

# Using Geospatial Information Component to Monitor the Watersheds along the Densu Basin in Ghana

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## Abstract

The Densu basin is a coastal river catchment in southern Ghana and a typical rural community like all other rural settlements in Ghana. It is the only basin amongst 43 other basins of the country that supplies water to two regional capitals of Ghana, namely, the capital city of Ghana, Accra and Eastern regional capital, Koforidua. The qualities of these water resources vary naturally and widely depending on climate, season, and the geology of the bedrock, as well as anthropogenic activities. The primary aim of this research is to determine data requirements for efficient and cost-effective development of a Geographic Information System (GIS) to map and detect the extent of the sources of the watersheds and how to protect the environment for continuous supply of water. Among the Nine catchment areas, only one catchment WSA\_05 (Koforidua Township) was determined to have a very high risk of being vulnerable and therefore required urgency to protect environment for continuous supply of water. Four catchment areas WSA\_02 (Weija Dam), WSA\_03 (Apedwa-Asafo), WSA\_06 (Suhum) and WSA\_09 (New Tafo) were determined to have a high risk of being affected and therefore there was the need to protect the environment for continuous supply of water. Ghana as a country will have to take a responsible step in protecting its water body and its environment to enable continuous and sustainable supply of water to its citizens. This study therefore reveals the state of the water users and how urgent its environment needs to be protected.

## Keywords

Watershed, Geographical Information System (GIS), Densu Basin, Water Service Areas (WSA), Land Use Land Cover (LULC)

## 1. Introduction

The watersheds for Densu River for some time now are experiencing cases of drought due to climatic variability and a number of factors such as poverty. This comes at the period when the need for consistent geospatial assessment of environmental impacts of severe climatic conditions of the river along with other problems has been dominated by food security. The environmental challenges in the new millennium are more intense than before, and this is by virtue of the fact that the existing problem is now changing from local to regional and even to global. The activities carried out by humans are expanding day by day which is causing major effects on almost all the Earth's systems [1]. The watershed which is an integrating point serves as the suitable spatial arrangement and functional piece for supervising difficult problems [1].

In view of the difficult nature of natural and human systems, the use of geographic information to understand and predict the future conditions of watershed has been on the increase. In recent years, Geographic Information System (GIS) has been applied in management of watershed, including assessing the conditions of watershed by using models to determine the impacts of activities on the quality of water and also analyze the impacts of other management options. It has become very necessary to develop efficient flood risk management models as a result of abnormal weather conditions and global warming occurring in recent years. A substantial change has been seen from structural defense against flood to a more robust approach which includes the adaptation of right land use, agricultural and forest practices [2]-[6]. GIS and remote sensing provides an excellent source of data, which can be used to update and analyze changes that occur geospatially in a more resourceful manner [7]. Remote sensing technique can be used to track watershed attributes and land use with little limitations [8]. The act of combining data management in GIS and the analysis of its watershed are being used by environmental modelers for some time now. This capability can never be ignored in the design of data infrastructure which is core in analysis of watershed [9], and the conservation of natural resources to sustain development [10]. Research in the area of watershed is very difficult to undertake in poor communities because it is mostly affected by inadequate data infrastructure. This condition results in the widening of the geo-spatial gaps as well as hindering the monitoring of watersheds [11]. However, various studies have been conducted in the application of geospatial information system in watershed management. Prakash [12] identifies the capability of using GIS in management of a basin and also ensuring the decrease in the destruction of future resources by adopting appropriate conservation measures. This paper presents the need for using Geographical Information System to detect the extent of the sources of the watersheds and how to protect the environment for continuous supply of water to the user.

## 2. Study Area

The Densu River passes through some densely populated towns in Ghana. The quality of land and water of the basin is being destroyed by unlawful practices carried out in areas where the basin traverses. The Densu basin lies between latitude 5°30'N - 6°20'N

and longitude 0°10'W - 0°35'W at the southern part of Ghana (**Figure 1**) [13]. It is bounded to the north by Volta basin and the east by the Odaw basin. It is also bounded to the northwest and the west by with the Birim basin and the Ayensu and Okrudu basins respectively. The topography of the basin is such that, it has steeply dissected landscapes with hilly and rolling land to the north. The southern part is characterized by flat coastal plains with slopes and erosion surfaces that vary from 30% in the upper sections to less than 2% at the coast. The area of the basin is about 2600 km<sup>2</sup> and it takes its source from the Atewa range [14]. It flows from the upstream sections in an easterly direction towards the Akwadum-Koforidua area and it gradually changes its course and flows in the southerly direction into the Weija reservoir in Accra, which is the main source of water supply for the Accra suburbs. The Densu basin has a total length of about 120 km and has five tributaries which include Pompon, Kuia, Adaiso, Dobro and Nsaki rivers. About 72% of the northern part of the basin falls within the Eastern Region, with 23% falling within the Greater Accra Region and the remaining 5% falling within the Central Region. The people in the rural areas practice agriculture as their main source of employment [14].

The ecology of the Densu basin which used to be moist semi-deciduous forest with lots of rich flora and fauna has been changed to forest ecology at an increasing rate by virtue of human activities. The degradation of the forest has intensified with also an increase in shift of the land use which is caused by “urbanization” in the eastern corridor of the basin starting from the Weija area through Nsawam to Koforidua. The Densu basin has three types of vegetation zones, and the north-eastern section is the forest land which is de-vegetated by agricultural activities. The second zone is made up of scattered trees developing into areas of shrub and grassland. The third vegetation zone is the coastal savannah zone which is at the extreme southern section of the basin [14]. Also this basin falls under two distinct climate zones. The first zone is the dry equatorial climate of the south-eastern coastal plains and the second zone is the wet semi-equatorial climate which is at the extreme north of the basin. The two climatic zones are characterized by a bi-modal rainfall regime with different intensities. The main rainy season extends from April to July with the peak in June. The second which is the less intense rainy season occurs between September and November [14].

