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Research Paper

Analysis of the abundance of abandoned tanks in Hambantota District, Sri Lanka using GIS techniques

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Abstract Around two thirds of the area in Sri Lanka is covered by the dry zone, which receives less than 1750 mm average annual rainfall, but not equally distributed over the land. Due to rainfall variations, dry zone of Sri Lanka faced periodic drought conditions in the past. On the basis of surface water availability, Hambantota District appears to be a highly affected area. Tanks have been constructed in order to harvest rainwater to overcome this problem. But, there are many abandoned tanks in Hambantota, which decrease the effectiveness and efficiency of water harvesting. In order to minimize the number of abandoned tanks, an analysis is carried out to find the cause for the abundance of abandoned tanks in the area. Integrating GIS techniques with the relevant data such as rainfall, topographic contours, spot heights, land use, temperature, geology, etc. gives an accurate and updated database, which helps to analyze the reason for the abundance of the abandoned tanks in the area, and hence facilitate the increase of efficiency and effectiveness of rainwater harvesting through a proper water management system.

1. Introduction

The average annual rainfall in Sri Lanka ranges from below 1270 mm to 5000 mm (Herath, 1985). Although Sri Lanka is considered as a tropical island, the annual rainfall is not well distributed over the island. Sri Lanka is traditionally divided into 3 main zones, according to the average annual rainfall variations, namely Wet Zone (receiving over 2500 mm of average annual rainfall), Intermediate Zone (receiving 1750–2500 mm of average annual rainfall) and Dry Zone (receiving less than 1750 mm of average annual rainfall) (Department of Agriculture – Sri Lanka, 2010). Nearly two thirds of the country is covered by the Dry Zone which receives less than 1750 mm of

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average annual rainfall. Due to these variations of rainfall, the Dry Zone of the country faces drought conditions from time to time. On the basis of surface water availability, Hambantota District [(5°58′12.33″N–6°34′47.33″N), (80°36′20.99″E–81°42′14.65″E)] appears to be a heavily affected area by the recent periodic drought conditions. Although many tanks are distributed over the District in order to harvest rainwater, by integrating the layers prepared by the Survey Department of Sri Lanka, it can be seen that most of the tanks in the area are abandoned today (Fig. 1).

Abundance of the abandoned tanks decreases the efficiency and effectiveness of the water harvesting as well as wastes a lot of national revenue, by incurring unnecessary expenditure to construct them. Therefore, investigation of causes for the abundance of abandoned tanks plays an important role to propose proper rainwater harvesting systems, and hence an efficient water management system.

Geological and soil conditions, infiltration, rate of evaporation, land use pattern, rainfall, improper location of tanks with respect to the catchments and drainage pattern, etc., can cause this occurrence of abandoned tanks.

Integration of Geographic Information System (GIS) techniques can give an accurate database which can be used to verify the proper locations to construct tanks in order to harvest rainwater according to the slopes and drainage pattern of the area and also to find out the cause of abandoned tanks due to the improper location of those tanks.

2. Objectives

The objective of this research is to use Remote Sensing and Geographic Information System (GIS) techniques to develop a methodology to determine the main reason for the abundance of abandoned tanks in Hambantota District and select the suitable areas for locating the tanks.

The available 1:50,000 data prepared by the Survey Department of Sri Lanka were inadequate to conduct this research for the whole Hambantota District with 100 feet interval contour data. Therefore, Suriyawewa District Secretariat area [(60°11′34.07″N–60°23′52.52″N), (800°55′4.36″E–81°4′48.05″E)] was selected as the project area considering its location within the Hambantota District and representing average climatic conditions of the district. The research was carried out by using 1:10,000 detailed digital data (5 m interval contour data) prepared by the Survey Department of Sri Lanka.

This methodology can be extended to the entire District, as Suriyawewa Divisional Secretariat area represents average conditions in the Hambantota District.

3. Methodology

The rainfall data of 17 rainfall stations and the temperature data of Hambantota District in the last 15 years were obtained from the Meteorological Department of Sri Lanka. The Average Annual Rainfall Map (Isohytal) of Hambantota District and Monthly Rainfall Maps were generated by interpolating the rainfall data using ArcGIS software.

