

EFFECTIVENESS OF HAPA AS SMALL RAINWATER HARVESTING PONDS FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT IN DIVERSIFIED ARID REGIONS: COMPARATIVE CASE STUDIES FROM BANKURA IN INDIA

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Abstract

Water is a unique constituent, which is essential for the survival of humans, animals and plants. Agriculture needs water in large quantities. Supplying irrigation water is a crucial factor in preserving groundwater, determining the water balance and subsequent cropping pattern of any region. The challenge is even greater when it is dryland. The present study is confined to the Bankura district, the arid region of West Bengal in India. Here, for irrigation, small customised ponds, known as hapa, are dug up by individual farmers to store the rainwater. The government encourages farmers by providing funds for hapa creation. In the last 10 years, about 2900 hapas, which can harvest a large quantity of water, have been dug up in croplands. This harvested water indirectly helps in recharging groundwater too. The present study aims to highlight the need for hapas in such arid regions. This study demonstrates a positive link between hapa creation with changing land use land cover patterns, increasing agricultural areas, growing population, and declining rainfall patterns. In support of this, spatial and statistical analyses were performed according to certain key remote sensing indices VCI, NDWI, and Z Scores of the pre-hapa and post-hapa creation periods. The study found that the implementation of the hapa irrigation technique has significantly increased the yield of crops besides generating agricultural labour. Land owners started cultivating multiple crops on their lands which helped to increase annual income. The complete research shows the noteworthiness of hapa irrigation technique as an alternative to a sustainable development programme in arid areas.

Keywords: Arid Region, Water Scarcity, Rainwater Harvesting, Hapa, Remote Sensing; Z-score, Sustainability.

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Introduction

Rainwater harvesting is a water conservation method by collecting and storing it at the surface or in the subsurface aquifer before it is lost as surface runoff. As land pressure rises, cities are growing vertically, and in the countryside, forests are being encroached on for agricultural purposes (Boers & Ben-Asher, 1982). The term rainwater harvesting was coined by Geddes of the University of Sydney. He defined rainwater harvesting as the collection and storage of any form of water, either runoff or creek flow, for irrigation purpose (Myers, 1975). India has 4 per cent of the world's freshwater and 80 per cent of it is used in the agriculture sector (Dhawan, 2017). Indian agricultural system is largely dependent on groundwater and to protect the limited groundwater resources, there is an urgent need to start using rainwater as an alternative (Minhas & Reddy, 2017; Gupta et al., 2020). To balance groundwater and surface water availability in arid and semi-arid areas, the construction of small rainwater harvesting ponds is very important (Oweis & Hachum, 2006; Liebe et al., 2005; Machiwal et al., 2017). In India, most farmers depend on monsoonal rainfall (July to September) for irrigation, and every year about 90 districts become drought-affected (CPCB, 2016). So, in India, during the post-monsoonal season, rainwater harvesting is an alternative cost-effective option to store water for irrigational usage. From ancient times, India has a long tradition of rainwater harvesting in rural areas, especially in arid and semi-arid regions such as Kutch and Saurashtra in Gujarat and Western Rajasthan (Machiwal et al., 2017). In these regions, water harvesting is not only a technique but a part of their culture (Bhattacharya, 2015).

In the arid regions of India, the number of small rainwater harvesting ponds has shown an annual growth rate of 60 per cent with 1,20,000 small ponds conveying 4.12 Mha of irrigation water (Downing et al., 2006). In India, it was approximated that in totality, such small ponds contribute irrigation water to 20 per cent of cultivable lands (Li & Gowing, 2005). However, small ponds, with little care and lack of

management, in particular, can be overlooked in hydrological research (Mustapha, 2009; Fowe et al., 2015) mainly due to a lack of sufficient information to understand their hydrological processes (Adwubi et al., 2009; Liebe et al., 2009).

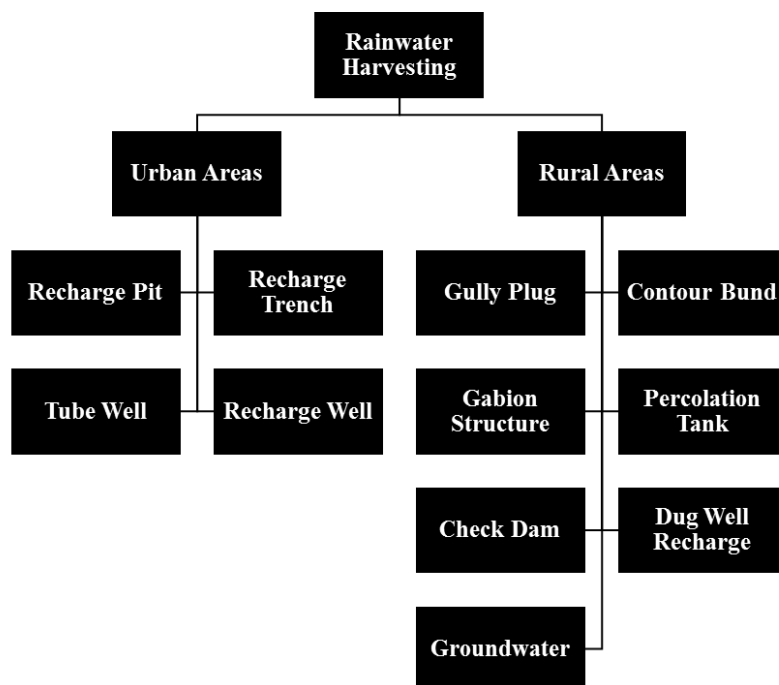
In West Bengal, Bankura district receives lower annual rainfall than other districts as per the record of India Meteorological Department (IMD). It is necessary to imply rainwater collecting structures to store monsoonal rainfall for post-monsoonal irrigation, especially in arid areas. Hapa is a rainwater collecting arrangement introduced in Hirbandh block of Bankura district, which is financed by the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS).

Rainwater harvesting is essential for overcoming surface water shortages to meet demands, arresting groundwater depletion, augmenting the availability of groundwater, utilising rainwater for sustainable development, increasing rainwater infiltration through the subsoil that is drastically minimal in the urban areas for making pavements in the open spaces, and lastly, increasing agricultural production. Several methods of rainwater harvesting are narrated in Figure 1 and different rainwater harvesting structures traditionally adopted in India are given in Table 1 (Khullar, 2018).

Literature Review

Hapa: Few research works have been done on hapa construction processes. Banerjee (2012) attempted to find out the impact of hapa construction in Hirbandh block using qualitative and quantitative methods. The questionnaire survey among 64 people (32 hapa owners and 32 non-hapa owners) revealed an increase in agricultural productivity in the block.

Mandal and Gupta (2012) examined the relevance of the hapa system in agricultural water utilisation by interviewing 25 beneficiaries. They concluded that hapa could make positive changes in Bankura district and people would benefit from it in the near future.

Figure 1*Recent Methods of Rainwater Harvesting***Table 1***Different Rainwater Harvesting Structures in India*

State/UT	Type of rainwater harvesting structure
Jammu and Kashmir	Zing
Uttarakhand	Kuhls
Rajasthan	Khadin, Kund, Jhalna, Talab, Bawari, Tanka, Nadi
Gujarat	Kund
Maharashtra	Ramtek, Bhandara, Phad
Madhya Pradesh	Pat
Bihar	Ahar pynes
West Bengal	Hapa
Nagaland	Zabo
Assam	Zabo
Meghalaya	Bamboo
Odisha	Johads
Karnataka	Johads
Kerala	Panam Keni
Tamil Nadu	Eri

Jana (2011) tried to assess the ecological and social impact of hapa on Bankura district. The study explored the socio-economic conditions of hapa owners and found that it created positive effects on the lifestyles of the farmers and increased agricultural productivity. Guha (2018) tried to estimate the maximum benefits from the hapas by conducting a study in Damodarpur, Biradi, and Bamni villages of Hirbandh block. The results show that hapas have been a benefit to farmers - they transformed single cropland into multiple croplands and created new livelihoods.