### 3. Methodology

Datasets from River basins of Ghana (layer), Data on water users, River bodies (layer), The settlement (layer), NDVI 1982, 1992 and 2002 information from maps produced [15] was used to confirm the existence of water bodies and Land use Land cover maps (Hard copy map). Each of the intake points of the water users for the various sites was compiled for each of the watershed in a vector-based GIS. A vector model was chosen for data development and analysis because it provides an excellent platform for development and mapping of points (e.g. water users site) and lines (watershed) data as well as for spatial data analysis. A thin layer was created out of the contour layer in Arcscen. The layers were displayed to enable digitization of watershed for all the water users in

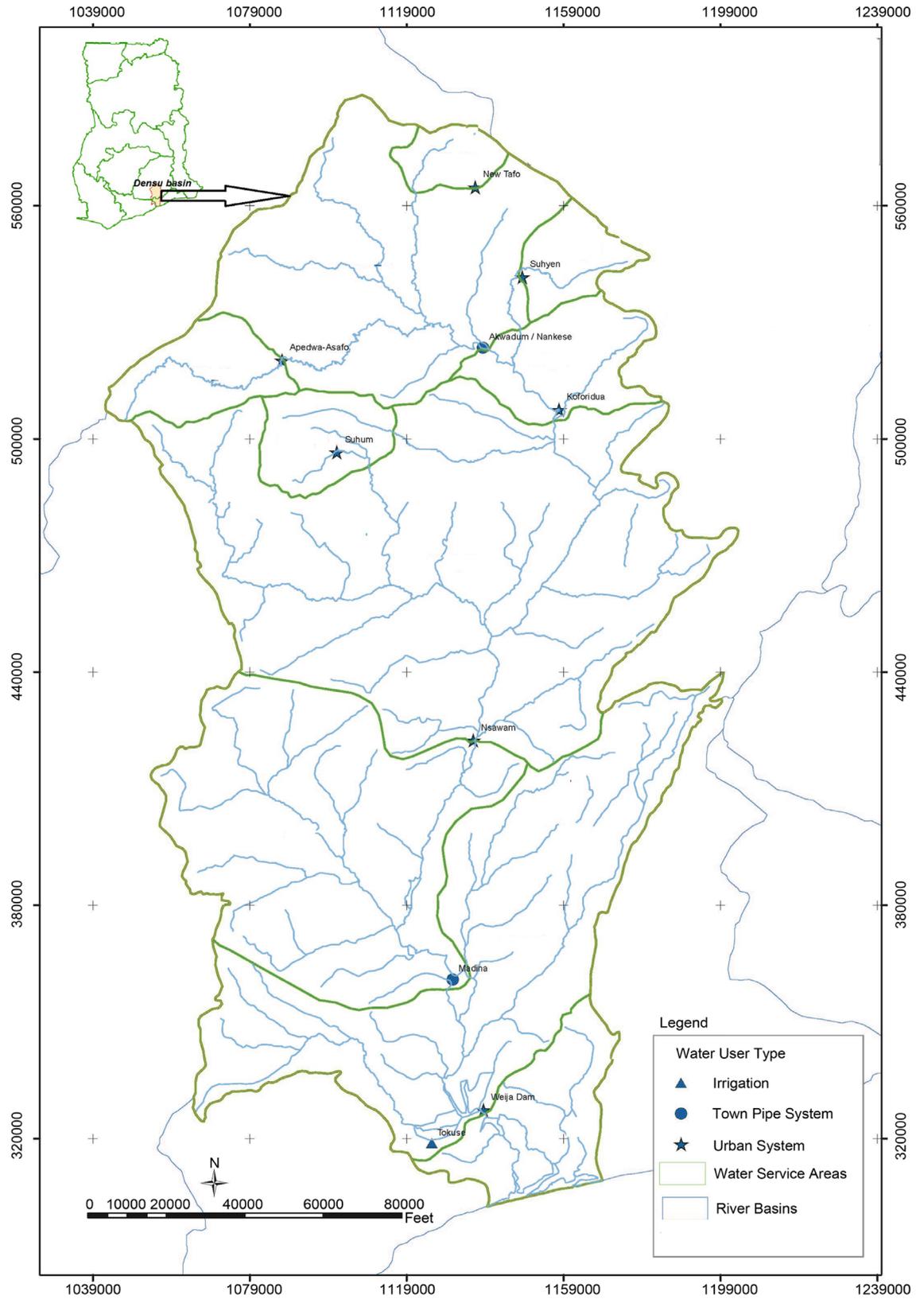


Figure 1. The Densu basin and some sampling communities [14].

the Densu Basin. The hard copy map of the project area was scanned and digitized. Georeferencing was done using the topographical data on roads, towns and localities. The attributes covering the digitization was populated. A geo-database was then created after which a GIS map was produced (Figure 2).

#### 4. Results and Analysis

A composite GIS map of the Densu Water Service Area (WSA) is produced. The map consists of nine catchment areas spreading from the Eastern region to the Greater Accra region with their water user information. Three major water user types is used in all the nine communities (which include town pipe, urban system and Irrigation). Urban system is predominantly available in most of the catchment areas along the Densu Basin WSA (Figure 3).