Thereafter, the geology and soil maps of Suriyawewa area (National Atlas of Sri Lanka, 1988) were digitized by using ArcGIS software.

The lesser variation of rainfall within Suriyawewa area (Fig. 2) implies that there is no effect of rainfall on the abundance of abandoned tanks in the area.

The distribution of both abandoned and existing tanks in the same soil and geological conditions shows that the cause for the abundance of abandoned tanks is independent of the geology and soil conditions.

Further, settlement of a silt layer at the bottom of reservoirs in the dry zone of Sri Lanka seals the reservoir beds; hence prevents water leakages. As a result, the effect from

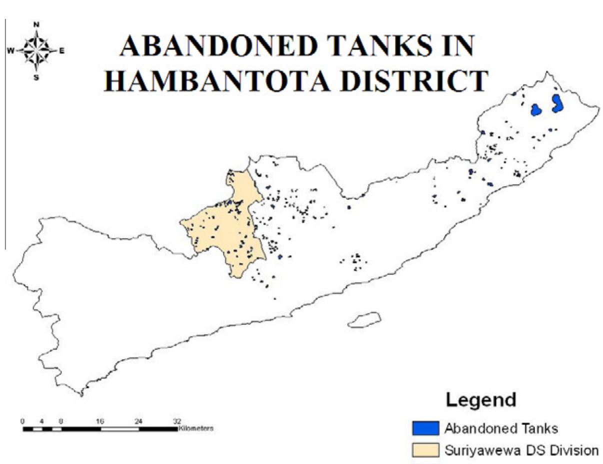

Figure 1 Location map of abandoned tanks in Hambantota District, Sri Lanka.

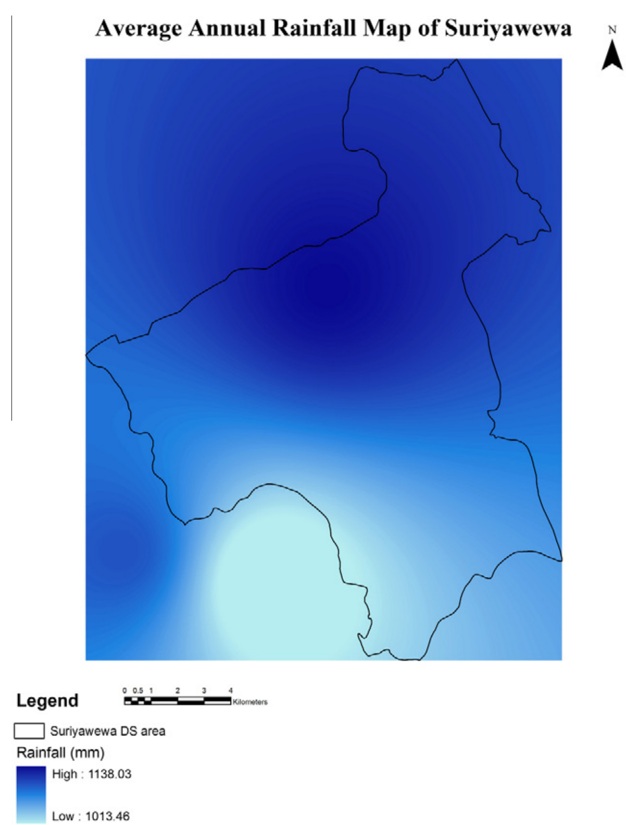

Figure 2 Average annual rainfall map of Suriyawewa DS area, Hambantota District, Sri Lanka.

