International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Water Harvesting Structures and Agricultural Sustainability: An Assessment of Irrigation Potential in Birbhum District

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Abstract

Water harvesting structures are of immense importance in enhancing the sustainability of agriculture, particularly in areas where agriculture is seasonal, water availability is erratic, and the system is heavily dependent on the monsoon. Birbhum district of West Bengal is a district of considerable geographical diversity in terms of its physiography, rainfall patterns, soils and the nature of agriculture practised. Traditional water harvesting structures (ponds, tanks, reservoirs and a range of small water harvesting systems) have the potential to make a significant contribution to irrigation, groundwater recharge and agricultural diversification. The present study is an attempt to assess the irrigation potential of such structures and to examine their role in promoting sustainable agricultural development in the Birbhum district. The study is undertaken in a geographical framework utilising secondary data, spatial assessment and a proposed field investigation into the water harvesting infrastructure. The various aspects that will be looked at are the spatial distribution of the structures, their irrigation potential, cropping intensity, the seasonal requirements of agriculture and the extent to which farmers are reliant on different sources of irrigation. The study contends that the effective restoration and rational management of these traditional water harvesting systems can go a long way towards improving water security at the local level, reducing the vulnerability of agriculture and enhancing the resilience of rural livelihoods. It also points to the importance of incorporating local knowledge, community participation and modern water resource management approaches in the pursuit of sustainable agricultural development.

Keywords: Water harvesting, agricultural sustainability, irrigation potential, cropping intensity, water resource management, Birbhum District.

1. Introduction

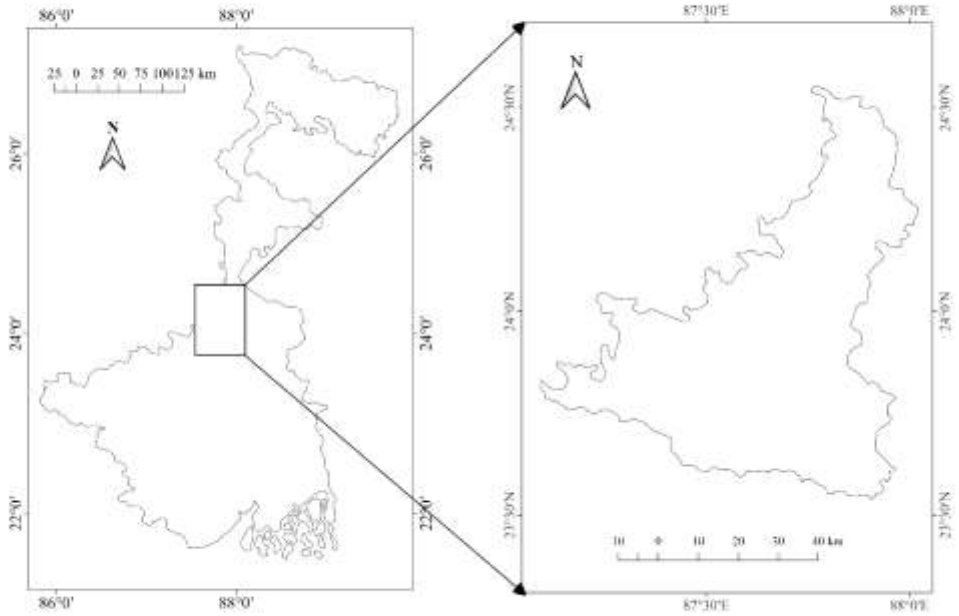
Agriculture is inextricably linked to the availability, accessibility and efficient utilisation of water. In developing countries such as India, agriculture is still very much rainfall dependent, particularly in areas where the irrigation infrastructure is either non-existent or is unevenly distributed. The pressure on groundwater resources is increasing, rainfall patterns are changing, droughts are becoming more frequent, and the demand from agriculture is rising. There is therefore an ever greater need for sustainable management of water resources. Water harvesting is the collection, storage and conservation of surface runoff and rainwater for subsequent use. It encompasses traditional ponds, tanks, reservoirs, check dams, farm ponds and a variety of other small-scale water retention structures. The various water harvesting structures are, of course, a major contributor to agricultural development in that they provide

