The Surface Water Management Plan in Arkasha Watershed with Site Suitability Analysis using Geospatial Information Technology

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Abstract

The most important natural resources, i.e., water and land are the two greatest gifts of nature which supports both the human needs and economic development. This study mainly focuses on the role of Remote Sensing and Geographical Information System (GIS) techniques for the assessment of Site Suitability Analysis and identification of different Structures for Surface Water Management Plan in Arkasha Watershed, Bankura & Purulia District, West Bengal, India. The main objective of the study is the surface water management plan in Arkasha Watershed with site suitability analysis using geospatial information technology. The multispectral Landsat7 ETM+ and ASTER DEM data were analyzed in ERDAS IMAGINE and Arc GIS platform. This study has been done on the effectiveness of remote sensing and GIS for the identification and delineation of the site suitability structures. It focuses on three most suitable structures i.e. Check dam, Nala bund and Drought pond. In this area mainly selection of each structure has been done based on suitability of the site generated through overlay analysis. Finally, a site suitability map have been developed using different structures which shows the suitable sites for harvesting surface water.

Keywords: Harvesting Surface Water, Surface Water Management, Overlay analysis, Site Suitability

Introduction

Water and Land are the two greatest gift of nature [1]. Water is one of the most important natural resource which supports both of human needs or economic development [9]. Basically water is needed for agriculture, industries, domestic activities etc. For particular purpose water must be pure, so we must take to increase good quality of water. Ground water is a major source of irrigation, drinking, and other purpose of water requirement in several areas of India. In India, about more than 70% rural and near about 30% urban population are depended on it for drinking water. Surface water is water on the surface of the planet such as in a stream, river, lake, wetland, or ocean. It can be contrasted with groundwater and atmospheric water (Surface water Wikipedia, the free encyclopedia). The water flows on the surface of the earth that is generally referred as runoff. Reduction of surface runoff can be achieved by constructing suitable structures, which automatically helps to manage the other natural resources like soil and vegetation. For the efficient management, one has to take suitable measure of management. Here, by taking watershed as a unit the water, soil, and vegetation can be managed efficiently, collectively, and simultaneously. Rainwater harvesting (RWH) primarily consists of the collection, storage and subsequent use of captured rainwater as either the principal or as a supplementary source of water. This means that the rainwater falling on an area coming within a ridgeline can be harvested and will flow out of this area thorough single point. Some refers it as a catchment area or river. The management of the surface water is very complex issue till the historical precedent. Here most of the information we found from remotely sensed data or from satellite imagery. After collecting data we must survey from field with GPS techniques. The advantage of using remote sensing techniques together with GPS techniques in a single platform and using the GIS techniques gives better facilities for spatial data analysis and their interpretation [10]. Remote Sensing technology has already been established as an effective complementary tool in natural resource mapping all over the world. Extensive hydro-geological studies using remote sensing have been carried

out by several workers in delineating for surface water management plan [5]. Geographical Information System (GIS) has been used for integration and overlaying of lithological, geomorphological, soil and slope map which help in making management plan for storing surface water. The remote sensing technique has been applied for suitable site conserving area of this watershed in the region. Suitable site for various water harvesting structure such as Check dams, Nala bund, Farm pond, Gully plug, Gabion structure etc. Thus the integration of Remote Sensing and Geographical Information System (GIS) is a power full spin-off from space exploration and it has emerged as a powerful tool for watershed categorization, conservation planning and management of surface water [8].The area of Bankura and Purulia is first heading towards water crisis [4]. Its storage is likely to be show acute that the future may be forgotten on sharing of water resources among various villages [7].

Aim

Aim of the study is to locate site suitable for surface water management using deferent structures.

Objectives

- Physiographic setup of the study area
- Identification Drainage system.
- Delineation of micro watershed boundary.
- Identification of suitable site for deferent structures.