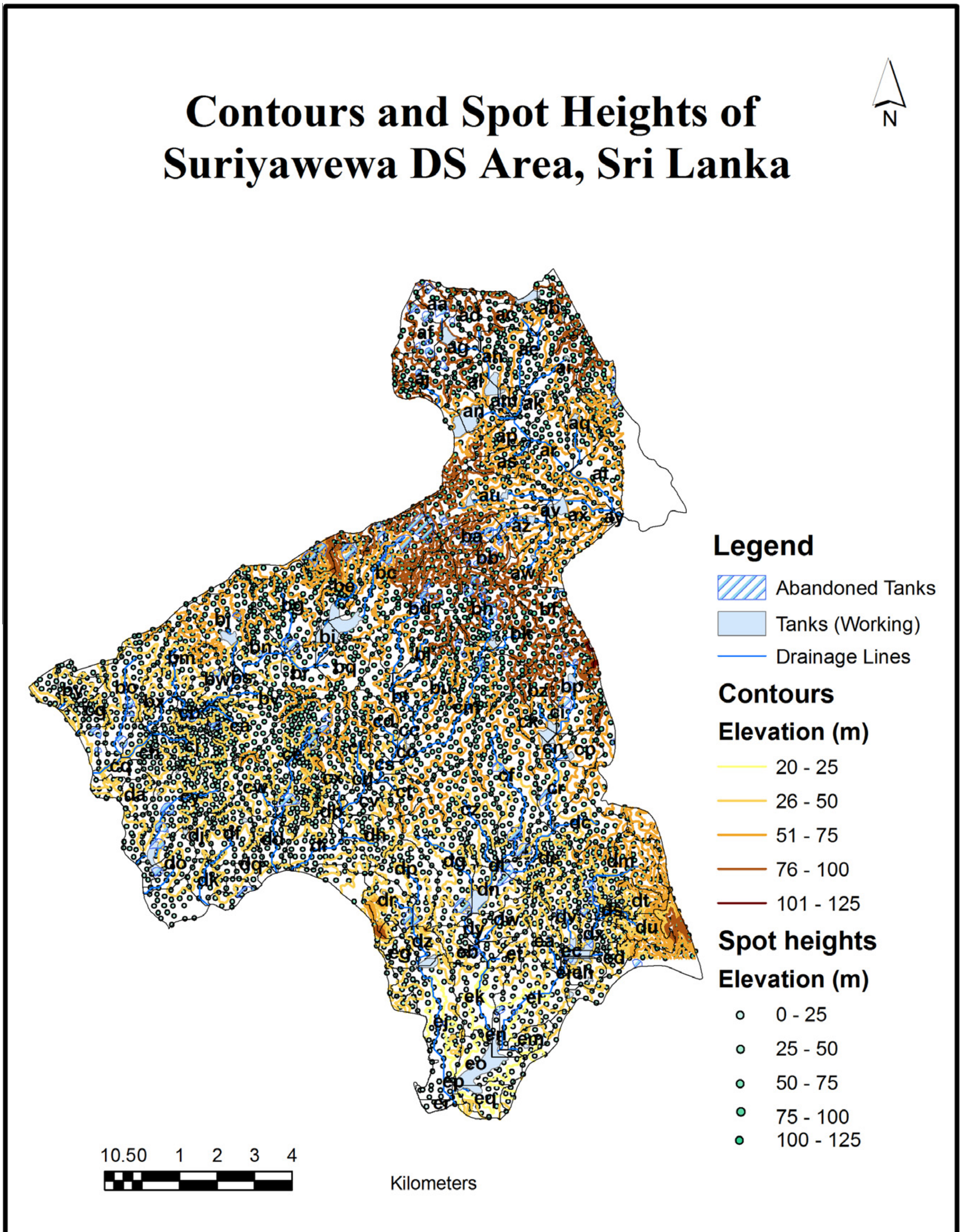

Figure 3 Map showing topographic contours and spot heights of Suriyawewa DS area of Sri Lanka superimposed with tributaries and tanks of the area.