An application interface was created for easy use for policy makers, Managers of water users, who need to be abreast themselves with information on the Densu River Basin. On the Interface is a slider which helps in making queries on the rankings on the vulnerability of the various service areas. The red square point on the maps (Figures 4-8) indicates the ranking of the water services area when the slider attains a particular rank value of the R\_Total (sum of all relative rankings). When the slider is pushed from

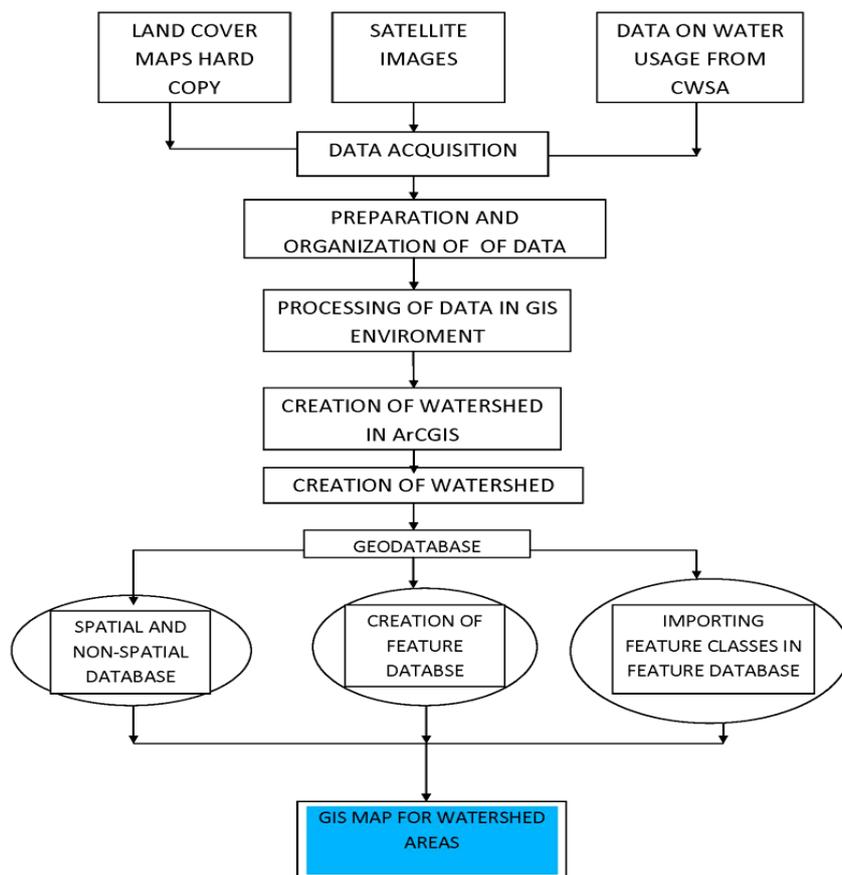


Figure 2. Flow chart of methodology.

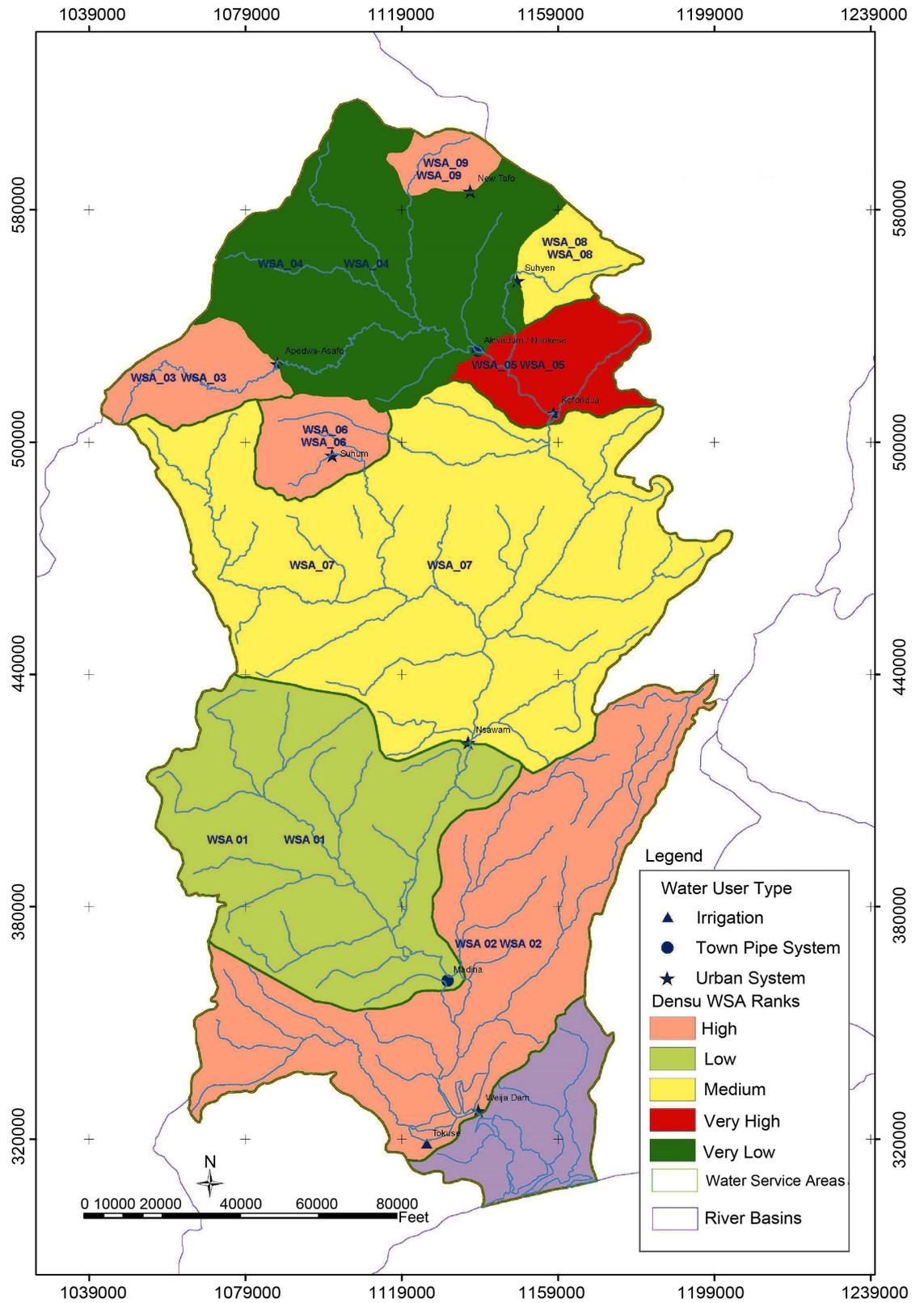


Figure 3. Image showing the map of Densu Water Service Area and its Water User.