Study Area

The study area consisting watershed namely DEWARAKESWAR watershed situated at the southern slope of Puruliya & Bankura, which is extended over block. This area contains Hura, Kashipur, and Puncha Blocks of Puruliya and Indpur, chatna, Bankura-I blocks of Bankura district of West Bengal state. The latitude & longitudinal extension of the area is 86 °31' 03.68"E to 87° 02' 45.81"E longitude and 23° 31 '38.68" North to 22° 57 ' North latitude (Fig.1).

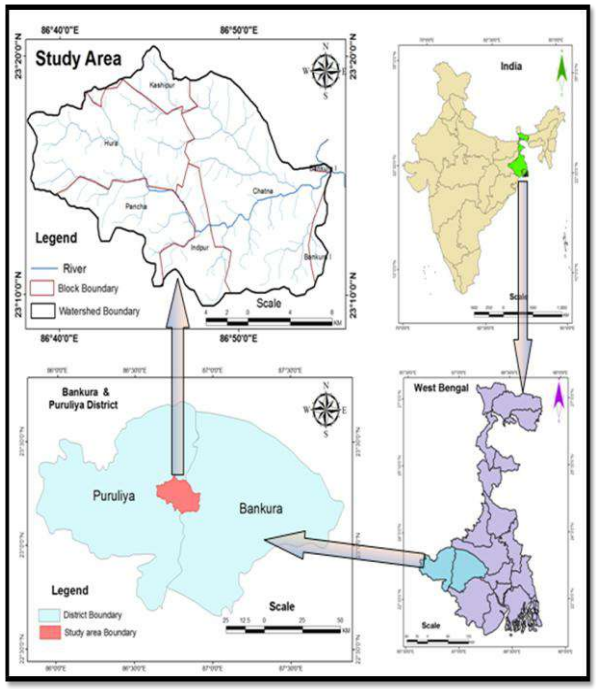

Fig. 1 Location Map

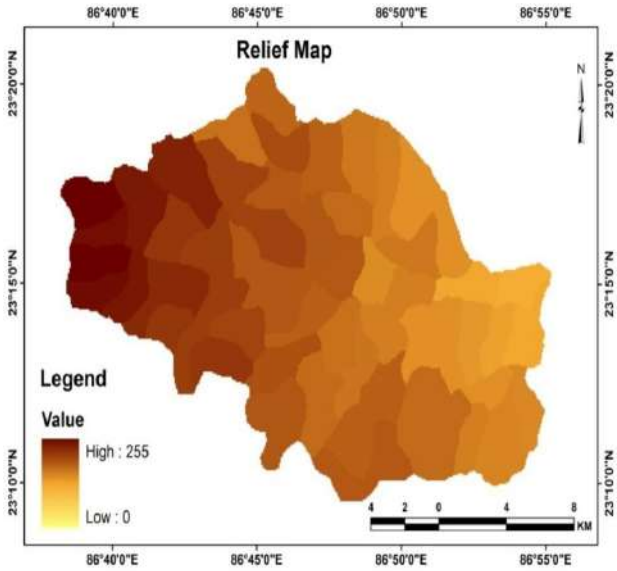

Fig. 2. Relief Map

Relief

The relief map (Fig. 2) of the study area shows that it is a plateau region .In the south western part of the study area elevation is very high (>200m), in the north east part relief is low, with a gentle gradient from west to east.

Slope

For each cell, Slope calculates the maximum rate of change in value from that cell to its neighbors. Basically, the maximum change in elevation over the distance between the cell and its eight neighbors identifies the steepest downhill descent from the cell (Fig. 3). Conceptually, the Slope function fits a plane to the z-values of a 3 x 3 cell neighborhood around the processing or center cell. The slope value of this plane is calculated using the average maximum technique. The direction the plane faces is the aspect for the processing cell. The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain.