supplementary irrigation, aid in groundwater recharge, reduce surface runoff and increase the availability of water during the dry season. Birbhum district (in the western part of West Bengal) is a good example of a district where the relationship between water harvesting and agricultural sustainability can be studied. The district has a range of physiography, soils and agricultural conditions. The western plateau fringe is fairly undulating, whereas the eastern part is considerably flatter (alluvial). The variation in the topography has a bearing on the drainage characteristics, the water-holding capacity and the type of agriculture that can be practised. Agriculture in Birbhum is very much a function of the seasonal rainfall and the availability of irrigation. Paddy is of course a major crop, with wheat, pulses, oilseeds, vegetables and a range of other crops also grown. The traditional water bodies and the small-scale water harvesting that we have could potentially be of some assistance in meeting the irrigation requirements, particularly in the post-monsoon and the dry agricultural season. In this respect, the present study looks at the irrigation potential of water harvesting structures in Birbhum district and their role in promoting sustainable agricultural development. It stresses the importance of recognising traditional water conservation systems as an integral part of decentralised agricultural water management.

2. Study Area

Birbhum District is in the western part of West Bengal, India, roughly lying between 23°32' N and 24°35' N latitudes and 87°05' E and 88°01' E longitudes. It is bounded on the west by Jharkhand, on the east by Murshidabad, on the south by Bardhaman and on the northwest by parts of Jharkhand. The physiography of Birbhum is a clear transition from the Chotanagpur

LOCATION MAP OF BIRBHUM IN WEST BENGAL



Plateau fringe to the alluvial plains of the Bengal Basin. The western part is undulating with lateritic soils and relatively high surface runoff, the eastern part being comparatively flat alluvial land with a much

greater degree of agricultural development. The district is drained by a number of rivers and streams including the Mayurakshi, Ajay, Bakreshwar, Kopai, Brahmani and Dwarka. These river systems have a bearing on the drainage pattern, the agriculture and the availability of water. Agriculture is a major economic activity in the district. The level of productivity and the type of crops grown vary significantly due to differences in rainfall, soil moisture retention, the state of the irrigation infrastructure and the topography. The use of locally available water harvesting structures therefore presents a significant opportunity to improve irrigation access and agricultural resilience.

3. Review of Literature

Water harvesting and its links to agricultural sustainability have been a major topic in agricultural geography, hydrology and the environmental sciences. There's been a lot of work done in the past on the value of decentralised water storage in terms of improving irrigation efficiency, enabling rainfed agriculture and providing a boost to rural livelihoods.

Gunnell and Krishnamurthy (2003) looked at the historical and contemporary relevance of runoff harvesting systems in dryland India. They found traditional tanks and small reservoirs to be of considerable importance in the management of agricultural water. They also point to siltation, groundwater depletion and changing patterns of resource management as the principal threats to the long-term viability of these systems.

Van Meter et al (2014) looked at the environmental, social and economic aspects of agricultural rainwater harvesting systems in India. They found that rainwater harvesting can be a means of improving food security and helping to address water scarcity. They also recommended that rainwater harvesting systems be assessed on a watershed basis.

Research by Alam et al. (2022) looked at the benefits, equity and sustainability of community-based rainwater harvesting structures. The study showed the importance of understanding who benefits from the structures (i.e. the distribution of benefits across the farming households) and the role of institutional arrangements in determining the sustainability of the structures over the long term.

Gavhane et al. (2023) looked at the use of geospatial tools and analytical techniques for the identification of appropriate sites for rainwater harvesting structures. The study highlighted the value of incorporating GIS, topographic features and hydrological parameters in the planning of water harvesting.

In the case of Birbhum district, Ganguly and Patra (2014) looked at the relationship between irrigation and cropping intensity. That study provides a very relevant geographical basis for the discussion of the impact of the availability of irrigation on agricultural development.

Although these studies are of considerable value in terms of understanding water harvesting and agricultural sustainability, further work is required in a geographical sense to get a proper understanding of the spatial distribution, the functional conditions and the agricultural utility of the water harvesting structures in Birbhum district. The relationship between traditional water storage, irrigation availability, cropping intensity and agricultural sustainability in particular needs to be looked at more closely.

4. Research Gap

The existing literature has largely been concerned with irrigation development, agricultural productivity, groundwater use and traditional water conservation. The specific contribution of water harvesting structures to the sustainability of agriculture in Birbhum district, however, has yet to be properly assessed from a geographical perspective.

The major research gaps are:

1. Insufficient assessment of the spatial distribution and accessibility of traditional water harvesting structures.
2. Very limited understanding of their contribution to supplementary irrigation during the Rabi and pre-Kharif seasons.
3. Inadequate investigation into the relationship between water-holding capacity and cropping intensity.
4. Limited assessment of the socio-economic benefits accruing to small and marginal farmers.
5. Insufficient integration of traditional water conservation with modern agricultural water management.