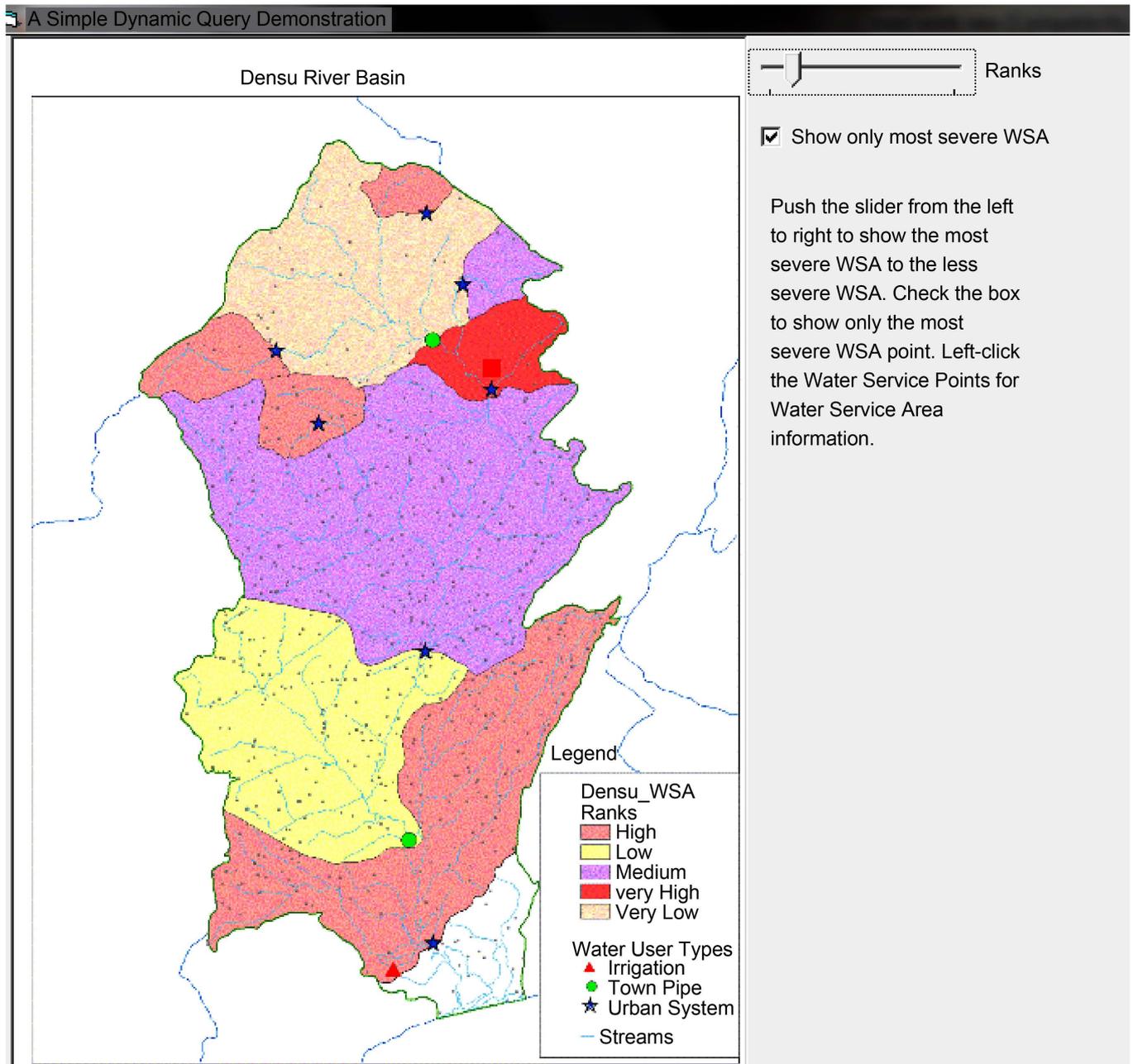


Figure 4. Showing the very high rank WSA (ranking value of 3).

the left to the right, it will display the most vulnerable (very high) water service areas to the less vulnerable (very low) water service area. After determining the vulnerability of each water service area is indicated by a rectangular box indicator, information about them can be ascertained by right clicking on the box. The information is shown on a bar at the lower end of the interface. The information shown entails the major water user and the population of the area.