Chatterjee (2018) tried to find out the impacts of hapa on rural development in Hirbandh block through a questionnaire survey among 100 beneficiaries. The study found the hapa system to be very effective besides improving the socio-economic conditions of the people. Pani and Mishra (2021) did a cost-benefit study to determine the prospective for future investment in applying hapas. The study shows the signs of advantages in relation to the recharge of groundwater, apart from increasing agricultural productivity in Bankura district. The farmers were cultivating both Kharif (summer) and Rabi (winter) crops. Narain, in an article on hapas published in March 2021, states that hapa construction is not limited to Hirbandh and Khatra blocks as other blocks of Bankura district are also putting emphasis on hapa creation.

Waterbody Identification Techniques:

Normalised Difference Water Index (NDWI) is a popular remote sensing index used for water body identification worldwide. Sarp and Ozelik (2017) applied the supervised image classification method and NDWI to identify water bodies in the Lake Burdur area using Landsat TM images. The study found that the classification method and NDWI have produced minute differences, which means both methods produced good accuracy. Rawat and Kumar (2015) identified land use and land cover (LULC) changes in Almora district from 1990 to 2010. For this purpose, NDWI was used to identify water bodies. Saha and Pal (2019) applied the NDWI index to identify water presence in the Atreyee River basin in India and Bangladesh. The NDWI was applied to compare water presence

before and after the construction of the dam. The authors found that NDWI was the most suitable index for this analysis. Chen et al. (2006) examined the relationship between urban heat islands and LULC changes in the Pearl River Delta of Guangdong, China. They used several remote sensing indices for LULC classification. For the identification of water bodies, they opted for NDWI. Rhee and Carbone (2010) monitored agricultural drought in the semi-arid and humid regions of the western Great Plain areas of the United States and used NDWI to identify drought-prone areas. The literature on NDWI revealed the usefulness of the index, and thus it is applied in this study for hapa identification.

This present research is an endeavour to analyse land use and land cover changes of the Khatra and Hirbandh blocks after Hapa creation. Different remote sensing indices have been incorporated to evaluate the changes, and a decade-wise study has been made to analyse the changes. The prime objectives of this research are to discuss the concept of hapa as a rainwater harvesting structure for sustainable agricultural use and highlight the impacts of hapa creation.

Data Collection and Methodology

The study is based on secondary data sets. Retrieval of decade-wise satellite images from 1991 to 2020 was done from the USGS EarthExplorer website. The change in land use and land cover has been analysed using the maximum likelihood classifier method (Strahler, 1980). To compare total irrigated areas before and after the creation of hapa, census data was collected from the Census of India website for the years 2001 and 2011.

The study examined the impact of hapa creation on the Hirbandh and Khatra blocks. The following geospatial and remote sensing techniques have been judiciously used.

- Downloaded Landsat TM 5 images of Hirbandh and Khatra blocks for the years 1991 to 2020 from the USGS EarthExplorer website.

- Done preprocessing in ERDAS Imagine software by clearing the haze of the images. Then subset the area of interest (Hirbandh and Khatra blocks) from the images.
- Downloaded SRTM DEM image of Bankura district from USGS EarthExplorer to perform elevation and slope analysis.
- Groundwater piezometric level data of different stations of the Bankura district were obtained from the India - WRIS portal. The IDW interpolation method has been used to analyse pre-monsoon, monsoon, and post-monsoon groundwater level fluctuations.
- The Vegetation Condition Index (VCI) has been used to determine the drought intensity of the study area. The VCI is the percentage of the NDVI. Multiyear maximum and minimum NDVI layers are used to obtain VCI. According to Kogan et al. (2010), the expression of VCI is given in Eq. (1).

$$VCI = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \times 100 \quad (1)$$

where, $NDVI$ = NDVI magnitude of the particular year, $NDVI_{max}$ = Multilayer maximum $NDVI$ magnitude, $NDVI_{min}$ = Multilayer minimum $NDVI$ magnitude.

- Applied supervised image classification using signatures to have a brief picture of the study area. A maximum-likelihood algorithm is used for creating a detailed supervised classification. Thus, six types of LULC (vegetation, water body, barren land, built-up and agricultural land) have been recognised. All types of dense, moderate, and scattered natural vegetation are included under the vegetation class type and roads, settlements, and markets are included under a built-up category (Rawat & Kumar, 2015).
- To analyse water bodies, the Normalized Difference Water Index (NDWI) has been used here. The index makes use of Green and NIR (Near Infrared) bands of images of remote sensing. The NDWI can improve water information proficiently. Water bodies only reflect within the visible portion of the electromagnetic spectrum. Waterbodies have higher reflectance on the blue spectrum (0.4 μm to 0.5 μm) than on the green (0.5 μm to 0.6 μm) and red (0.6 μm to 0.7 μm) spectrums. Clearwater has maximum reflectance in the blue segment among the observable spectrums. So, water logically applies to blue. There is no reflection in NIR and beyond. The index was planned to maximise the water reflectance to identify water bodies with green wavelengths and minimise the lower NIR reflectance through water features (Gao, 1996). The NDWI formula is as follows (Eq. 2):

$$NDWI = \frac{GREEN - NIR}{GREEN + NIR} \quad (2)$$

- To analyse, the village-wise distribution of irrigated area Z-scores have been calculated. The Z-score is a statistical method that describes a value's relationship to the mean of a group of values. The Z-score is measured in terms of standard deviations from the mean. It may be positive or negative. The positive value indicates that the score is above the mean and the negative value indicates below the mean score (Mahmood, 1999).

$$Z \text{ score} = \frac{x - \bar{x}}{\delta} \quad (3)$$

where, x = individual value, $\bar{x}$ = mean, δ = standard deviation (SD)

Rainwater Harvesting in Bankura District

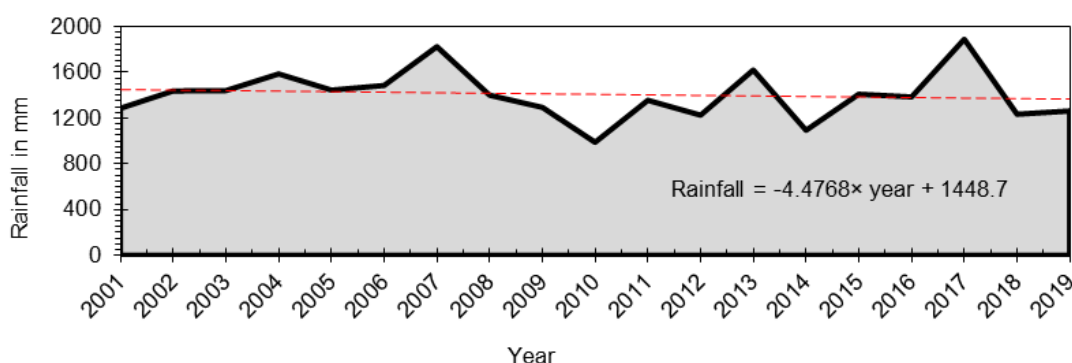
The rainfall data has been retrieved from the website of India Meteorological Department. Bankura district, West Bengal receives around 1100 mm to 1400 mm rainfall (Figure 3) per year, which is insufficient for the district as rainwater is very high due to undulating terrain.

