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Development of Sustainable Water Resourcrs Management Plan for Pothakamuru Watershed using RS and GIS

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Abstract: ***Sustainable water resource management plan aims the suggestion of soil and water conservation measures which includes agronomical and engineering structures for the reduction of soil erosion, safe disposal of runoff as well as drained water and for the increase of groundwater recharge. For the development of management plan, different parameters were considered which includes the slope of area, drainage network, drainage density, runoff from the area and land use land cover map of watershed. Pothakamuru watershed lies on Darsi Mandal in Prakasam District of Andhra Pradesh. The area is facing high water scarcity. Slope map, drainage network map and drainage density map of the area were developed in ArcMap. Runoff from the study area was estimated with SCS Curve Number method and using ArcGis. About 25% of the total rainfall being flow as runoff. Land use land cover map prepared with Sentinel 2 satellite image using ERDAS IMAGINE 2019. Decision rules for the suggestion of conservation measure were made.***

Keywords: Soil and water conservation structures, DEM, Geographical Information System (GIS)

1. Introduction

Water is an important natural resource for the survival of life and crop growth in earth. But unfortunately, adequate amount of water is not available in earth to meet these requirements. UN Water Development Report 2019 says that water requirement has been increasing worldwide by about 1% per year from 1980's. About two billion people living all over the world is suffering from water stress. Even though the global average is only 11 %, 31 countries are facing water stress between 25 - 70 % and 22 countries are suffering from heavy water stress of above 70 % i. e., Water availability not only depend on the amount of water physically present on the world but also the management of available water, allocation water to different user and storage of water, which means the management, allocation and storage of both surface water and groundwater.

Agriculture (including irrigation, livestock and aquaculture) sector is the largest water consumer, accounting for 69 % of annual water withdrawals globally. (UN annual water development report 2019). Roughly 70 % in the world's least developed Countries, over 90 % of freshwater withdrawals take place in rural areas, primarily for the irrigation of agricultural crops. India has 18 % of world population, having 4 % of world's fresh water, out of which 80 % is used in agriculture. Even though 80 % of fresh water available is used for agriculture, India is not yet a food secured country. Other than agriculture sector, domestic and industrial sectors are also facing water scarcity. Globally about 8 - 15 % of fresh water had diverted from agriculture to domestic and industrial sectors because of increasing demand of water in domestic and industrial use [1].

Pothakamuru watershed area is mainly depends on rainwater for the purpose of agriculture. Paddy fields were irrigated by bore well most of them were dried. So that farmers are shifting from paddy cultivation to other crops which has less crop water requirement.

For the development of water resource management plan which includes surface as well as groundwater resources, decisions rules were considered separately for soil conservation measures and water conservation measures. The measures adopted includes both agronomical as well as engineering measures. Decision rules were applied to the study area using ArcGis. Different layer, i. e., slope layer, land use land cover layer, drainage network layer and runoff layer were made in ArcGis for the application of decision rules.

2. Materials and methods

Materials required for the adoption of soil and water conservation measures includes generation of slope map, drainage network map, land use land cover etc. SRTM DEM was used for the generation of watershed characteristic layers.

2.1 Study area

The study area Pothakamuru watershed which lies in Darsi Mandal of Prakasam District in Andhra Pradesh. The

watershed is located between latitude 15°49'43.266"N and longitude 79°41'46.794"E at ridge point and latitude 15°41'29.861"N and longitude 79°45'8.953"E at valley point. The total geographic area of the watershed is 12953 ha. The area is receiving varying rainfall of about 540mm. location map of the study area is shown in the figure 1

2.2 Drainage network and drainage density map

Drainage density of a watershed area can be defined as the ratio of length of stream to the area of the basin. It can be considered as a criterion for the drainage of a stream channel. If drainage density is high for a particular area it can be considered as a well - drained area. Drainage density of a watershed can be affected by so many factors such as topography, land use land cover, rainfall characteristics, soil type etc.

Drainage network of watershed was developed from SRTM DEM (figure.2). Study area has drainage network of first order to forth order having a total length of 2098 Km. Drainage order of the watershed is found to be forth order having a length of 147 Km whereas first order has a stream length if 301 Km, second order has a stream length of 818 Km and third order has a stream length of 832 Km. nearly 40 % of drainage network of the first order. Second and third order streams are suitable for rainwater harvesting structures and recharge structures [2].

