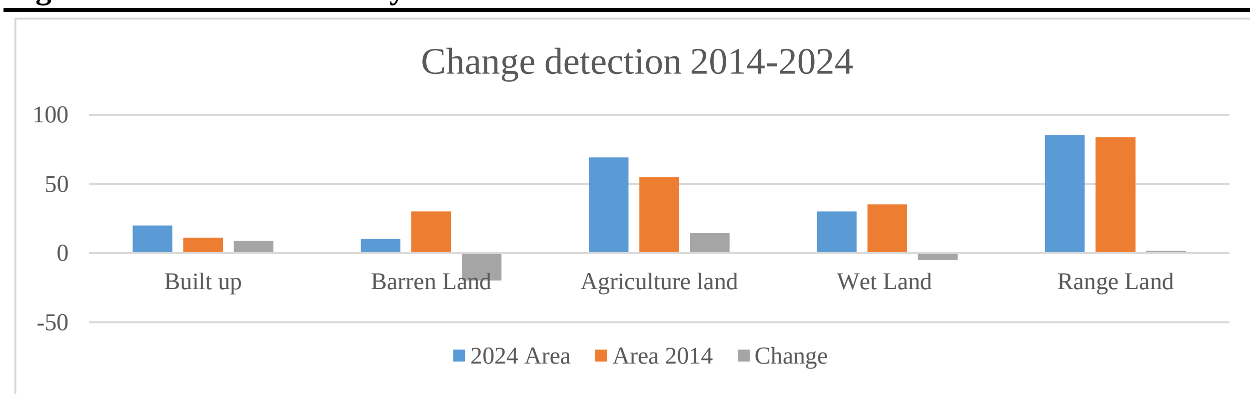



**Table 7: Change Detection 2014-2024**

| LULC Comparison 2014-2024 | | | | | |
|---|---|---|---|---|---|
| Land Use | **2024 Area** | **%age** | **Area 2014** | **%age** | **Change** |
| Built up | 20.03 | 9.31 | 11.13 | 5.18 | 8.9 |
| Barren Land | 10.33 | 4.80 | 30.18 | 14.03 | -19.85 |
| Agriculture land | 69.26 | 32.20 | 54.93 | 25.54 | 14.33 |
| Wet Land | 30.07 | 13.98 | 35.13 | 16.33 | -5.06 |
| Range Land | 85.38 | 39.70 | 83.7 | 38.92 | 1.68 |
| Total Area | **215.07** | **100** | **215.07** | **100** | |

**Figure 9: LULC of the study area 2014 and 2024**



**NDVI Analysis for 2014 and 2024**

The analysis of Normalized Difference Vegetation Index (NDVI) provides valuable insights into the changes in vegetation health and land use over a decade, from 2014 to 2024. The NDVI values for the year 2014 ranged from a low of -0.138124 to a high of 0.3986, while the values for 2024 ranged from -0.194901 to 0.385292. The change in NDVI values from 2014 to 2024, calculated as the difference between the two years, ranged from -0.228 to 0.362. This change was classified into five categories: significant increase, moderate increase, no change, moderate decrease, and significant decrease.