The present study seeks to address these gaps by looking at water harvesting structures as potential instruments of agricultural sustainability.

5. Objectives of the Study

The major objectives are:

1. To identify and classify the various types of water harvesting structures in the Birbhum district.
2. To look at their spatial distribution and geographical characteristics.
3. To assess their potential contribution to irrigation development and to agricultural sustainability.
4. To analyse the relationship between water availability, cropping intensity and agricultural productivity.
5. To look at the problems relating to the maintenance and use of the existing water harvesting infrastructure.
6. To suggest appropriate strategies for the improvement of water harvesting infrastructure and for sustainable agricultural development.

6. Research Questions

The study attempts to address the following research questions:

1. What are the major types and the spatial characteristics of water harvesting structures in Birbhum district?
2. To what extent can these structures be of any use in terms of agricultural irrigation?
3. How does water availability affect cropping patterns and cropping intensity?
4. What are the main constraints to the effective use of the water that is harvested?
5. How can traditional water harvesting systems be incorporated into sustainable agricultural planning?

7. Database and Research Methodology

7.1 Research Design

The study is a descriptive and analytical geographical research exercise. It draws on secondary statistical information, spatial analysis, and a proposed primary fieldwork element to assess the agricultural importance of water harvesting structures. The district is the primary unit of analysis with block and village level work proposed to identify differences in water availability and irrigation potential.

7.2 Sources of Data

The research is based on both primary and secondary sources.

Primary data (proposed field investigation):

1. GPS co-ordinates of water harvesting structures.
2. Field observation of ponds, tanks, reservoirs and check dams.
3. Interviews with farmers and with local residents.

4. Information on seasonal water availability.
5. Irrigation practices and water requirements by crop.
6. Farmers' views on the usefulness of water harvesting structures.
7. Information on structural conditions, maintenance and community involvement.

Secondary data:

1. District agricultural statistics.
2. District Statistical Handbook, Birbhum.
3. Agricultural and Irrigation Reports of the Government of West Bengal.
4. Central Ground Water Board publications.
5. Rainfall and meteorological records.
6. Satellite imagery and topographical maps.
7. Published research articles, books and government documents.

7.3 Classification of Water Harvesting Structures

For the purpose of the study, water harvesting structures can be classified into the following categories:

Category	Examples	Agricultural significance
Traditional structures	Ponds, tanks and Dighis	Supplementary irrigation
Surface water storage	Reservoirs and water retention tanks	Seasonal water storage
Runoff harvesting	Check dams and earthen bunds	Runoff conservation
Farm-level structures	Farm ponds and small reservoirs	Protective irrigation
Groundwater recharge structures	Recharge pits and percolation tanks	Groundwater replenishment

7.4 Spatial Analysis

GIS techniques can be used to look at the spatial distribution and agricultural accessibility of water harvesting structures. The following thematic maps are proposed:

1. Drainage map.
2. Depth of water table map.
3. Groundwater draft map.
4. Irrigation Pattern map.

GPS field observations can be used in combination to identify potential sites for further water harvesting infrastructure.

8. Agricultural and Geographical Characteristics of Birbhum District

Agriculture in Birbhum is of course shaped by the physical environment of the district, particularly the rainfall, the nature of the soil, the topography and the drainage. The official district agricultural profile puts the average annual rainfall at 1430 mm. The total geographical area of the district is around 454,500 hectares of which 320,610 hectares is cultivated. The district administration states that 54.58% of the cultivated area is irrigated. Despite the rainfall and the presence of several rivers, agriculture is still very much at the mercy of the seasonal variations in water availability. The western part of the district is of particular importance in terms of rainfed agricultural development given the undulating topography and the lateritic soils. The eastern area, with its relatively flatter topography and alluvial soils, offers different prospects for intensification of agriculture. Water harvesting therefore needs to be planned in accordance with the local geomorphology and hydrology rather than adopting a one-size-fits-all approach across the whole district. Paddy is the principal crop, with wheat, pulses, oilseeds, potato and vegetables providing

crop diversification. Development of local water storage can provide scope for supplementary irrigation and cultivation outside the main monsoon season.

9. Water Harvesting Structures and Their Irrigation Potential

Water harvesting structures are a key element of decentralised agricultural water management. Their contribution to irrigation will be a function of storage capacity, catchment characteristics, seasonal rainfall, water losses and the distance between the storage and the agricultural land.