The trendline shown in Figure 3 confirms that the annual rainfall has been declining gradually with a negative slope of -4.4768 for the last 20 years. Moreover, as the soil of the Bankura district

is lateritic, the soil moisture content is pretty low. Thus, most of the farmers rely on rain-fed agriculture. They are only able to cultivate paddy and some vegetables during the Kharif season with the help of water from the monsoon rain. It is very much necessary to store rainwater for agricultural production in both seasons (Kharif, Rabi). Against this background, an experimental rainwater harvesting structure like hapa was introduced around the year 2006 in the Bankura district to store rainwater.

Figure 3

Year-wise Rainfall of Bankura District



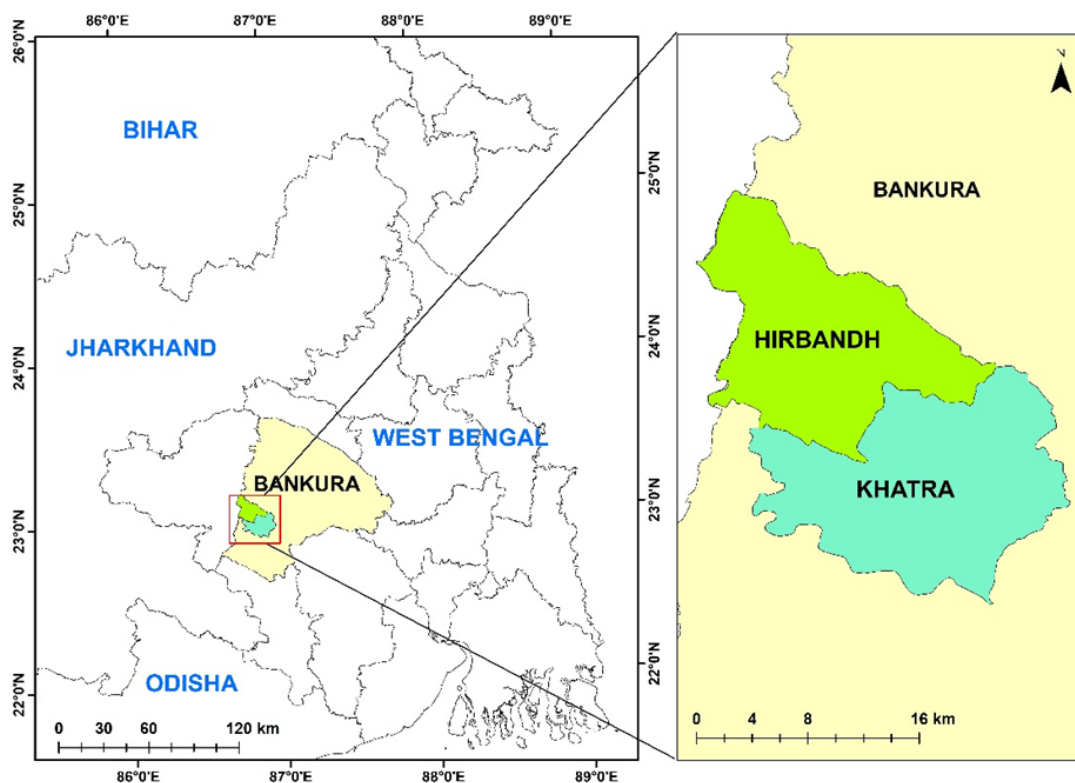
Concept of Hapa

Hapa is basically a pond of small size dug up on any farmland by individual farmers to store rainwater. Farmers individually use 5 per cent of their land for hapa creation. The depth of hapa is normally around 10 ft (3.048 m) but the size and depth are not fixed; it changes according to the farmer's requirement. This hapa creation programme is funded by the Mahatma Gandhi National-Rural Employment Guarantee Scheme (MGNREGS). In Bankura district, the concept of hapa was brought by PRADAN, an NGO, around the year 2006, because lack of water made crop cultivation impossible in the dry season. All wells dried up during the dry season resulting in

migration of the people of this block. To stop migration, PRADAN convinced the Secretary of Panchayat and Rural Development office to use the MGNREGS fund for hapa creation.

Study Area Selection

Two adjacent blocks of the Bankura - Hirbandh (191 sq. km) and Khatra (231.8 sq. km) - have been chosen as case study areas (Figure 4). Both the blocks have lateritic soil with a hot and humid climate according to the Bankura district profile given on the official website of the Government of West Bengal.

Figure 4*Location Maps Showing Hirbandh and Khatra Blocks*

In these agro-economy-based regions, nearly 80 per cent of total workers are directly involved in agricultural activities. Before hapa creation, people used to migrate to other districts and states for

employment; however, the scenario changed later. (Pani & Mishra, 2021). Figure 5 shows a hapa under construction and another one stored with rainwater.

Figure 5*Photographs Showing Hapas under Construction and after Construction*

Source: MGNREGS

Aims behind Construction of Hapa

Bankura district is a transitional zone of undulating Chotonagpur plateau in the west and alluvial plain in the east. The average elevation of the district is 230 metres. The general slope of the district is from west to east. Hirbandh and Khatra blocks are situated in the western part of the district which is an eroded part of the Chotonagpur plateau. Thus, both the blocks are situated in undulating terrain with moderate slopes resulting in more surface runoff. Therefore, hapa construction is very necessary to store rainwater. Figure 6 depicts the elevation and slope maps of the Bankura district. According to Figure 6, in most of the places, the slopes of the Hirbandh and Khatra blocks are high to very high.

Bankura district receives low annual rainfall compared to other districts of West Bengal. The Vegetation Condition Index is applied here for drought monitoring. From the year 1991 to 2020, satellite images of Bankura district have been used to calculate the VCI of the district.

Figure 7 shows that Bankura district is a moderate drought region. The study area - Hirbandh and Khatra blocks - are in a light drought region (30 per cent - 40 per cent). Hence, being situated in a drought-prone region, Hirbandh and Khatra blocks should implement rainwater harvesting structures for irrigation purposes.

Figure 8 shows the groundwater level of the pre-monsoon, monsoon, and post-monsoon seasons of the Bankura district. In the pre-monsoon season, Hirbandh and Khatra blocks have high and moderate groundwater levels but in the monsoon season, the water level rises due to rainfall. In the monsoon season, groundwater levels of the Hirbandh and Khatra blocks range between 8 to 11 metres.

During the post-monsoon season, the groundwater levels of Hirbandh and Khatra blocks, ranging from 3 to 5 metres, decline. Since this leads to water, rainwater harvesting is very much needed for irrigational usage during the post-monsoonal season.