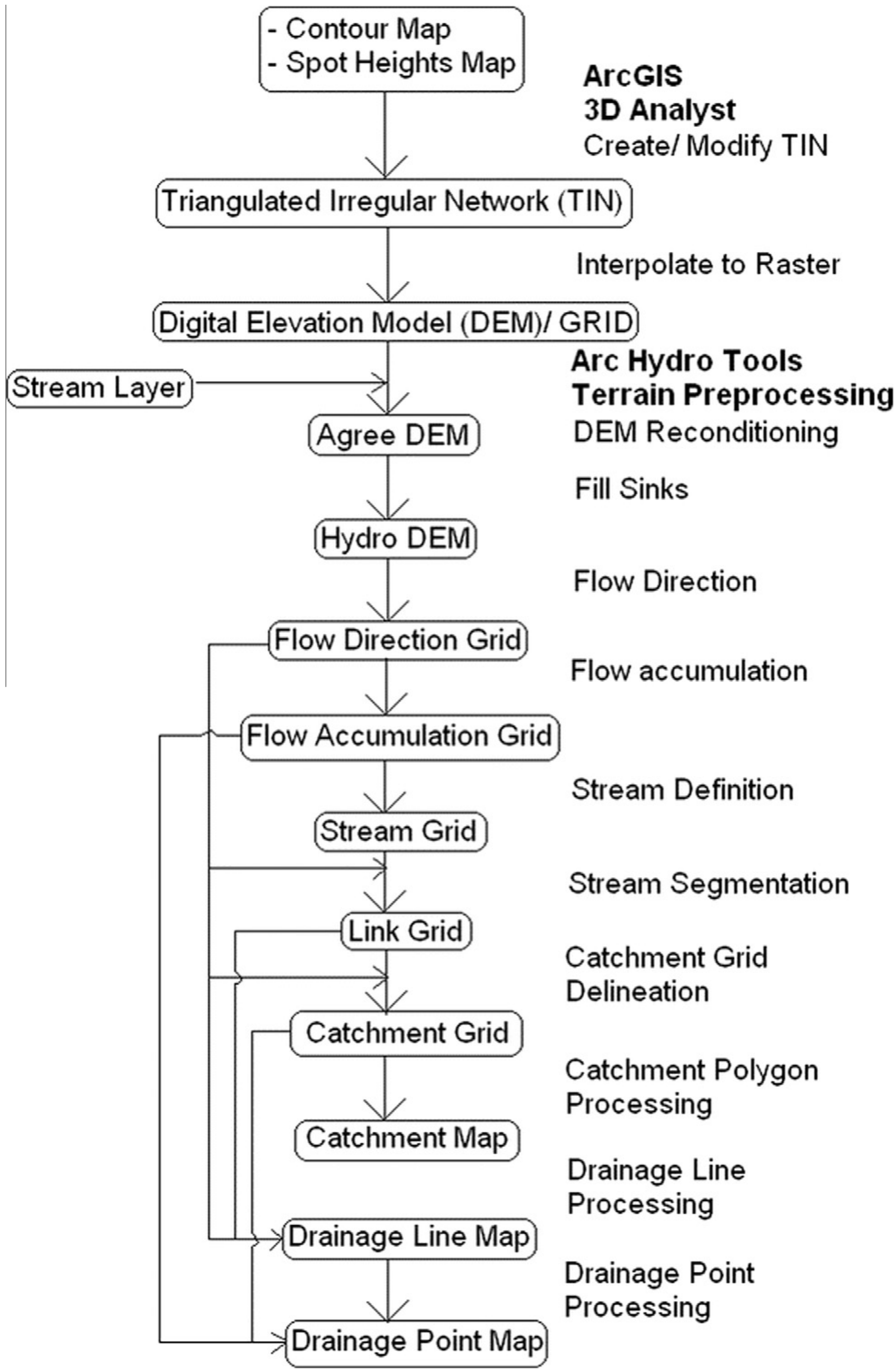

Figure 4 Flow sheet of the hydrological analysis of the Suriyawewa DS area, Hambantota District, Sri Lanka.

lithology and structures for the retention of water can be neglected for small and medium sized reservoirs in the dry zone of Sri Lanka.

Therefore, the cause for the abundance of abandoned tanks must be mainly due to improper location of tanks in the area.