9.1 Traditional Ponds and Tanks

Traditional ponds and tanks are probably the most straightforward form of water storage in the rural landscape. They catch the rain and surface runoff in the monsoon and can then be used for supplementary irrigation during the dry season. In Birbhum, the restoration of traditional ponds and tanks could be of considerable benefit to small and marginal farmers who have very little access to large-scale irrigation infrastructure. Desilting, embankment repair and improvement of the water distribution systems could go a long way to increasing their functional utility.

9.2 Check Dams and Small Reservoirs

Check dams and small reservoirs are of particular relevance in areas with undulating topography and seasonal drainages. They act to temporarily store runoff and can contribute to improved local groundwater recharge. Their agricultural value is entirely dependent on site selection, catchment size and the availability of appropriate command areas. In the western part of Birbhum, such structures could be of some use in reducing runoff and increasing moisture availability.

9.3 Farm Ponds

Farm ponds offer the opportunity for individual- or community-based water storage. They can be used to store runoff from agricultural land and the surrounding catchment. Stored water can be used for protective irrigation during the critical crop growth stages (especially where rainfall becomes erratic). Farm ponds can also be used for vegetable production and other higher value forms of agriculture.

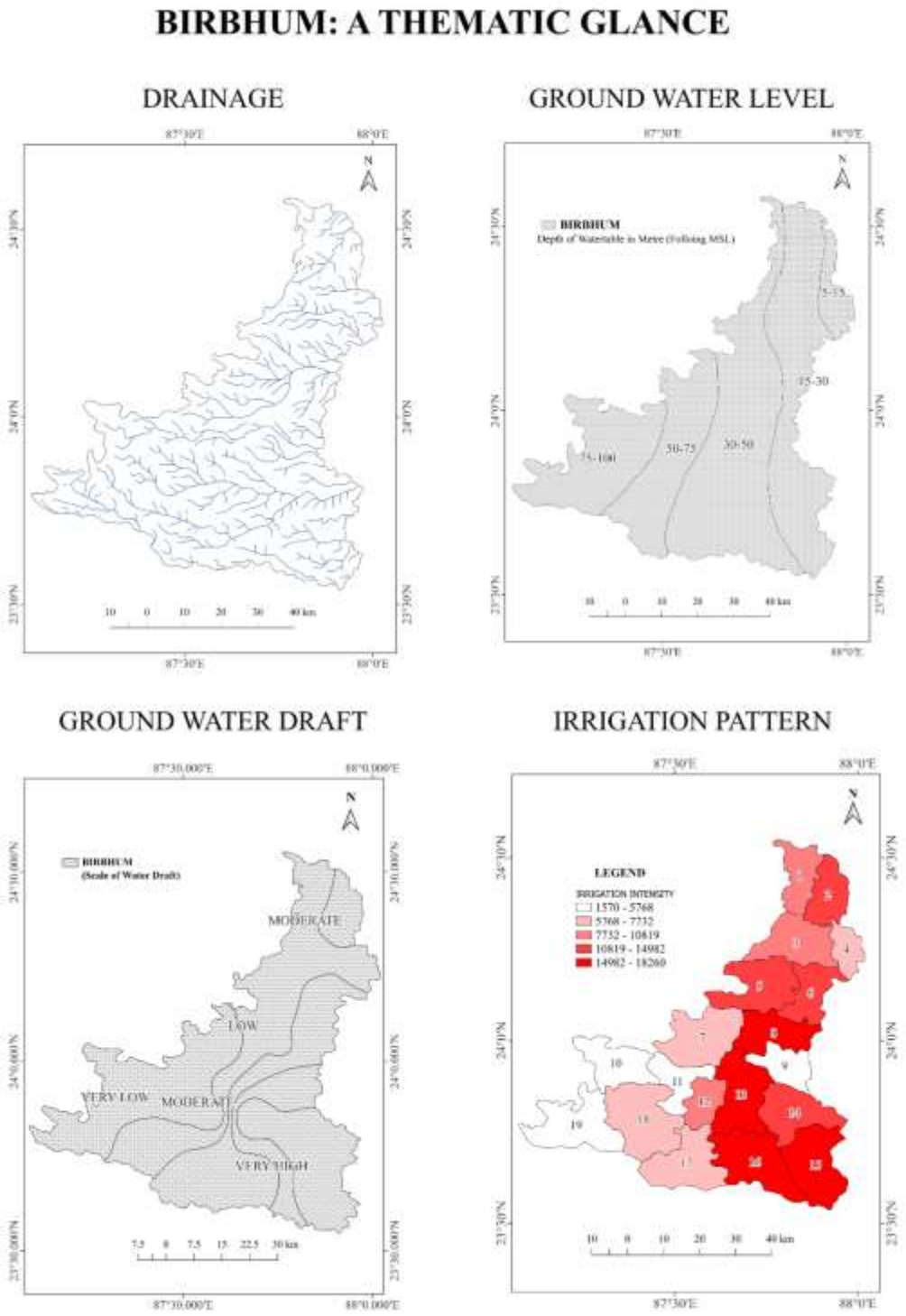
9.4 Groundwater Recharge Structures

Recharge pits, percolation tanks and other infiltration-type structures can all contribute to groundwater recharge. This is of particular relevance given that the district administration has identified groundwater depletion and the consequent fall in groundwater levels as a major concern for both agricultural and drinking water security. However, the groundwater recharge structures should be designed taking into account the local hydrogeological conditions and the quality of the groundwater.

10. Agricultural Sustainability: Major Dimensions

10.1 Improvement of Irrigation Availability

One of the key benefits of water harvesting structures is the provision of supplemental irrigation during periods of low rainfall. In rainfed agriculture, even small quantities of stored water can be of considerable value in protecting crops through their most critical growth stages. The official agricultural profile of Birbhum lists rainwater harvesting as a key intervention, as groundwater depletion has become a major issue in several areas of the district. Restoration of ponds, tanks and small reservoirs may therefore lead to a reduction in exclusive reliance on groundwater for irrigation.



10.2 Enhancement of Cropping Intensity

The availability of stored water can enable farmers to grow additional crops post-monsoon. In particular, supplementary irrigation can be used to grow Rabi crops (wheat, pulses, oilseeds and vegetables). Improved water availability could also enable multiple cropping and lead to a reduction in the area under mono-cropping. The extent to which cropping intensity actually increases will, however, be a function of water storage capacity, landholding patterns, soil conditions and the farmers' own economic resources.