Figure 6

Elevation and Slope Maps of Bankura District with Four Different Classes

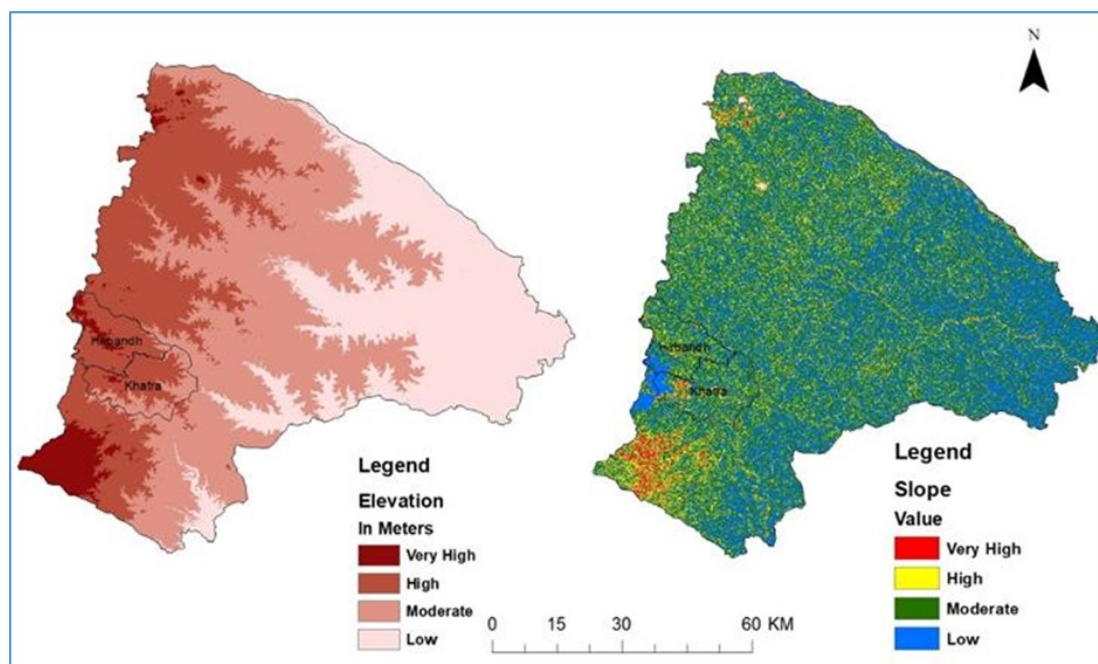
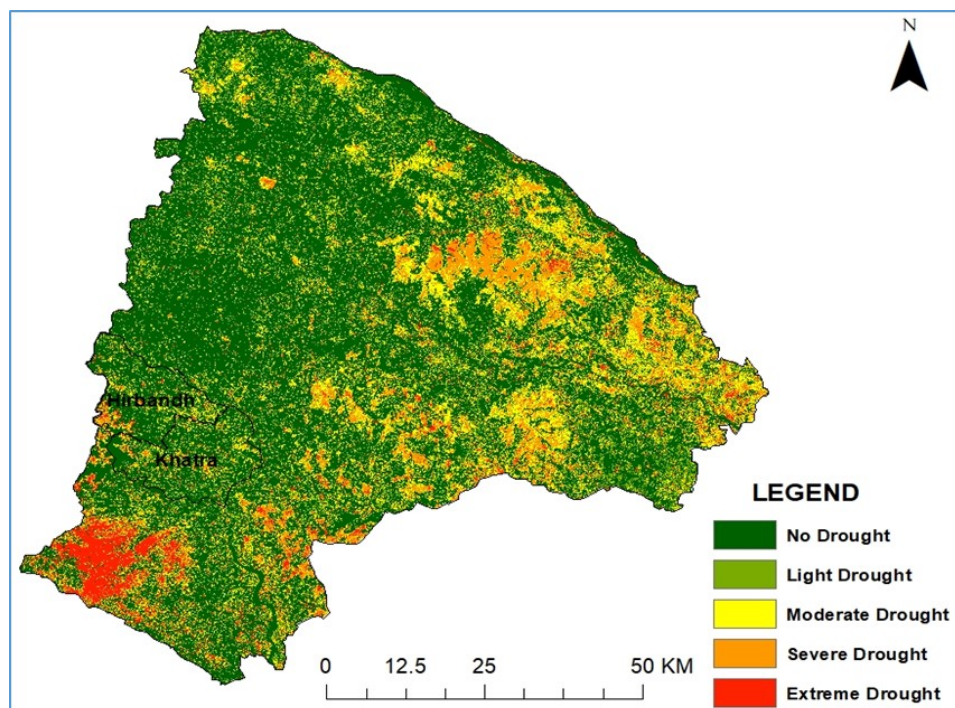


Figure 7*Vegetation Condition Index of Bankura district (1991-2020)*

The data available with the Panchayat and Rural Development Department under the Government of West Bengal shows that groundwater depletion has stopped after hapa creation. According to the West Bengal Pollution Control Board, these types of water management projects may help to meet non-monsoon water demand in future.

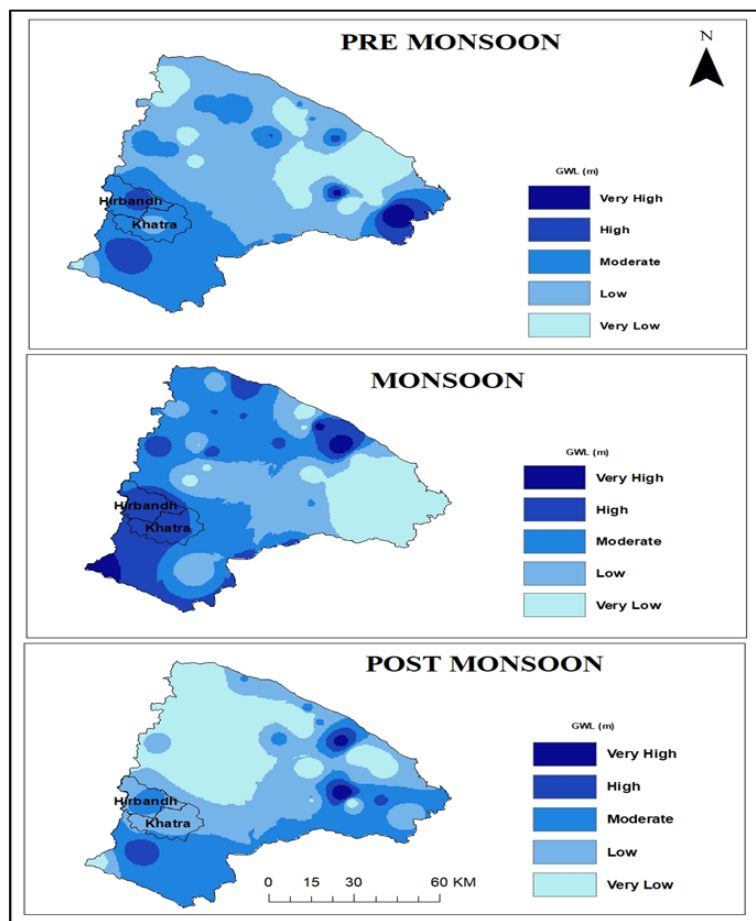
Results and Discussions

Hapas are constructed to offer supplementary irrigation opportunities to the cultivators of the Hirbandh and Khatra blocks. Because of hapa creation, villagers are now able to cultivate both Kharif and Rabi crops. The impact of Hapa's has been discussed with different methods.

The LULC (land use and land cover) map in Figure 9 shows five different classes, namely vegetation, water body, barren land, built-up and agricultural lands of 1991, 2001, 2011, and 2020 in

Hirbandh and Khatra blocks. A comparative analysis (Figure 10) has been done between the Hirbandh and Khatra blocks to show the decade-wise change of LULC. In the year 1991, Hirbandh and Khatra blocks, respectively, had 50 per cent and 59 per cent vegetation cover of the total area.