The Nine catchment of WSA in the Densu Basin were classified into six major LULC types as shown in Table 1 and Table 2. Each of the LULC type was assigned a value

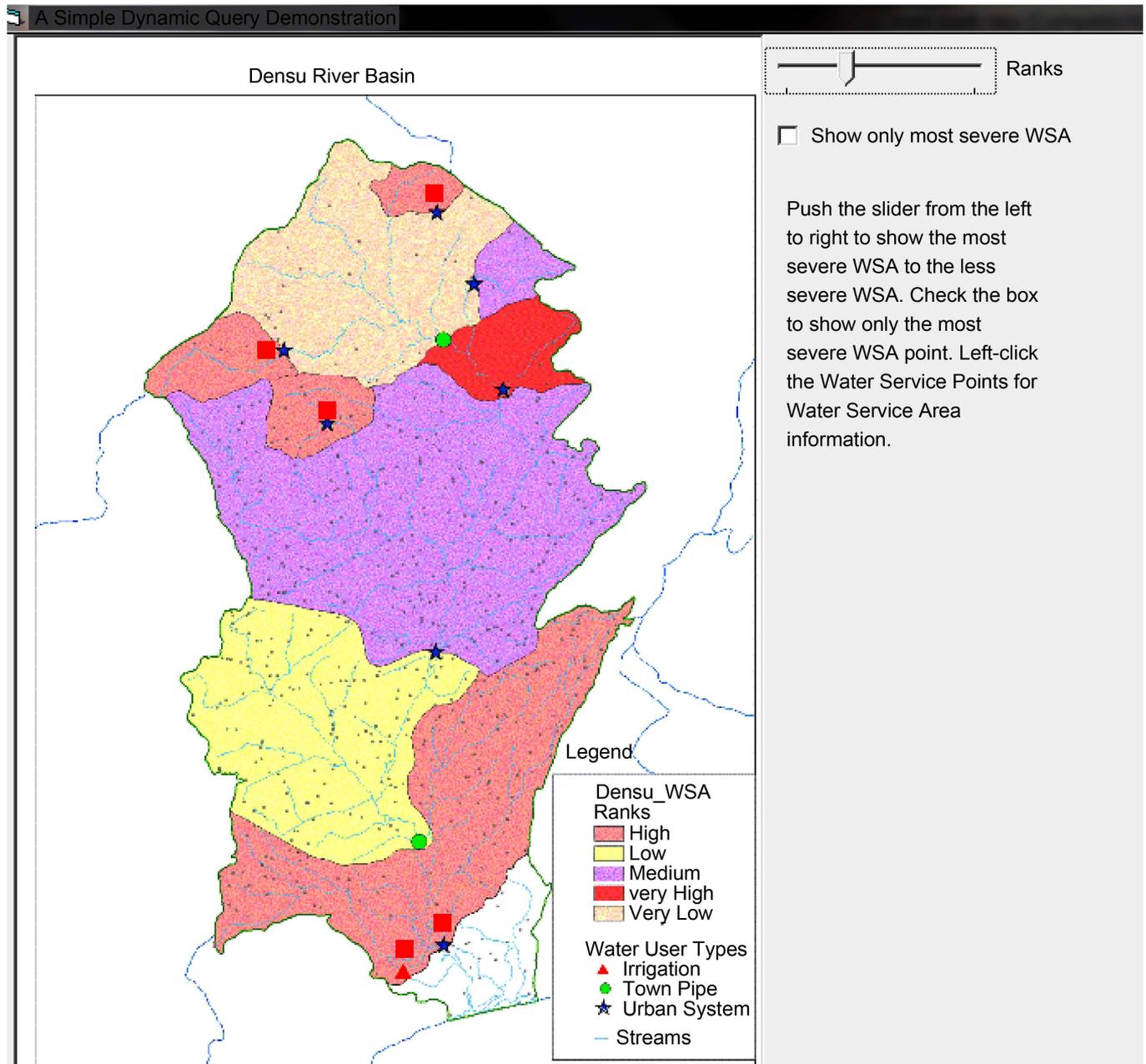
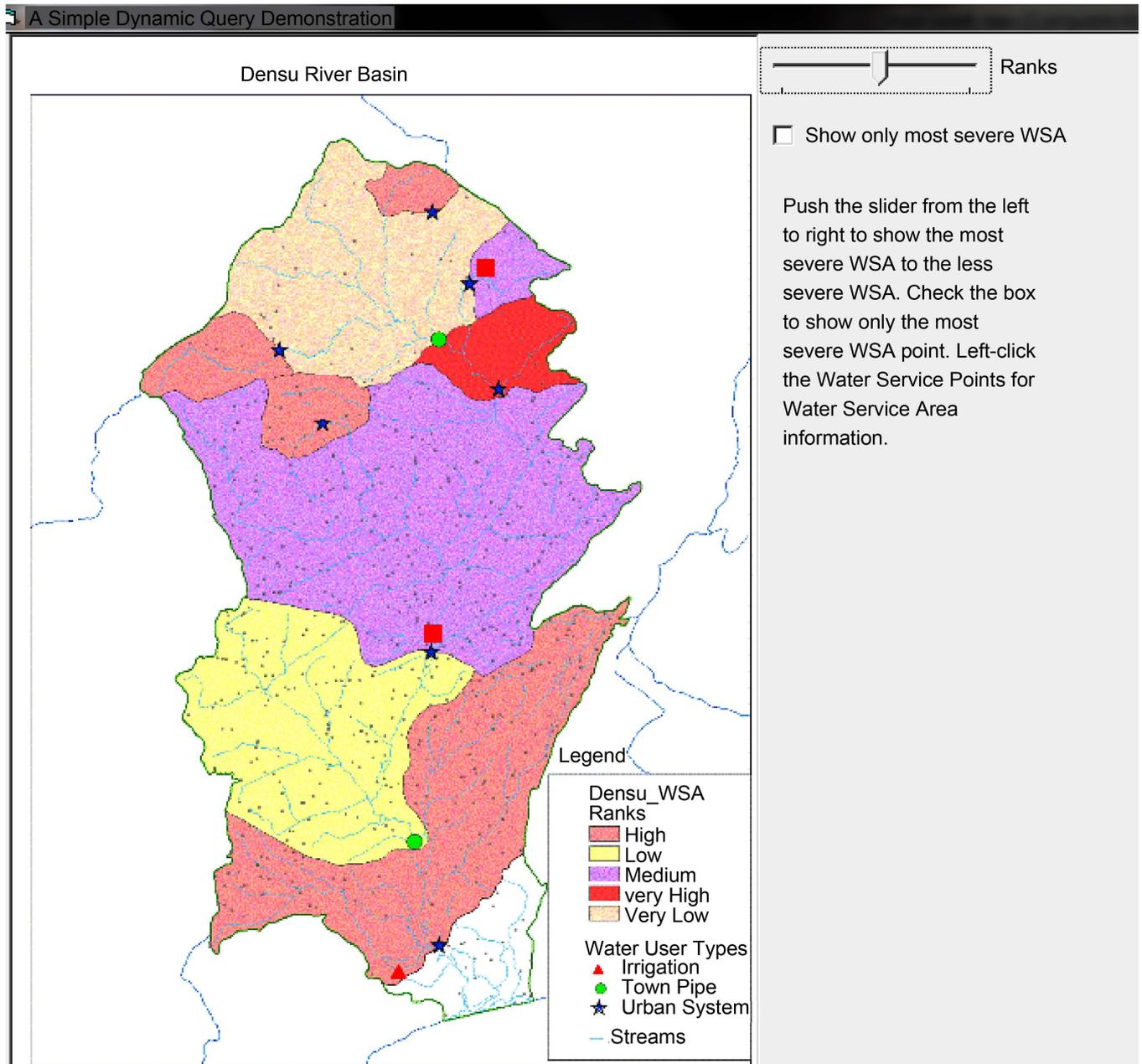