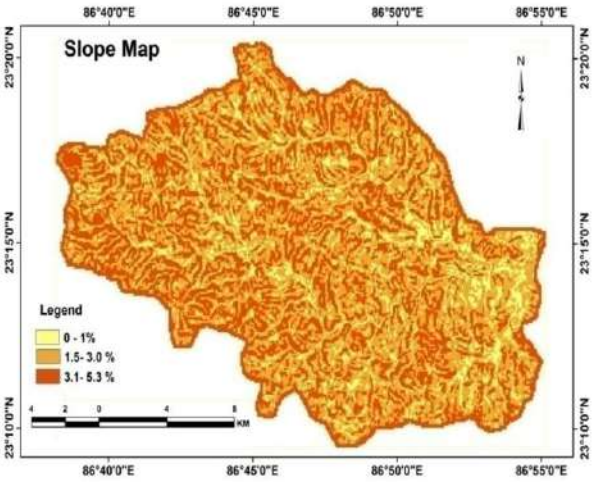

Fig. 3. Slope Map

Aspect

Present day of the study area to derive the aspect map from SRTM DEM are generate in Arc GIS software a raster surface option. So the Aspect map identifies the down slope direction of the maximum rate of change in value from each cell to its neighbors and Aspect can be thought of as the slope direction of the study area. The present values of the output raster in (Fig. 4) will be the compass direction of the aspect.

Soil

Soil is a natural product formed from weathered rock the action of climate and living organisms. A good understanding of soils with reference to their natural and distribution is essential to formulate any land base production system. Soil is diminishing resources whose loss/degradation is slow and not perceived readily (Fig. 5). Spatial distribution and variability of soils are mainly controlled by the geological and geomorphologic factors. In fact, the soils geographic distribution patterns could be identified more reliably from the association of the geomorphic environments [11]. The soil map of the study area has been prepared according to National Bureau of soil Survey and land use planning, Dept. of agriculture, Govt. of West Bengal.

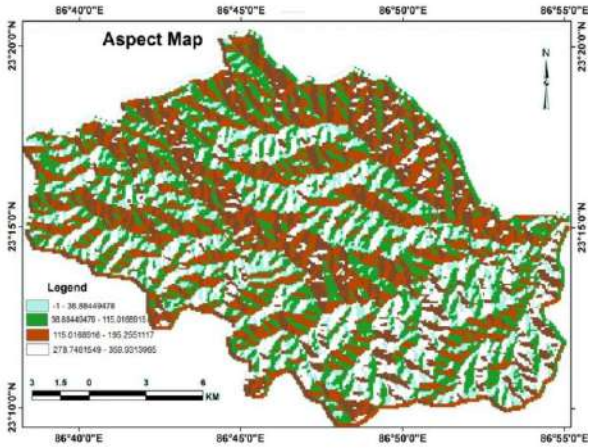

Fig. 4. Aspect Map

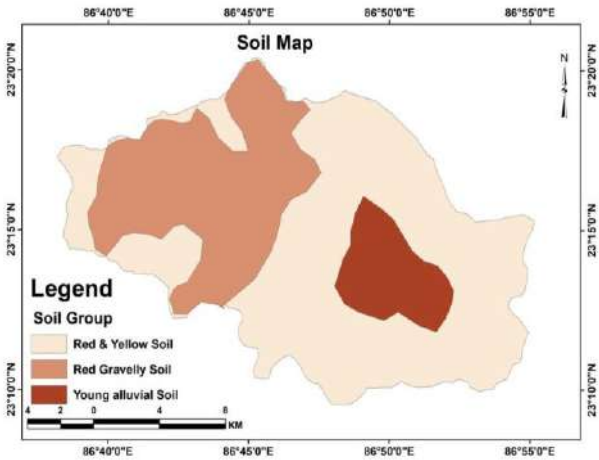

Fig. 5. Soil Map

Geology

The study area is under the Chhota Nagpur granitic gneisses complex, which is mainly constitute of Granite gneisses (cover most part of the study area) Pegmatite vein, quartz vein

Lateritic As far as lineament is concern; there is west-east lineament, identified in the imagery through the east of Amdih village. Present study reveals that the lineament curvilinear feature of a surface whose parts align in a straight or solidly curving relationship that may be the expression of a fault or other line of weakness the surface features making up a lineament (Fig. 6) may be geomorphic (caused by relief) or tonal (caused by contrast differences). Straight stream valleys and align segments of valleys are typically geomorphic expressions of lineaments.