The contour map and the spot height map of Suriyawewa DS area were developed by using 1:10,000 digital data of Suriyawewa obtained from the Survey Department of Sri Lanka. Remote sensing and GIS techniques have been utilized for digital data preparation by the Survey Department of Sri Lanka. The Triangulated Irregular Network (TIN) of the terrain of Suriyawewa area was generated using the contour layer and the spot height layer. Thereafter, the TIN was converted to a Digital Elevation Model (DEM) of the terrain of Suriyawewa by using ArcGIS 3D Analyst. ArcGIS 9, Using Arc Map (Harlow et al., 2000) and ArcGIS9, Using ArcGIS 3D Analyst (Bratt and Booth, 2000) were used as references in working with ArcGIS software. Further, by using Arc Hydro tools (Merwade, 2008), the AgreeDEM was generated using

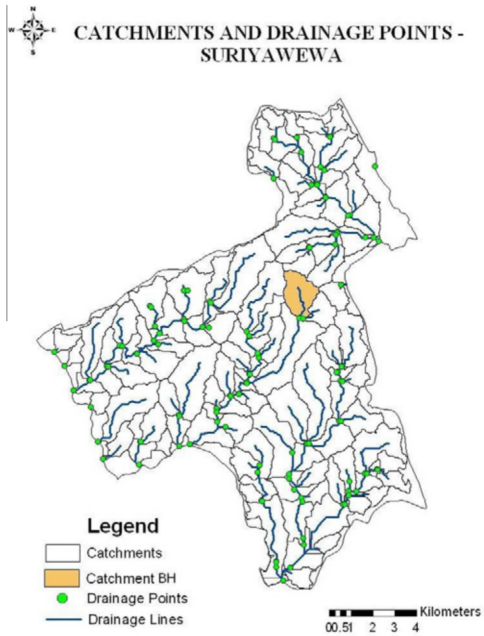

Figure 5 Map showing catchments and drainage points of the Suriyawewa DS area, Hambantota District, Sri Lanka.

the DEM and the stream layer in the area by using the DEM reconditioning function, which pushes the raw DEM along the streams to generate a distinct profile of streams, which are not in the raw DEM. Next the AgreeDEM was hydrologically corrected by using fill sinks function and the HydroDEM was developed. The fill sinks operation eliminates the obstructions to a smooth flow of water, which occur when a single cell is surrounded by cells with higher elevation, forcing water to be trapped in that cell.

Subsequently, the Flow Direction Grid was generated by using the HydroDEM. The Flow Direction Grid indicates the direction of flow in the area, by the values of cells which represent the direction of the steepest descent from that cell.

Further, the Flow Accumulation Grid was developed using the Flow Direction Grid, which indicates the number of cells accumulated in the upstream to each cell. Using the Flow Accumulation Grid, the Stream Grid was generated adopting the default threshold value (1410.48) calculated by the software, which represents one percent of the maximum flow accumulation.

By using stream segmentation function, the Link Grid was generated using the Flow Direction Grid and Stream Grid. This assigns a unique identifier to each segment along a stream, separated at each junction. Further, by using the Flow Direction Grid and the Link Grid, the Catchment Grid was developed. Catchment Grid indicates which catchment each cell belongs to.

Subsequently, the Catchment Map and the Drainage Line Map were developed by using Catchment Polygon Processing, Drainage Line Processing and Adjoin Catchment Processing respectively, which converted the raster data developed into vector data.

Contours and spot heights of the Suriyawewa area have been superimposed with tanks, tributaries and catchments in Fig. 3 to give a clear picture of the overall scenario of the area with ground elevation.

The drainage lines related to each catchment were generated by using the Flow Accumulation Grid and the Catchment Grid. Subsequently, by using Drainage Point Processing Function, the Drainage Point Layer was developed. This methodology followed is given in a flow chart in Fig. 4 (Senanayake et al., 2009).

These Drainage Points locate the outlet point of each of the catchments. Hence, the runoff of the individual catchment leaves it from this point, after being subjected to losses due to infiltration and evaporation. Therefore, at these drainage points, the water collected at the upstream of the catchment can be harvested.

Nevertheless, when analyzing the tanks, catchments and the drainage points of the Suriyawewa Area, it becomes clear that the main cause of the abandoned tanks is improper location.