10.3 Agricultural Diversification

Water harvesting can be used to promote agricultural diversification by providing water for crops that require more controlled irrigation. There is potential for vegetable cultivation, pulses and oilseeds to provide an opportunity to increase agricultural incomes and reduce reliance on a single crop. The Government of West Bengal has introduced a Diversified Cropping Programme for dryland and rainfed areas (including Birbhum) with a view to promoting crops such as maize, groundnut, mustard, sesame, lentil and pigeon pea (arhar). This diversification can be a useful complement to local water conservation efforts.

10.4 Groundwater Recharge and Soil Moisture Conservation

Water harvesting structures can enhance infiltration and groundwater recharge where the local geology allows. They can also help to reduce uncontrolled surface runoff and assist in soil moisture conservation. These benefits are of particular relevance in the western plateau fringe areas of Birbhum where the topography has an impact on runoff and water retention. Recharge potential, however, will have to be ascertained through local hydrogeological investigations.

10.5 Livelihood Security of Small and Marginal Farmers

Small and marginal farmers are typically the most vulnerable to agricultural water shortages due to their limited financial resources and lack of access to irrigation infrastructure. Community-based water harvesting structures can provide an opportunity for shared water management and supplementary irrigation. Alam et al. (2022) go on to show that the benefits of community water harvesting structures are not necessarily distributed equally, with benefits being a function of the farmer's distance from the structure and their level of involvement in the maintenance of the structure. So equitable access and participatory management are absolutely key to ensuring agricultural sustainability.

11. Major Challenges and Constraints

Despite their potential, water harvesting structures are beset by a number of geographical, environmental, technical and institutional constraints in Birbhum district.

11.1 Siltation and reduced storage capacity: siltation is a continuous process which leads to a reduction in the water storage capacity of ponds, tanks and small reservoirs. Desiltation therefore has to be carried out on a regular basis.

11.2 Seasonal water availability: Most of the water harvesting structures will be dependent on monsoon rainfall. Their effectiveness during extended dry periods is likely to be constrained by poor runoff and inadequate carryover storage.

11.3 Groundwater depletion: Excessive withdrawal of groundwater for agricultural irrigation will, of course, undermine the sustainability of the local water resource. The District Administration have already flagged the issue of falling groundwater levels as a major one.

11.4 Poor maintenance: Damaged embankments, poor drainage arrangements and lack of regular maintenance all serve to reduce the functional efficiency of the traditional water bodies.