Only 5 per cent (Hirbandh) and 4 per cent (Khatra) area were under water bodies. Agricultural land covered 37 per cent (Hirbandh) and 30 per cent (Khatra) of the total area. In 2001, vegetation cover decreased in Hirbandh (16 per cent) and Khatra (14 per cent) blocks. Waterbodies were reduced to 3 per cent in Hirbandh and 5 per cent in Khatra, and agricultural lands remained almost the same. After the launch of hapa programme in 2011, agricultural lands and water bodies in both the blocks (Hirbandh 60 per cent and Khatra 57 per cent) increased. In 2020, both the blocks witnessed a positive change in agricultural land (Hirbandh 75 per cent and Khatra 62 per cent) and water bodies (Hirbandh 35 per cent and Khatra 23 per cent). The

Figure 8*Season-wise Groundwater Level Changes of Bankura District (2010)*

comparative study of land use and land cover illustrates that after hapa creation, Hirbandh block has more agricultural lands and hapas than Khatra block (Figure 10).

Figure 11 displays the change in land use and land cover over a decadal time interval from 1991 to 2020 of the Hirbandh and Khatra blocks. Maximum positive change has been noticed in agricultural lands and water bodies.

Vegetation covers turned into agricultural lands and water bodies, barren lands are also transformed into agricultural lands, water bodies, and settlements. So, from Figure 11, it can be assumed that agricultural productivity has increased in both blocks after hapa creation.

The NDWI maps have been created to precisely identify the total area of water bodies. The NDWI (Figure 12) displays that after hapa creation, the number of water bodies increased from 2001 to 2020. The scale of irrigation also increased in Hirbandh and Khatra blocks, which has a progressive impact on agricultural development.

Figure 13a shows the changes in water bodies. Before hapa creation in 2001, the total area of water bodies was nearly 16 sq. km. But in 2020, it increased to 28 sq. km, which indicates the growth of hapas. Subsequently, agricultural lands also increased. Comparatively, Hirbandh block has intensified hapa irrigation than Khatra block.

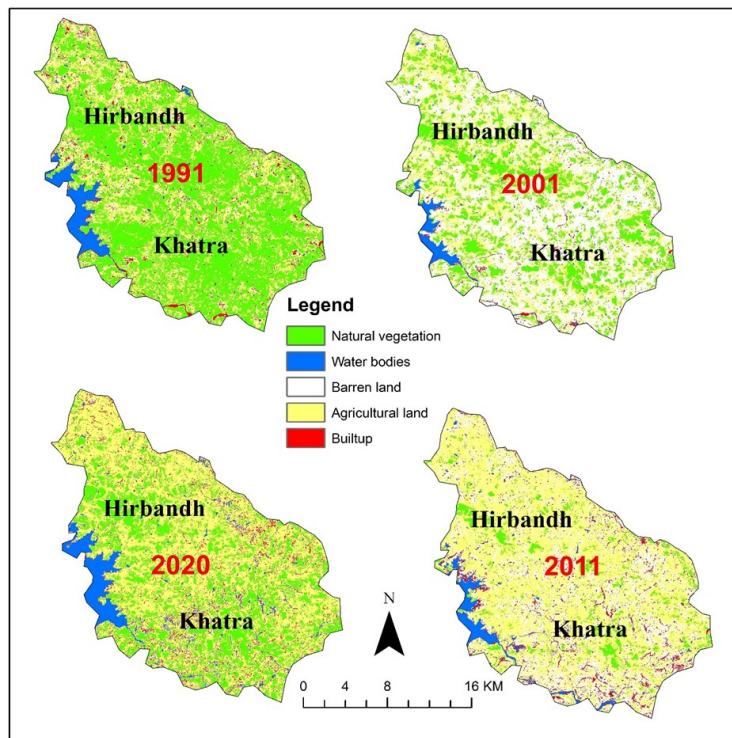
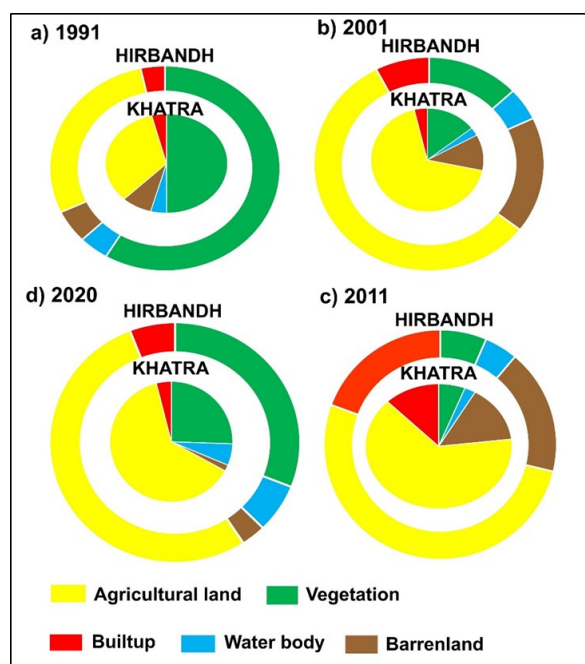
Figure 9*LULC Maps of Hirbandh and Khatra Blocks during 1991 to 2020***Figure 10***Comparison of LULC from 1991 to 2020 between Hirbandh and Khatra Blocks*