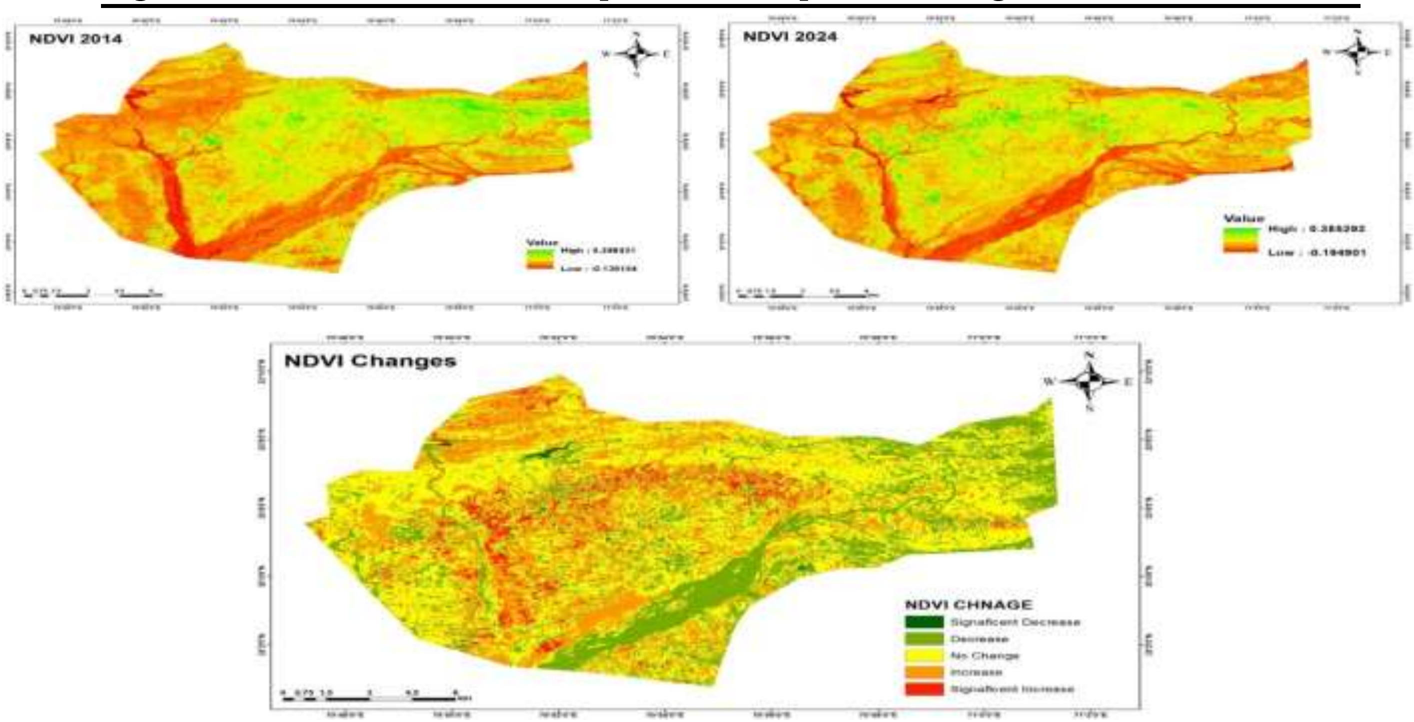
The classification revealed the following distribution of changes in NDVI values:

**Table 8: NDVI Change Classification from 2014 to 2024**

| NDVI Change Category | NDVI Change Range | Percentage of Area (%) |
|---|---|---|
| Significant Increase | 0.18 to 0.36 | 22 |
| Moderate Increase | 0.01 to 0.18 | 18 |
| No Change | -0.01 to 0.01 | 30 |
| Moderate Decrease | -0.11 to -0.01 | 20 |
| Significant Decrease | < -0.22 to -0.11 | 10 |

The data indicate that 22% of the area experienced a significant increase in NDVI, suggesting improved vegetation health and possibly increased agricultural productivity. A moderate increase in NDVI was observed in 18% of the area, while 30% of the area showed no significant change in vegetation cover. On the downside, 20% of the area experienced a moderate decrease in NDVI, and 10% of the area saw a significant decrease, indicating potential vegetation degradation or changes in land use patterns.

**Figure 10: Show the NDVI 2014 map and 2024 maps and it changes**



## Conclusion

The implementation of the mini dam project has resulted in notable changes in the cultivation areas of various crops like maize and rice. This trend was observed across multiple crops, indicating a general increase in agricultural activity and productivity. The data indicate a significant increase in wheat yield, from 451.67 kg/acre before the dam to 997.22 kg/acre after the dam. Additionally, the cropping area for vegetables (Rabi) increased from 0% before the dam to 25% after the dam, highlighting a diversification in crop cultivation. Average farm sizes also saw a notable change, with the Rabi season average increasing from 23 acres to 34 acres. A considerable majority of respondents reported an increase in their agricultural income, with 85% attributing this rise directly to the mini dam project.

The mini dam project in Latamber village has had a transformative impact on agricultural practices, productivity, and socioeconomic conditions. The increased availability and reliability of water have enabled farmers to diversify their crops, adopt new technologies, and significantly boost their yields. The project has also contributed to improved soil quality and better water management practices, further enhancing the sustainability of agricultural activities in the region.

In conclusion, the mini dam project has demonstrated the potential for infrastructural improvements to drive significant positive changes in rural agricultural communities. Continued monitoring, support, and adaptive management will be crucial in maintaining and building on these gains, ensuring that the benefits of the project are sustained and enhanced over the long term.

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