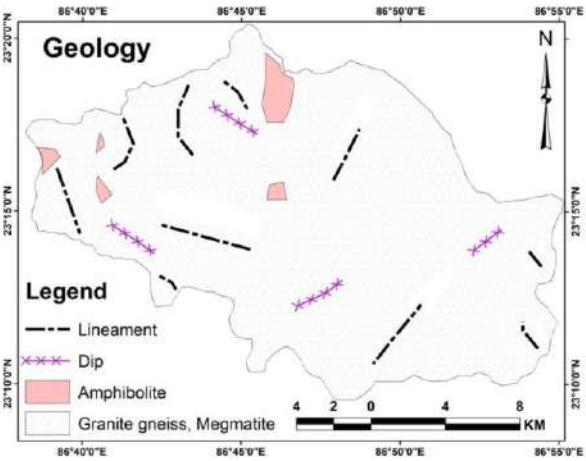

Fig. 6. Geology Map

Land use / Land cover

Land use is the surface utilization of all the development and vacant land on a specific point at a given time and space. Land use is the use actually made of any parcel of land, house, and apartments. In a rural areas tree crop and corn crop would identify the land use (Fig. 7), whereas orphaning, truck farming and grazing indicate a system of land utilization (Table. 1).

Structures

Check Dam: A check dam is a small, sometimes temporary, dam constructed (Table. 2) across a swale, drainage ditch, or waterway to counteract erosion by reducing water flow velocity. These structures will be constructed on rivers / drainage channel with alluvial bed and will be primarily used for providing irrigation facility by lifting water. At places existing, ongoing and future foot bridges may be used for storing water by providing wooden planks / steel shutters between the piers or through putting sand bags considering safety of the structure. In the study area there are 7 structures are suitable for check dam, in these Structure 12 & 18 number structures are not suitable because of no.12 structure runoff velocities is high and no. 18 structure is covering less area.

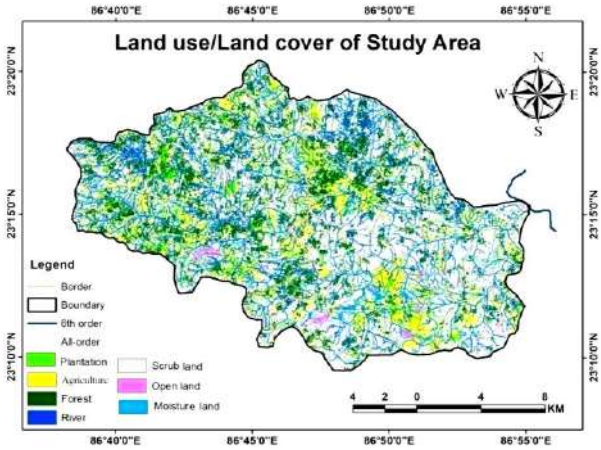

Fig. 7. Landuse and Landcover Map

Table No. 1	
Class Name	**Area In Hector**
Existing Agriculture	24636.16
Forest	9345.631
Open Fallow	17004.12
Water Body	17004.12
Agricultural Fallow	38114.4
Wet Fallow	11450.05
Sand	350.9386
River Channel	28240.35
River	4451.588

Table. 1. Total area LULC in Hector

Slope	Gentle (1-10%).
Drainage	1-3 order.
Soil type	Loamy Soil.
Land Use	Forest and Scrub land
Height	2 m

Table. 2. Check Dam Unit

Results and Discussion

Identification of the suitable site in the study area is used to prepare through the different thematic map (Work Flow chart) from remote sensing data and those are analyzed by Geographical Information System (GIS). All the maps are analyzed and identified for the suitable place of storing the surface water. For human uses pure water is most important. In this region people are facing many problems for harvesting water. Water harvesting mainly depend on some structure like Check dam, Nala bund, Small reserver, Gulley plug, Gabion structure etc. All structures may not be suitable for a particular area on the basis of their criteria. There are so many management plans for the harvesting of water, like identification of the suitable place for construction some structure. Here in the output result of the study shows three most structures suitable, i.e. Check dam, Nala bund and Drought pond. These harvesting structures are artificially recharged and those are purifying in fresh surface water. Suitable sites of water harvesting are analyzed and demarcated by using some thematic layers, i.e. Geology, Soil, Slope, Land use/Land cover.