Figure 5. Showing high ranked WSA (ranking values of 6, 7 and 8).

based on its vegetation intensity (how green the vegetation). The values chosen for the intensity was ranked between 1 and 6. The value 1 represents LULC with less intensity of vegetation cover and the value 6 represents LULC with highest vegetation cover. *i.e.* the smaller the degree of intensity of vegetation cover, the smaller the value assigned to the class. The higher the intensity of vegetation cover the higher the value assigned to the class.

Analysis is done in order to evaluate the Water Service Areas. The evaluation of the WSA has been ranked in terms of the urgency to protect its environment (vulnerability).

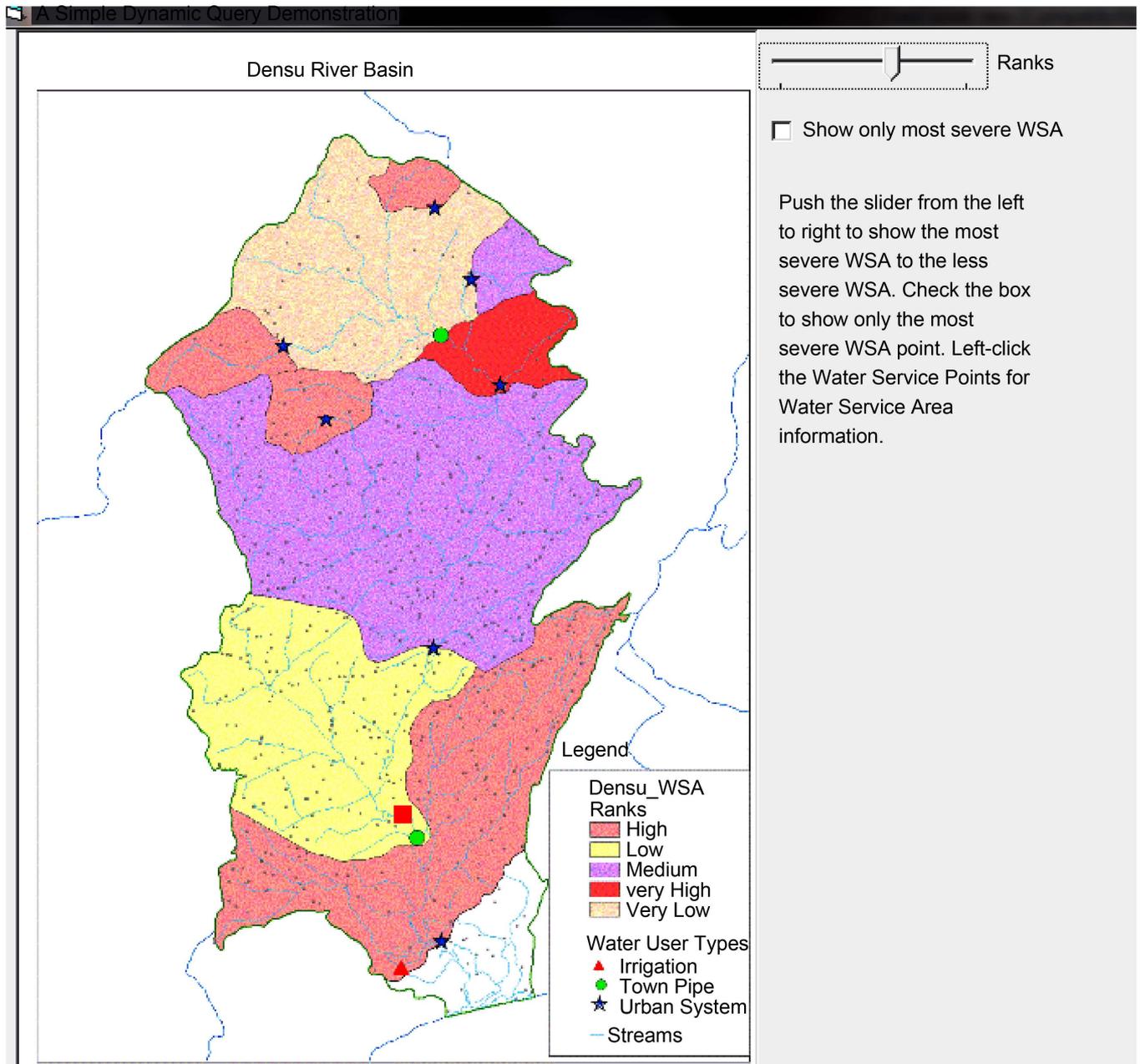


**Figure 6.** Showing medium ranked WSA (ranking values of 11 and 13).

The WSA area which is most vulnerable is ranked Very High; the next vulnerable WSA is ranked High, followed by Medium which is the next vulnerable catchment area after High. After the ranking of the Medium the next vulnerable ones are assigned Low and Very low respectively in order of vulnerability.