4. Results and discussion

If we consider catchment BH [(6°18′21.59″N–6°19′34.25″N), (81°1′13.58″E–81°2′8.90″E)] from the catchment map (Fig. 5) as an example (Fig. 6), there are 6 tanks located upstream of the outlet point of the catchment, and located at higher elevations in the catchment. The best point to locate a tank to harvest the runoff in this catchment is point A. It can be seen that the working tank 7 has been constructed at the outlet point B of the catchment BK adjacent to the catchment BH with no tanks at its upstream. This working tank (Wewegamma wewa) was field verified for spatial accuracy using GPS survey. Therefore, this shows that the reason for the abandoned tanks in catchment BH, and similarly in most of the catchments in the area, is due to improper location of tanks at the uppermost area of the upstream of catchments. It prevents the runoff to fill the tanks at the most suitable locations at lower areas of the catchment, where high percentage of runoff can be collected.

Also, it can be clearly identified that the tanks 1, 2, 3, 4 and 5 in catchment BH cannot harvest rainwater, as they are located at the upper most area of the drainage lines or/and far outside of the drainage lines. Also, there is no runoff coming down from any surrounding catchment to that area. Therefore, a large runoff from the catchment cannot be harvested by those tanks, due to their improper location.

However, the working tank at the outlet point of the adjacent catchment BK shows that, if the tank is properly located close to the outlet point of the catchment, it can harvest the runoff upstream to that tank. Consequently, the water harvested by the tank can be used in the downstream command areas for agriculture and domestic uses.

Similarly, when concerning catchments BE and BC (Fig. 7), it can be seen that the tank 1 (New Suriyawewa) is located at the outlet points of the two catchments, hence it receives a high amount of runoff. Therefore, tanks 1 of the catchment BE harvests a large amount of rainwater and provides water for the paddy lands located downstream to the tank. At the same time, tank 2 of the catchment BE is abandoned, as it is located at the uppermost area of the catchment, where it does not receive any considerable runoff. Similarly, tanks 3, 4, 5 and 6 of the catchment BC are abandoned due to locating them at the uppermost area of the catchment. However, still catchment BC can collect runoff water from the large area below the abandoned tanks, which is finally harvested by tank 1. New Suriyawewa tank was field verified for spatial accuracy to confirm the results.