Finally, selections of each structure have been done based on the thematic layers on the suitable sites. After selection, the unsuitability criteria of the structure based on stream order, stream length, area and flow direction has also been mentioned. The unsuitable structures are mentioned because of easy understanding of the structures which are not suitable for place. It is already mentioned that a check dam's criteria are suitable but the runoff velocity is high so in that case the structure is not suitable for that site. Remote sensing and Geographical Information System (GIS) is used for extracting information about the surface structure. Finally, a suitability map have been developed which shows the suitable sites for different water harvesting in the study area. The suitability map shows that there are multiple areas suitable for each structure. The details of the structures are mentioned below.

Suitability analysis

Check Dam: A check dam is a small, sometimes temporary, dam constructed across a swale, drainage ditch, or waterway to counteract erosion by reducing water flow velocity. Check dams themselves are not a type of new technology; rather, they are an ancient technique dating all the way back to the second century (From Wikipedia, the free encyclopedia). These structures will be constructed on rivers / drainage channel with alluvial bed and will be primarily used for providing irrigation facility by lifting water. At places existing, ongoing and future foot bridges may be used for storing water by providing wooden planks / steel shutters between the piers or through putting sand bags considering safety of the structure.

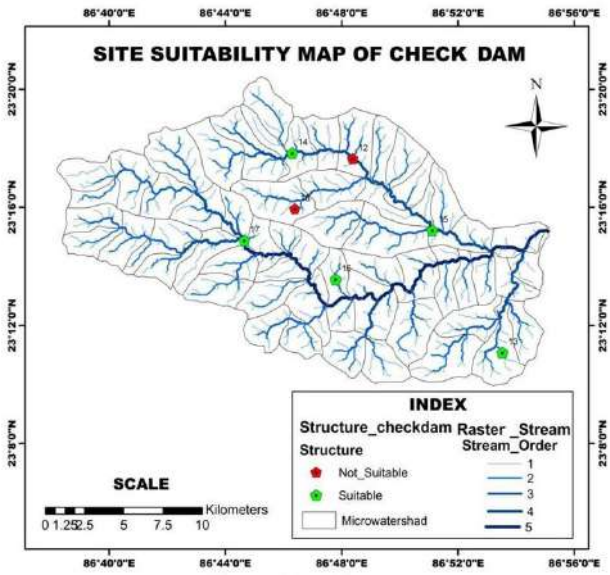

Fig. 8. Site Suitability of Check DAM

These structures can be used for the purpose of drinking water facilities to nearby villages, irrigation facility to the nearby areas with minimum lift [3]. The sites will be selected after detail survey & investigation as well as collecting the Remote sensing data and using the Geographical Information System (GIS) tools. These structures are low height structure about 2- 3 meter (Central Ground Water Board Ministry of Water Resources 2000). Where the stream waters are passes over the structure. A location select where exposed are available and reach is narrow should be preferred for reducing the construction cost [2]. Though the purpose of the structure is to be hydrological and technically feasible sites may be considered by local people are to be consulted prior to taking any action for implementation. The main emphasis on selection of a site will be proper use of water through people's participation. A properly designed, constructed, and maintained check

dam will reduce scour and channel erosion by reducing flow velocity and encouraging sedimentation. Check dams in conjunction with sediment basins are usually able to capture a large percentage of the sediments suspended in the water.

In this study area, check dam structure is mostly found suitable for surface water management plan. For this structure the criteria which are needed are matching in the region of Arkasha sub-watershed. In the study area there are 7 structures are suitable for check dam, in these Structure 12 & 18 number structures are not suitable because of no.12 structure runoff velocities is high and no. 18 structure is covering less area (Fig. 8). And the other structures are mostly suitable for Arkasha sub-watershed

The Advantage and Disadvantage of the Structure is given below.