The evaluation of the WSA was performed based on three major variables:

- 1) Relative population density (R\_PD which was determined from the population and the Size of the WSA);
- 2) Relative stream density (R\_SD) which was determined from the Number of



**Figure 7.** Showing low ranked WSA (ranking value of 16).

streams and the size of the WSA);

3) Relative LULC (R\_LULC which was determined from the LULC activities going in the WSA).

The values of these three variables R\_PD, R\_SD, R\_LULC are summed together to get the R\_Total which is used to rank the vulnerability of the WSA.

**Table 3** displays how the ranking of the WSA was done. The R\_Total was categorized into five ranges of values; the range of values for the R\_Total was at regular intervals for all the five ranges. Values between (0 - 5) are rated Very High, (6 - 10) are rated

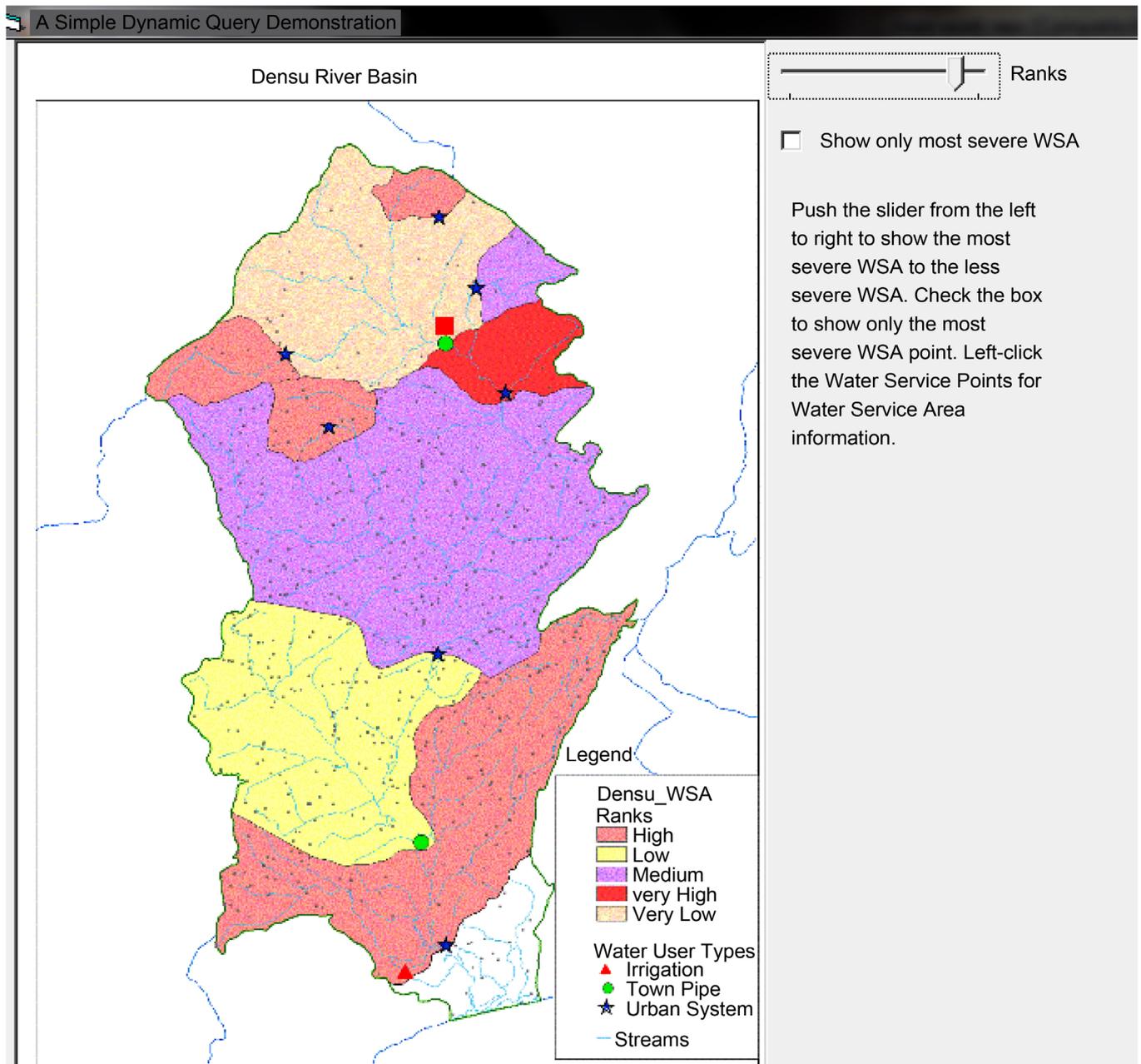


Figure 8. Showing a very low ranked WSA (ranking value of 22).