11.5 Unequal accessibility: Farmers in the vicinity of water harvesting structures are likely to benefit from irrigation to a greater extent than those who are further away. Small and marginal farmers may also find it difficult to access the pumping equipment and water distribution infrastructure.

11.6 Institutional constraints: Lack of coordination between the various agricultural departments, the irrigation authorities, the various local government institutions and the community organisations can have an effect on the successful implementation of water conservation programmes.

The Govt of West Bengal's Water Resources Investigation and Development Department run various lift irrigation and minor irrigation schemes in Birbhum. The Suri Agricultural Mechanical Division of the said department is also responsible for the installation and maintenance of irrigation schemes including river lift irrigation schemes. The institutional set up thus provides for the integration of harvested surface water with the existing irrigation infrastructure.

12. Strategies for Sustainable Agricultural Water Management

The following strategies may improve the agricultural utility of water harvesting structures in Birbhum:

1. **Restoration of traditional water bodies:** Existing ponds, tanks and dighis to be identified, mapped and restored via de-silting and improvement of embankments.
2. **Development of farm ponds:** Farm ponds on a small scale should be promoted in rainfed areas as a means of achieving protective irrigation.
3. **GIS-based site selection:** GIS and remote sensing should be used to identify the sites for check dams, water harvesting tanks and recharge structures.
4. **Integration with existing irrigation systems:** Harvested surface water should be integrated with existing minor irrigation schemes and lift irrigation wherever technically possible.
5. **Promotion of micro-irrigation:** Drip and sprinkler irrigation can lead to more efficient use of stored water and reduce water losses.
6. **Community-based management:** Farmers' groups, water user associations and Panchayats should be involved in the maintenance and equitable distribution of the water that is harvested.
7. **Agricultural diversification:** Water availability should be linked to appropriate crop planning, particularly the cultivation of pulses, oilseeds, vegetables and other relatively water-use efficient crops.
8. **Monitoring and Evaluation:** There should be regular monitoring of the water stored, the groundwater levels, the area under irrigation and the cropping intensity to assess the impact of the water harvesting.

13. Discussion

The assessment suggests that water harvesting structures have significant potential to contribute to agricultural sustainability in Birbhum. Their importance goes well beyond just the storage of rainwater, as they can also play a role in irrigation security, groundwater recharge, agricultural diversification and rural livelihoods.

The difference in the geography between the western lateritic plateau fringe and the eastern alluvial plains would seem to dictate that water harvesting interventions should be spatially distinct. In the western area, we'd probably be looking at runoff harvesting, check dams and farm ponds. In the eastern area, where there are suitable alluvial and hydrogeological conditions, the restoration of traditional ponds and the use of recharge-based interventions could be of benefit.

The link between water harvesting and agricultural sustainability is not necessarily a straight one. The existence of a water harvesting structure does not in itself guarantee improved agricultural output. It's all down to the storage capacity, the rainfall regime, the quality of the water, the level of maintenance, the degree of irrigation access and the level of farmer involvement.

Research by Alam et al. (2022) is very relevant in this respect, as they show that the benefits of community-based check dams can vary depending on rainfall and on the distance of the farming households from the dams. This implies that any assessment of water harvesting infrastructure should take into account both physical availability and socio-economic accessibility.

Water harvesting should not be seen as a panacea to replace all existing irrigation systems. It should be viewed as a way of supplementing canal irrigation, groundwater management and minor irrigation. A decentralised approach that brings together traditional knowledge, scientific planning and community involvement may well be the way forward for agricultural water management in Birbhum.

14. Conclusion

Water harvesting structures are a key opportunity for improving the sustainability of agriculture in Birbhum district, West Bengal. The district's topography, the variability of rainfall throughout the year and the increasing pressure on groundwater all underline the need to improve water conservation and storage at the local level. Traditional ponds, tanks, farm ponds, check dams and all sorts of other small-scale structures can be of value in terms of supplementary irrigation, groundwater recharge, cropping diversification and agricultural resilience. Their use can be of particular benefit to small and marginal farmers who often find it very difficult to get assured irrigation. The agricultural benefits of these structures are contingent upon appropriate siting, adequate storage, regular maintenance, fair distribution of water and integration with the existing irrigation system. A GIS-based spatial assessment combined with farmer-level field surveys would be the way to properly assess their actual irrigation potential. Ultimately, the combination of traditional water harvesting with modern agricultural water management can lead to more sustainable farming, better rural livelihoods and greater long-term agricultural resilience in Birbhum district.

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