Advantage of the Structure

- Check dams not only prevent gully erosion from occurring before vegetation is established, but also cause a high proportion of the sediment load in runoff to settle out.
- In some cases, if carefully located and designed, these check dams can remain as permanent installations with very minor repairs.
- Slowed water speed which reduce erosion and help to harvesting water.
- This dam can be used local available materials.

Disadvantage of the Structure

- These are temporary nature; many of these measures have to be repaired regularly.
- Temporary check dams are only suitable for a limited drainage area and benefits are limited.
- If designed incorrect so it may blocks fish passes.
- These types of structures are may not be constructing in high velocities of water.

Nala Bund

Nala bunds are embankments constructed across Nala for checking velocity of runoff, increasing water percolation and improving soil moisture regime. In fact Nala bunds and percolation tanks both terms are synonym. of Nala bunds can be constructed across bigger streams of second order and Nala bunds also should be preferably located in area where contour or graded bund of lands have been carried out. Mainly there are two type of Nala bund:

i. Earthen Nala bund (ENB).
ii. Cemented Nala bund (CNB).

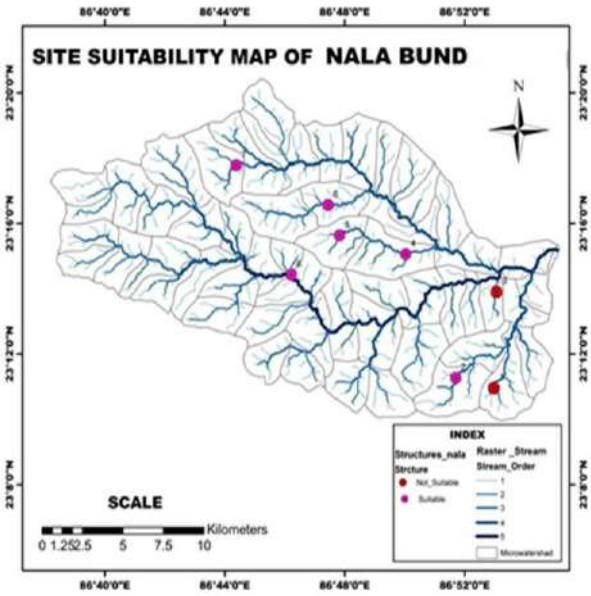

Fig. 9. Site Suitability of Nala Bund

ENB and CNB structure is to create a barrier to impound the water flow. The use of such structure can be provided water for drinking, domestic uses, agricultural purpose etc. The water conservation structures are divided only on the basis of construction materials used and related strength factor. A little variation of Nala bund is called cement bag structure, where the Nala bund materials used are cement bag filled with local materials like sand and stones. Nala bunds constructed by farmers to store water and collect sediments, creating a fertile small field where high value crops are grown.

In case of Nala bund in Arkasha sub-watershed this structure's criteria also matching so it is also an important structure for storing surface water. In the study area there are 8 structures of Nala bund, in the 8 structure 1 & 3 number structures are not suitable because of 1 structure is covering less area and no. 3 structure runoff velocities are high. The other structures are suitable for Nala Bund in the study area (Fig. 9).

Advantage

- Water bearing fractures generally available in the depth range of 6 to 15 meter.
- Cement grouting these fractures is sealed thereby arresting sub-surface run-off by way of cut-off wall.
- This is responsible for sub-surface run-off and due to this the structure does not store sufficient water.

Disadvantage

- This structure is not for long period.
- This structure is only suitable for Scrub land and Forest area.
- It is reconstructed after some days.