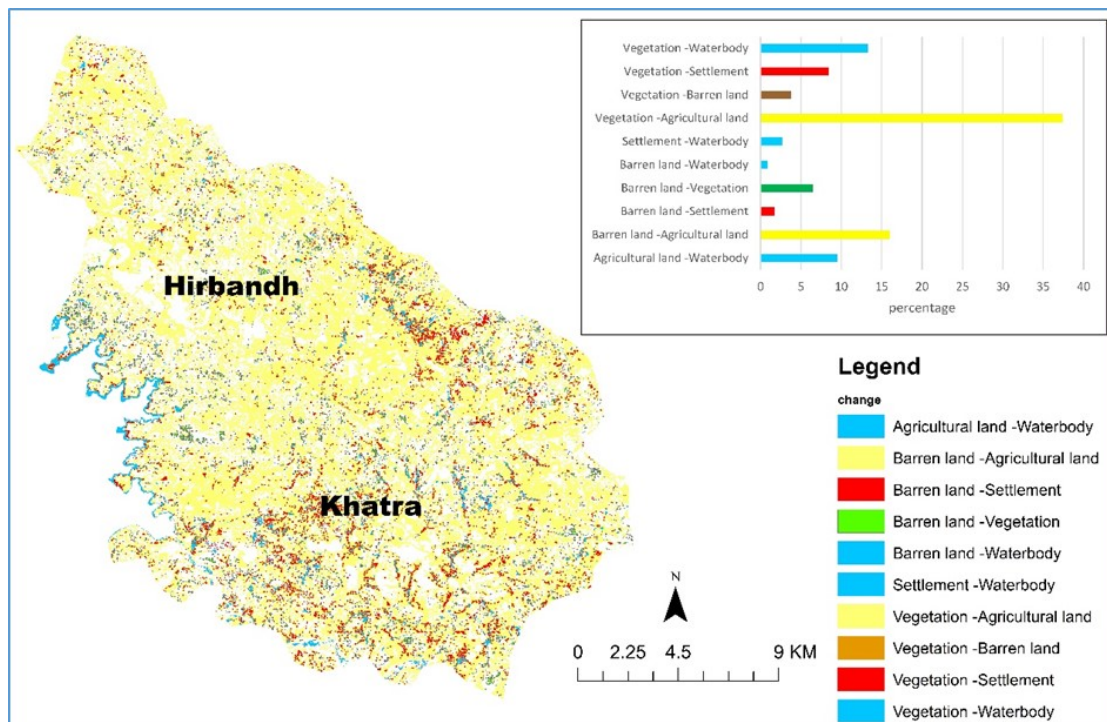
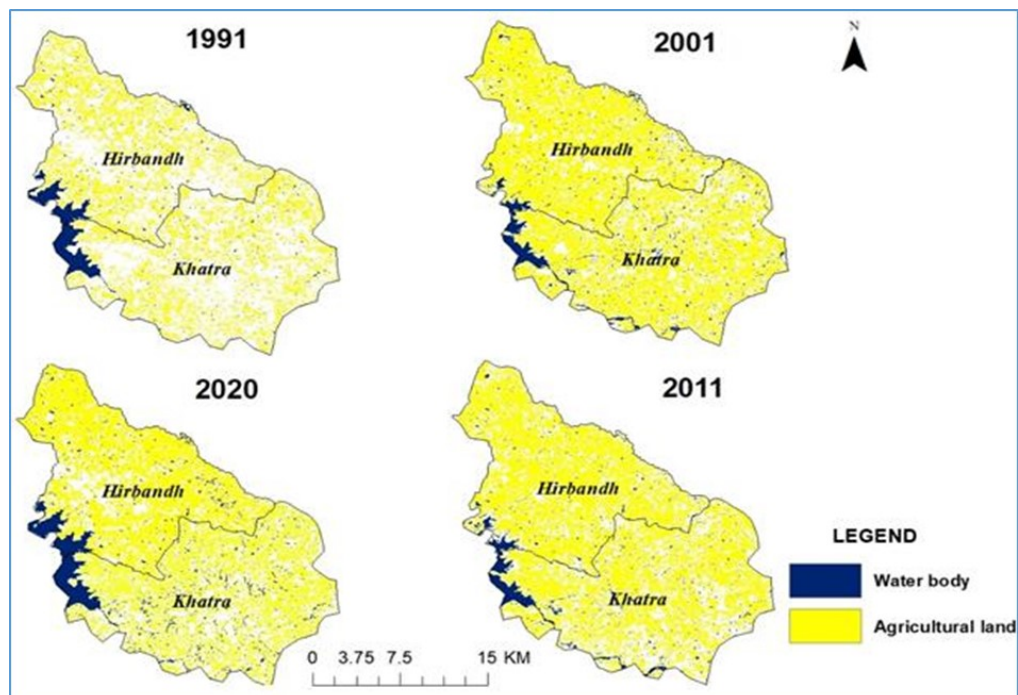
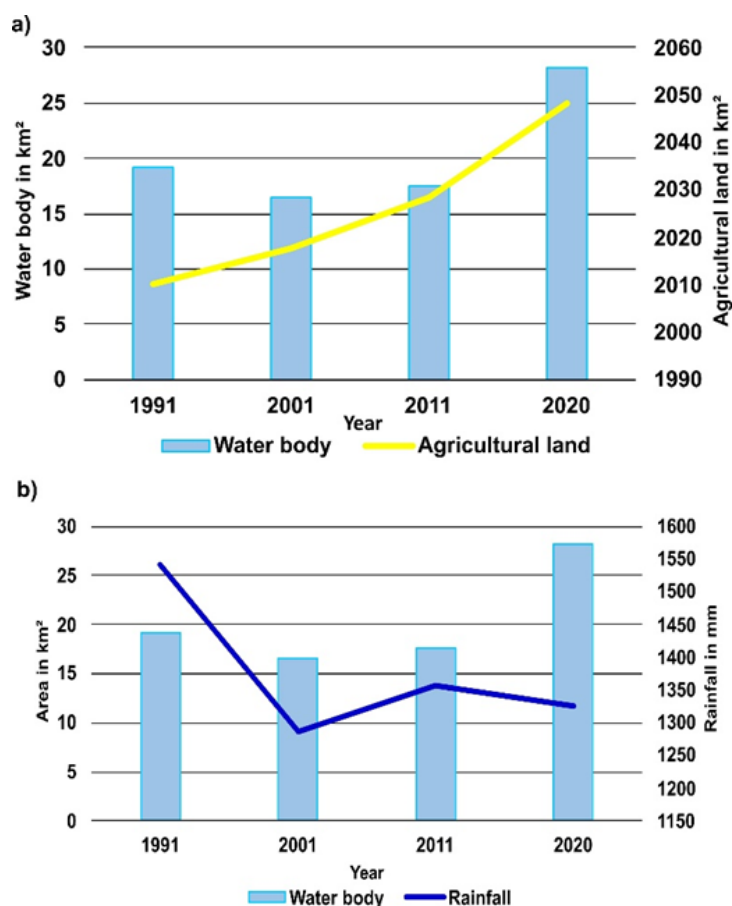
Figure 11*Change of Land Use and Land Cover from 1991 to 2020***Figure 12***NDWI Maps of Hirbandh and Khatra Blocks for 1991 to 2020*

Figure 13 (a)

*Relationship between Waterbodies and Agricultural Lands, and
(b) Relationship between Waterbodies and Rainfall*



Prior to hapa creation, rainwater in large quantities was getting lost due to surface runoff. Figure 13b shows that the total area of water bodies has increased since 2006 and the maximum amount of rainfall has been stored after hapa creation. The increase in water body area was significantly high after 2006. The increase rate was even much more from 2011 to 2020. There is a positive relationship between hapa and agricultural land. There was a slight decline in water body areas before the hapa creation period (1991 - 2005) maybe due to the decreasing and erratic rainfall, non-availability of surface water and the absence of hapas.

The total area of agricultural land has increased from 2006 to 2020. Both Kharif and Rabi crops

have been cultivated after hapa development. Figure 14 confirms that despite very low rainfall from 2011 to 2021, the increase in water area was significantly high. It only promotes the great success of hapa creation in such arid regions. In the present day, paddy, wheat, potatoes, pulses, and mustard are being produced by the local farmers from the Hirbandh and Khatra blocks.

According to the District Statistical Handbook, Hirbandh block produced about 19,285 tonnes of Aman paddy, about 107 tonnes of wheat, and 1431 tonnes of potatoes. On the contrary, the Khatra block produced about 22,770 tonnes of Aman paddy and 2552 tonnes of Boro paddy and potatoes in the year 2013-14.