High, (11 - 15) are rated Medium, (16 - 20) are rated Low and (21 - 25) are rated Very low. These are the criteria which were used to rank the urgency of protecting the WSA. When a WSA is ranked Very high, it means that a Catchment area is most vulnerable and that much attention must be paid in protecting the environment pertaining that particular WSA. In **Table 3**, the range of values for the various Water Services Areas is used in ranking the vulnerability of individual WSA. The R\_Total which is the addition of all relative rankings is shown in **Table 4(b)**. Thus the value for each of the three variables for each WSA was added together. This was done by using the formula

**Table 1.** Table of Water Services Area (WSA) and their water use (WU) Type.

WSA_CODE	COMMUNITY	WU_TYPE
WSA_01	MADINA	TOWN PIPE SYSTEM
WSA_02	WEIJA DAM	URBAN SYSTEM
WSA_03	TOKUSE	IRRIGATION
WSA_04	APEDWA-ASAFO	URBAN SYSTEM
WSA_05	AKWADUM/NANKESE	TOWN PIPE SYSTEM
WSA_06	KOFORIDUA	URBAN SYSTEM
WSA_07	SUHUM	URBAN SYSTEM
WSA_08	NSAWAM	URBAN SYSTEM
WSA_09	SUHYEN	URBAN SYSTEM
WSA_10	NEW TAFO	URBAN SYSTEM

**Table 2.** Table showing how names of LULC are assigned with numbers in the database.

Land Use Land cover class	No. Assigned to class
Mixed Arable Crops and fallow land	1
Mixed Arable Crops	2
Mixed Arable Crops and Tree Crops (Cocoa)	3
Mixed Arable Crops and Tree Crops (Palm oil)	4
Mixed Bush Fallow Cropping	5
Shrub Canopy	6

**Table 3.** Table showing how R\_Total are Ranked.

Range of Values for R_Total	Ranking
0 - 5	Very High
6 - 10	High
11 - 15	Medium
16 - 20	Low
21 - 25	Very Low

$$R\_Total = R\_PD + R\_SD + R\_LULC \quad [1]$$

where: R\_PD is the relative population density;

R\_SD is the relative stream density;

R\_LULC is the relative Land use Land cover change.

WSA with R\_Total between 0 and 5 is ranked Very high, this means that the catchment is highly vulnerable, so that particular WSA must be given a priority attention.

For example in **Table 4**, taking WSA\_01, the R\_LULC has a value of 4, the R\_PD has a value of 9.173 and R\_SD has a value of 2.138. Therefore the R\_Total for WSA\_01 is determined by summing ( $4 + 9.373 + 2.138 = 15.512 \sim 16$ ), the 16 falls between the

**Table 4.** (a) Table of water service information. (b) Table indicating the statistics that evaluated the Water Service Areas into Ranks in the database.

(a)						
WSA_COD	Area_Acres	Population	No_STREAM	Pop_Density	Str_Density	Ranks
WSA_01	116,879.977	12,741	13	0.109	0.000111	Low
WSA_02	126,765.539	1,263,695	27	25.746	0.000213	High
WSA_03	19,135.089	18,586	1	0.971	0.000052	High
WSA_04	95,150.250	6741	6	0.071	0.000063	Very low
WSA_05	23,950.0291	148,526	3	6.201	0.000125	Very high
WSA_06	16,906.215	35,877	1	1.944	0.000059	High
WSA_07	204,251.066	64,929	41	0.317	0.000201	Medium
WSA_08	12,156.691	4458	3	0.367	0.000247	Medium
WSA_09	8383.697	54,149	1	6.459	0.000119	High

(b)										
WSA	Area	Population	No_stream_1	Pop_Density	Str_Density	R_LULC	R_PD	R_SD	R_TOTAL	Ranks
WAS_1	116,879.9778	12,741	14	0.109	0.000111	4	9.17353	2.1389	15.312	Low
WAS_2	126,765.539	3,263,695	27	25.7459	0.000213	2	0.0388	4.0959	6.1348	High
WAS_3	19,135.089	18,586	1	0.9713	0.000052	6	1.0295	1.005	8.0345	High
WAS_4	95,150.2501	6741	6	0.0709	0.000063	6	14.1151	1.2128	21.3278	Very Low
WAS_5	23,950.029	148,526	3	6.2014	0.000125	1	0.1613	2.4088	3.5701	Very High
WAS_6	16,906.215	32,877	1	1.9446	0.000059	5	0.5142	1.1374	6.6517	High
WAS_7	204,251.066	64,929	41	0.3178	0.000201	3	3.1457	3.8603	10.006	Medium
WAS_8	12,156.6909	4458	3	0.3667	0.000247	6	2.72693	4.7452	13.472	Medium
WAS_9	8383.6969	54,149	1	6.4588	0.000119	6	0.1548	2.2938	8.4486	High

range (16 - 20) which is assigned low in its ranking. This means WSA\_01 has a low risk of being affected by these environmental variables. The same procedure is used to determine the ranking values of the remaining catchment areas which are shown in **Table 4**. From the results, it was established that only one WSA was ranked very high risk prone area which is Koforidua Community. Three WSA were ranked high risk prone areas which include the Weija town community, Apedwa-Tafo community, Suhum Community and New Tafo Community. Two WSA was ranked medium prone areas which are Nsawan and Suhyen Communities. Madina and Akwadum/Nankes were ranked low and very low prone areas respectively.

## 5. Conclusion

This research has presented the application of Geospatial Information component in the analysis of local management of watershed in Ghana with a focus on the assessment of local management of watersheds of the Densu River basin. It can be concluded that Geospatial Information component application points to a mix of gains and failures in

environmental features. Though there was sizeable number of water bodies, the emergency of stress indicators of LULC and population poses a growing threat to the availability of water and conservation efforts in the Densu River basin. With Geospatial Information component in the forefront of new technological advances, the management of watersheds such as the Densu River watershed will continue to be strong. The Geospatial Information component used in this research provides a decision support system for managers in the assessment of environmental hazards related to local watershed management. Ghana as a country will have to take a responsible step in protecting its water body and its environment to enable continuous and sustainable supply of water to its citizens. This project therefore reveals the state of the water users and how urgent its environment needs to be protected.

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