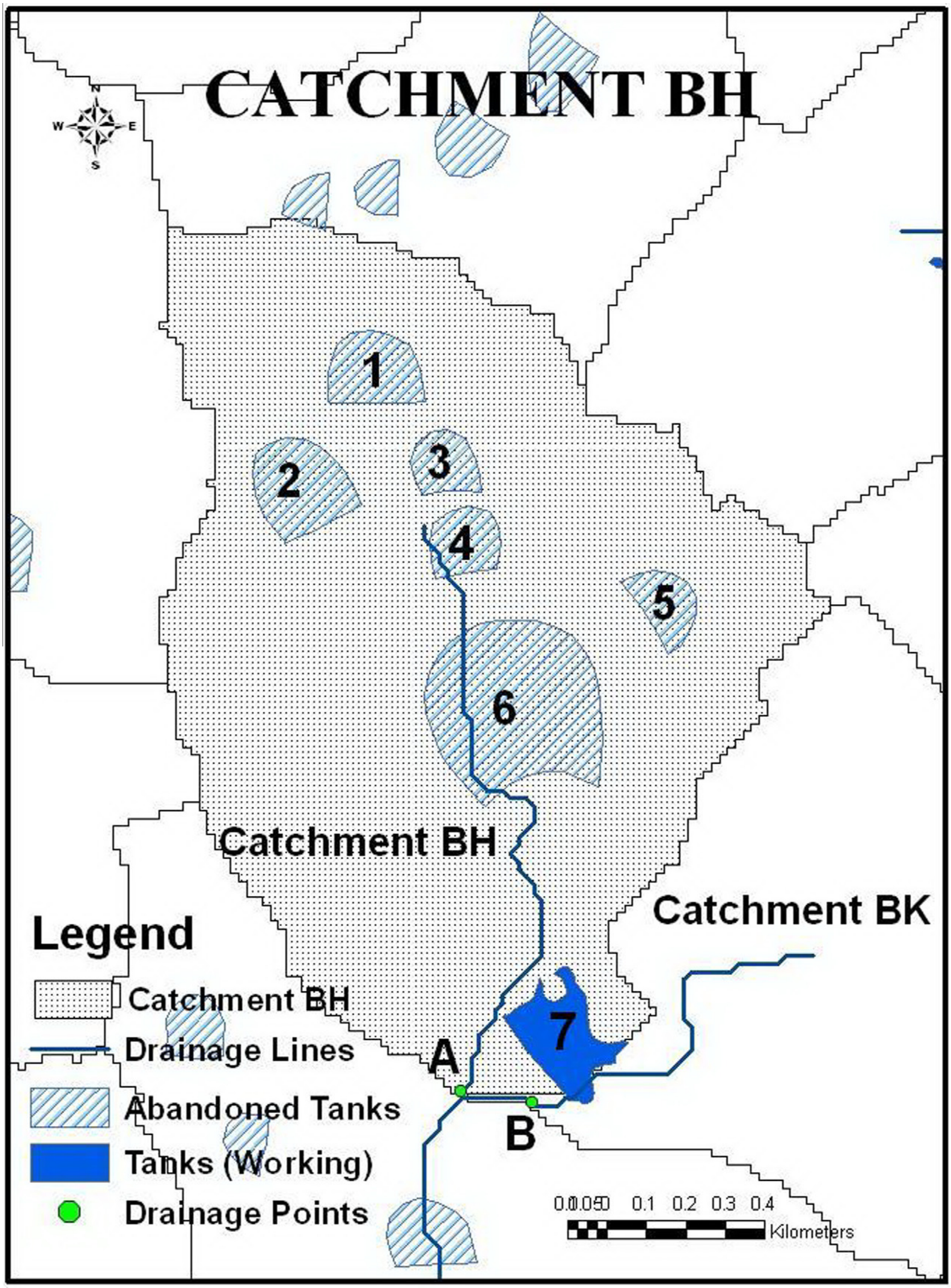

Figure 6 Map showing catchment 'BH' of the Suriyawewa DS area, Hambantota District, Sri Lanka.