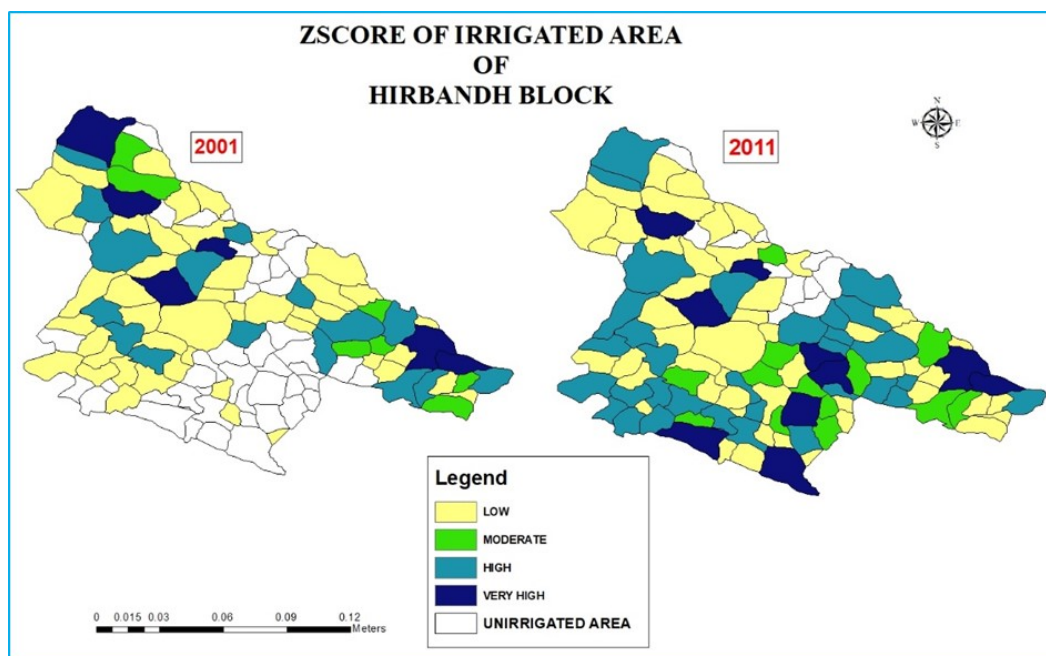
Irrigated Area Demarcation using Z-scores

The Z-score (Figures 14 and 15) magnitudes have been calculated to analyse the village-wise distribution of irrigated land in Hirbandh and Khatra blocks. The Z-score magnitudes have been categorised into four different classes, i.e. low, moderate, high, and very high. The high positive Z-score magnitudes (≥ 2) are considered very high, medium positive magnitudes (1.0 to 1.99) as high, low positive magnitudes (0 to 0.99) as moderate and negative magnitudes (-0.99 to -0.01) as Low.

According to census data, in 2001, the mean of the irrigated area was 10.21 hectares and the standard deviation (SD) was 24.68, whereas, after hapa creation in 2011, the mean of the irrigated area was 20.59 and the standard deviation was 25.73 in Hirbandh block. On the contrary, in Khatra block, the mean of the irrigated area was 31.79 and SD was 29 in the year 2001. In 2011, the mean of the irrigated area was 39.82 and SD was 35.2. Therefore, the SD is relatively higher in 2011 than in 2001 in both blocks.

Figure 14

Z-score of Irrigated Area of Hirbandh Block



The positive magnitude of Z scores has been considered here as a favourable symbol for the cultivators than the negative Z-score values because the negative Z-score value determines that the particular cultivator's village has a lower irrigated area than the average value. The Z-score with a smaller positive magnitude indicates a more secure state than the Z-score with a smaller negative value. Once the Z-scores are positive and high positive, it states that the block village concerned is in a better position than the other block villages. Near-to-negative and negative Z-

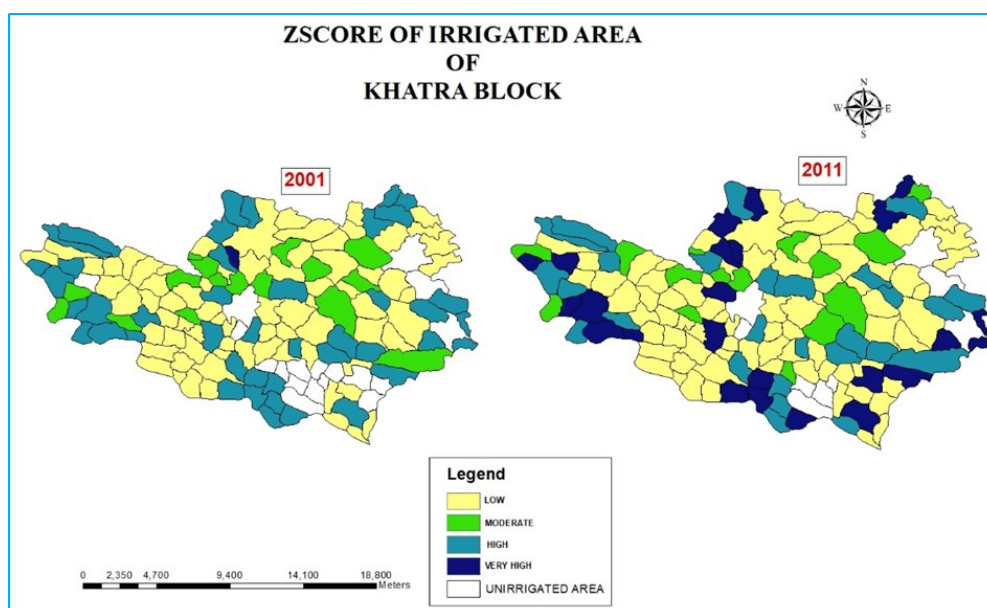
scores represent an inferior state in the block areas concerned. In Hirbandh block, six villages have been found in better condition with a Z-score magnitude of more than two. Consequently, in 2011, eleven villages had a Z-score magnitude of more than two. In 2001, Khatra block had only one village in a very high category but in 2011, 20 villages had more than two Z-score magnitudes. These consequences are improvement in irrigated areas in both blocks after hapa creation. In comparison, the number of moderately-irrigated villages also increased than low-irrigated villages in

2011. Figures 15 and 16 show that the number of poorly irrigated areas in villages came down from 2001 to 2011 and they turned into moderate to semi-moderate zones. Also, some unirrigated

villages covert into irrigated ones in 2011. Therefore, it is clear that after hapa creation, Hirbandh and Khatra blocks registered a lot of improvement in irrigation.

Figure 15

Z-score of Irrigated Area in Khatra Block



Interdependency on Increasing Population and Agricultural Land

Relationship studies have been made on population and agricultural land, agricultural labourers, and water bodies to define the impact of hapa creation. Figure 16a shows that both population and agricultural land have increased from 1991 to 2020. However, the growth rate of the population is less than the rate of increase of agricultural land and it signifies that hapa has a positive impact on the Hirbandh and Khatra blocks.

Figure 16b describes the relationship between population and agricultural labourers. Both factors have increased in the same ratio from 1991 to 2020. After hapa creation, 63 per cent and 53 per cent of total workers, respectively, in Hirbandh and Khatra blocks are engaged in agricultural activities, which indicates an upsurge in agricultural works.

Figure 16c indicates that the growth rate of

water bodies was very stagnant from 2001 to 2011 whereas the population growth rate was very high. The period from 2011 to 2020 saw a huge increase in water bodies. The incremental rate of the area of the water bodies is higher than the incremental growth of the population. These relationship studies indicate that hapa has a positive impact on Hirbandh and Khatra blocks.

Present Scenario of Hapa

Figure 17 gives a clear view of hapas in the present day. The pictures of hapas in March 2021 were taken from the Google Earth platform. All the hapas of Hirbandh and Khatra blocks have been marked from Google Earth and visualised through the map. About 224 hapas have been identified through this process in Hirbandh and Khatra blocks. Hirbandh block had more hapas than Khatra block.