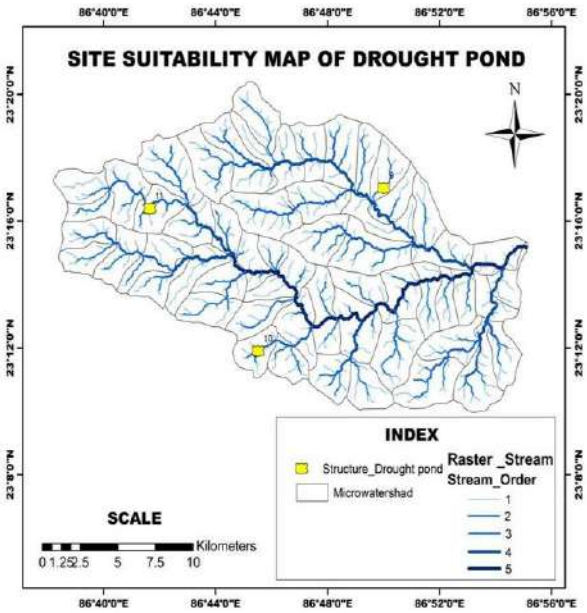

Fig. 10. Site Suitability of Drought Pond

Drought Pond

A drought pond for water storage is also called storage pond when it is constructed in scrub land and farm pond when it is constructed in the field or farm. The tank when excavated in the open and scrub forest it is referred to as forest tank. The prerequisite of the structures availability of the good catchment which can feed the low depression point to prevent excessive water accumulation in the pond and favorable spill out for overflow of water. If the spillway are not proper then the artificial ones are necessary [9]. Drought ponds are usually recommended in rain fed medium lands where water is not available for irrigation. The pond is kept the lower most corner of the field or on the downstream side on the field. The pond is most suitable for harvesting surface water and it is mostly used for agriculture purpose. The depth of the pond is about 2-3 meter and side slope as 1:1 [6]. In the Drought pond all structures are suitable for the region; these structures are mostly suitable for harvesting surface water in Arkasha sub-watershed (Fig. 10).

This study looks at the issues for management of surface/ sub-surface water. After investigation we observe that Bankura and Purulia has been facing severe problems water in agriculture, drinking purpose as well as human basic needs. It of be taken proper planning for harvesting or storage water. The suitable sites are selected using remote sensing data and for analyzing through GIS platform.

Finally the map (Fig. 11) shows that there are three structures are suitable for the area as well as it is also shows the suitable sites of the structures for storing or harvesting surface water in the Arkasha Sub-watershed.

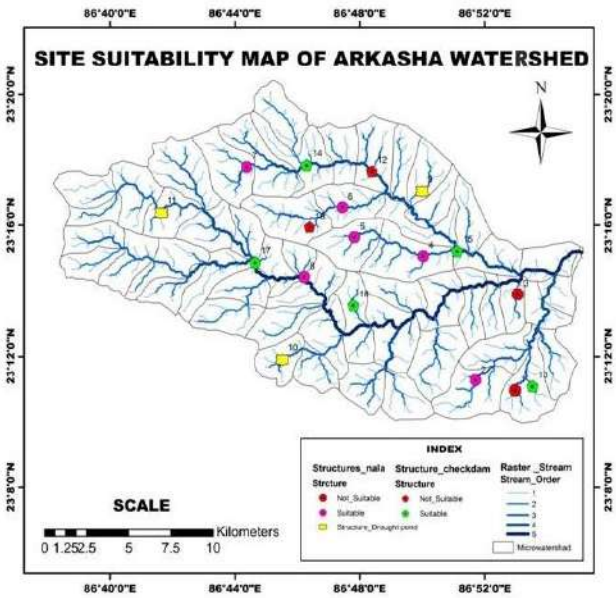

Fig. 11. Site Suitability Map

Conclusion

The remote sensing and Geographical Information System (GIS) technique has an important role in the management plan for the harvesting of water.

- The study has been done on the effectiveness of remote sensing and GIS in the identification and delineation the site suitability structures in Arkasha watershed.The output result of the study shows three most suitable structures i.e. Check dam, Nala bund and Drought pond.
- Finally, in this study area selection of each structures have been done based on the thematic layer on suitable site. But all structures may not be suitable for a particular area on the basis of their criteria.
- After selection, the unsuitability criteria of the structure based on stream order, stream length, area and flow direction has also been mentioned. The structure in some of the area is not suitable due to high volume of runoff.
- Finally, a site suitability map have been developed using different structures which shows the suitable and unsuitable site for harvesting surface water in the Arkasha watershed.

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