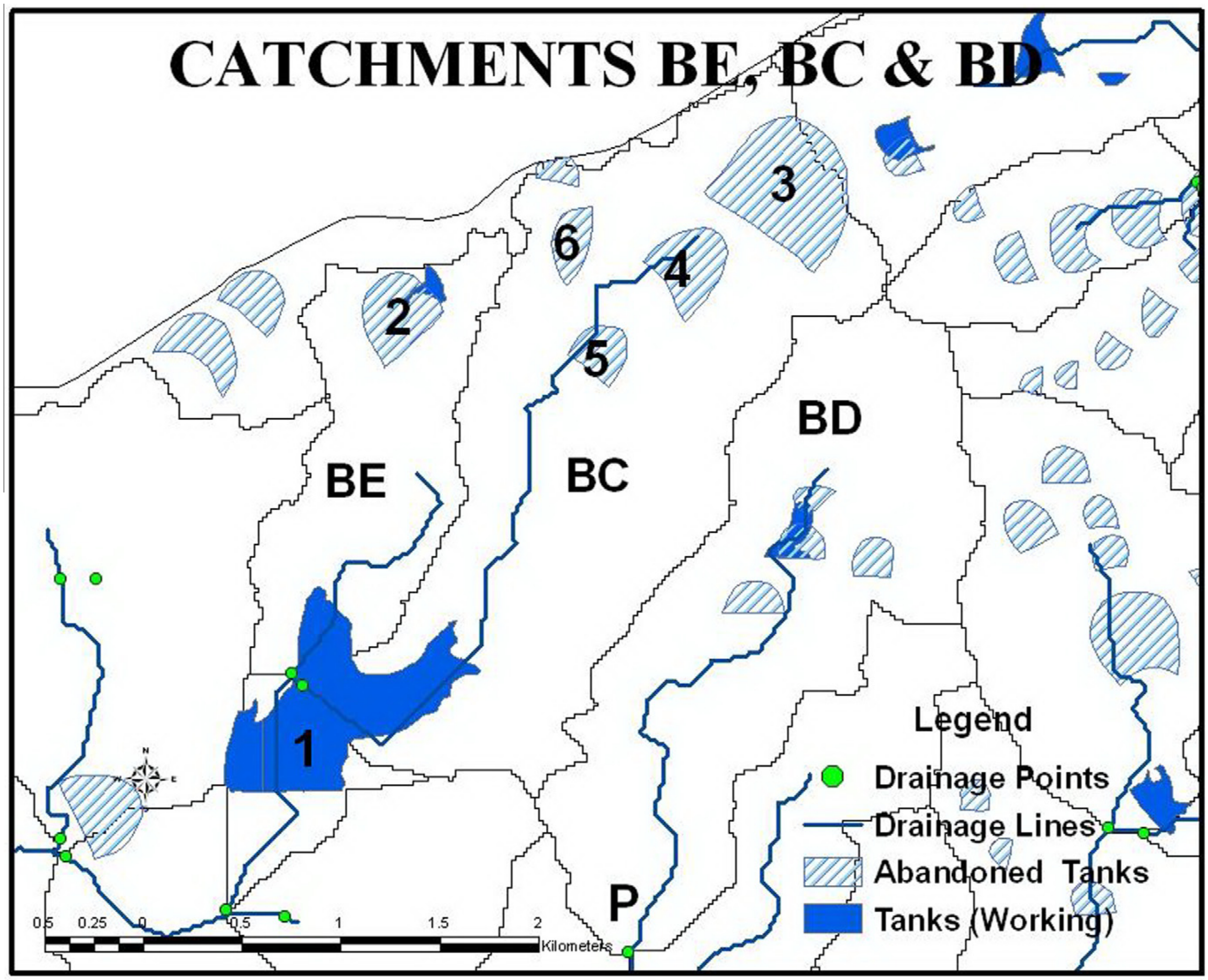

Figure 7 Map showing catchments BE, BC and BD of the Suriyawewa DS area, Hambantota District, Sri Lanka.

When looking at catchment BD (Fig. 7), it can be seen that few abandoned tanks are clustered around the uppermost area of the drainage line, where no considerable runoff can be collected. However, it is clear that, if a tank is located at the outlet point of the catchment (P), a large amount of run off can be collected from the catchment, if the other relevant conditions are suitable for the construction of a tank (geological conditions, soil, land use, rainfall, etc.).

Randomly selected abandoned tanks in the area were field verified for the spatial accuracy of Survey Department data.

Therefore, by proper location of tanks, the abundance of the abandoned tanks can be minimized. Hence, the national revenue can be saved, and the effectiveness and the efficiency of rainwater harvesting can be increased.

Also, it is recommended to extend this methodology to identify the most suitable sites to locate tanks to optimize rainwater harvesting in the area. The same methodology can be adopted by using local parameters to identify the potential sites for rainwater harvesting in the dry zone of the country.

5. Conclusion

With the increase of population and due to the high withdrawal rates of available water resources, a severe water stress condition can be predicted in the near future (Alcamo et al., 2000).

Hambantota District in Sri Lanka has periodically faced water scarcity conditions in the recent past, and this condition could get worse in the future with the global water stress conditions, human activities and interference with the nature. Therefore, a proper water management system as well as preservation of the existing water resources is a must to overcome this problem.

The abundance of the abandoned tanks causes wastage of a lot of national revenue and decreases the efficiency and effectiveness of water harvesting process. Identification of the cause for this will help to minimize the number of abandoned tanks in the area, and increase the effectiveness and the efficiency of the rainwater harvesting.

Integrating the data with Remote Sensing and Geographical Information System techniques provides an accurate and updated database, which can be used for quick analysis, overview and identification of the proper locations.

In Hambantota, the main cause of the abundance of the abandoned tanks can be identified, by the use of Remote Sensing and GIS techniques, as the improper location of the tanks, with respect to runoff and catchments, especially in the form of constructing many tanks at the upstream of the drainage lines inside a single catchment.

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