Figure 16

Relationships between (a) Population and Agricultural Land, (b) Population and Agricultural Labourer, and (c) Population and Waterbodies

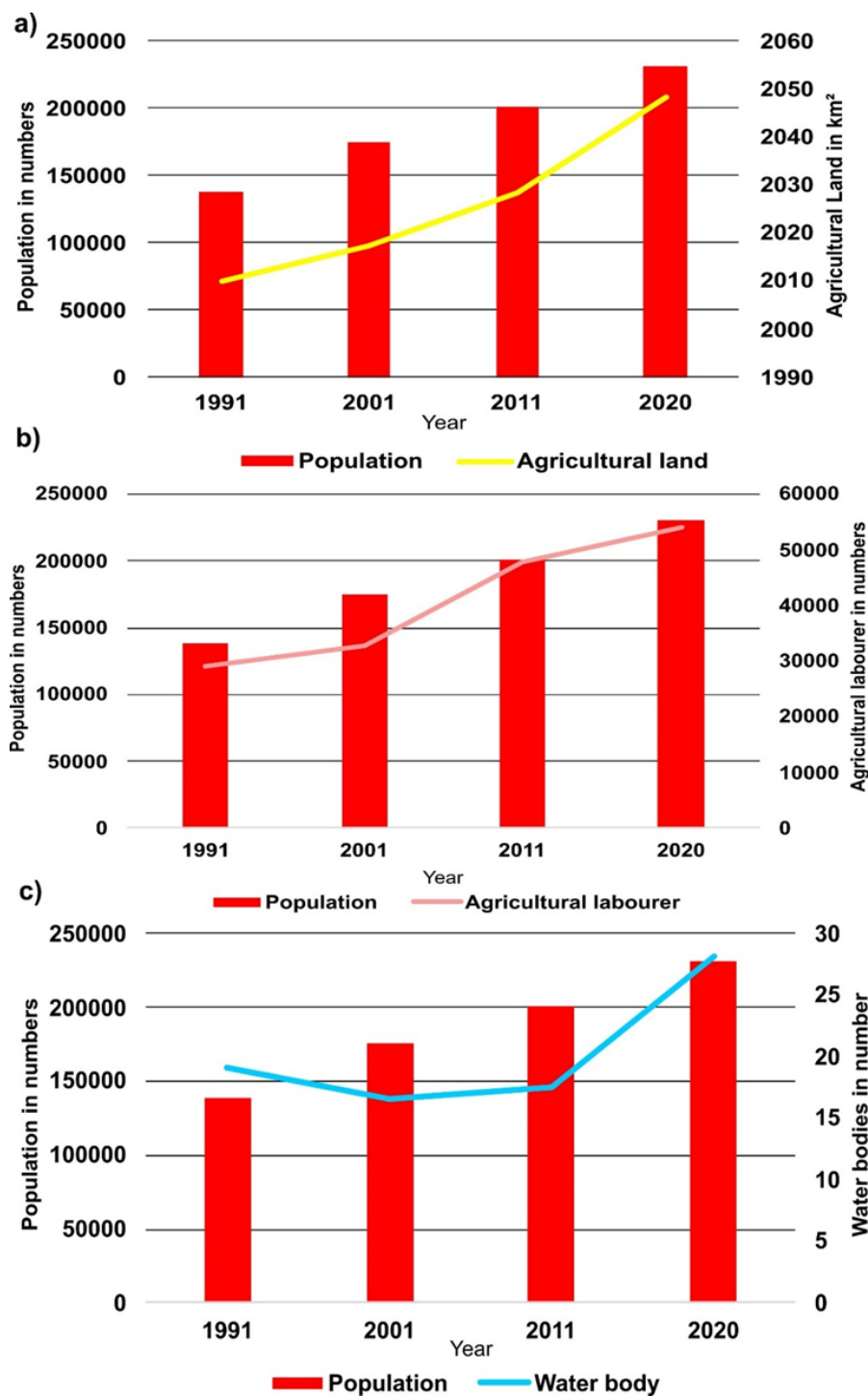
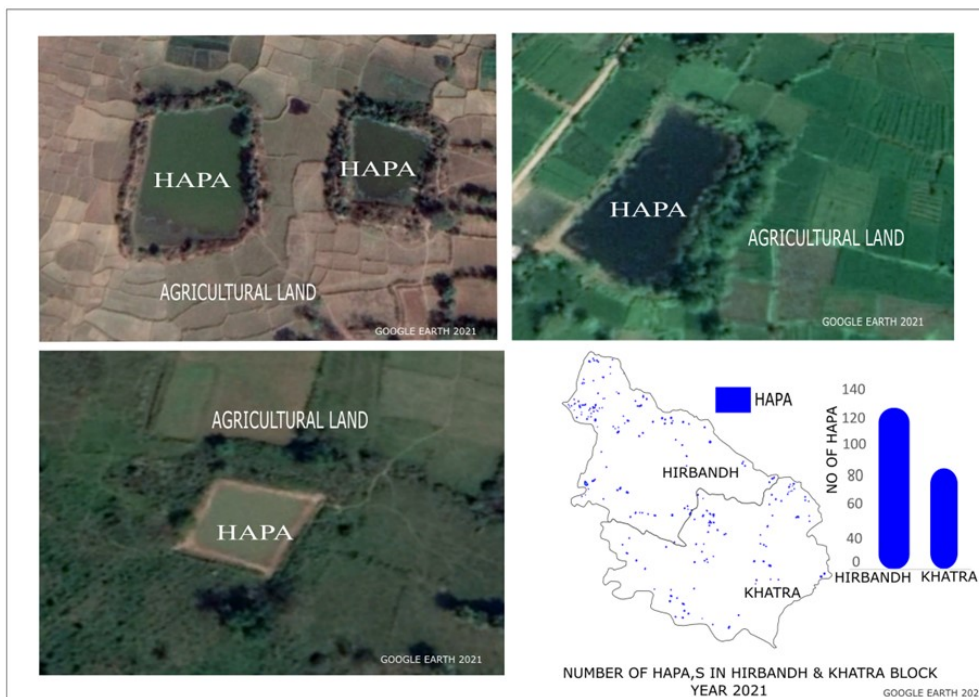


Figure 17*Scenario of Hapa in 2021***Conclusions**

Hapa is a customised rainwater harvesting pond constructed in arid regions. For hapa creation, farmers use 5 per cent of their total land. The current study discusses an encouraging link between the successful use of hapa with changing land use land cover patterns, agricultural areas, growing population, and decreasing rainfall. Geovisualisation and spatial and statistical analyses were done to conduct case studies in Hirbandh and Khatra blocks of Bankura district in West Bengal. Now, Hirbandh and Khatra blocks have more than 100 hapas, which have a positive impact on agricultural activities in these blocks. Farmers depend on hapa for domestic use, fishing, etc., and it helps to increase agricultural productivity. Production of Aman paddy, wheat, and potatoes has improved significantly after the formation of hapas. In comparison, Khatra block produces more crops than the Hirbandh block. The hapa-created water availability has allowed farmers to cultivate crops in two cycles in a year. After the

construction of the hapas, aquatic and agricultural areas have risen in the last 15 years. Thus, the availability of water has increased to meet the growing demand for agriculture despite the gradual decline in annual rainfall and the steady increase in population. Declining groundwater levels have also been controlled to some extent.

The overall study depicts that hapa has a significant impact on the lives of rural population in arid regions. People of water-scarce areas can easily imply the hapa model structure for benefits. Hapas can bring significant changes to the livelihood patterns of its owners. Non-irrigated and non-agricultural areas have turned into irrigated and agricultural areas of high productivity whereas increased job opportunities help reduce rural migration to cities. The most important change is the transition of the proprietary farmers to commercial farmers. It can, therefore, be said that the creation of hapa as an alternative to environmental sustainability, has a very positive impact on arid agricultural areas.

Author Contributions:

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