Drainage density of the study area was determined using line density tool of Arcmap 10.6. Drainage network which was digitised was used as the input for the generation of drainage density map. The drainage density of the watershed ranges from 0.01 to 6.4 Km/Km$^{2.}$ Drainage density of the area was classified as four classes where first class has the range between 0 to 0.75, second class has the range between 0.75 to 2, third class has values between 2 to 3.5 and fourth class has the value greater than 3.5 km/Km^2. The first, second, third and fourth classes encompassing an area of 4390 ha (about 33%), 3074 ha (about 34%), 4156 ha (about 23%) and 1332 ha (about 10%) respectively. First class was considered as poorly drained, second class was considered as moderately well drained, third class was considered as well drained and fourth class was considered as highly drained.

2.3 Slope map

Slope of the watershed varies from nearly plane to steep at the upstream region. The slope map of the area was extracted from SRTM DEM 2014 which is downloaded from USGS Earth Explorer using slope option in spatial analyst tool in ArcMap. The watershed has almost stable with high slope varying from 19.18% - 40.09% at upstream side and 0 – 1.72% at downstream side. Slope map of the study area was shown in the figure.3.

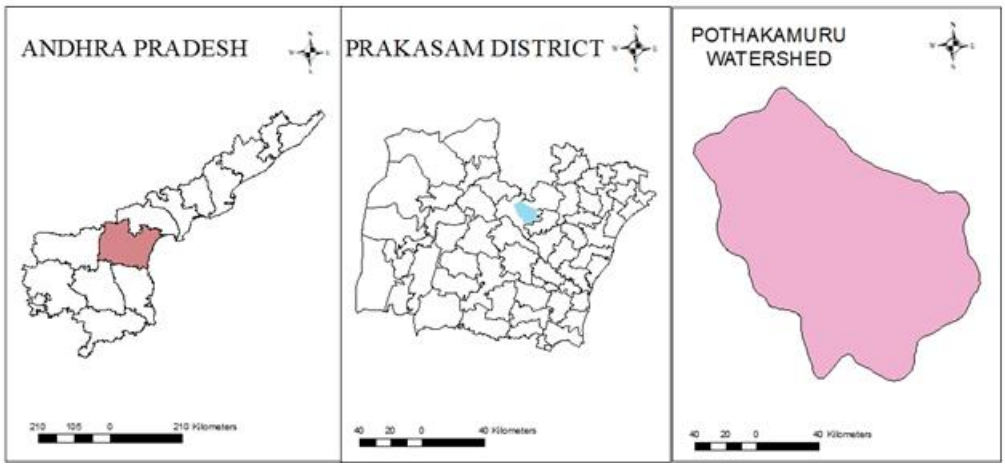

Figure 1: Location map of study are

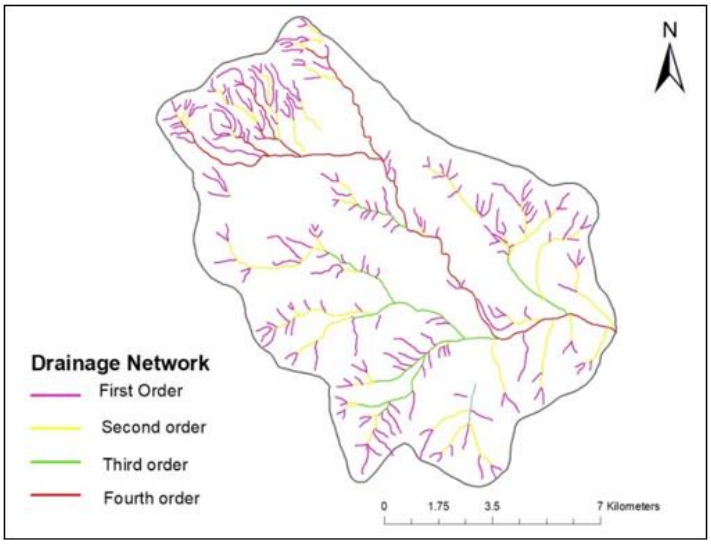

Figure 2: Drainage network map of study area

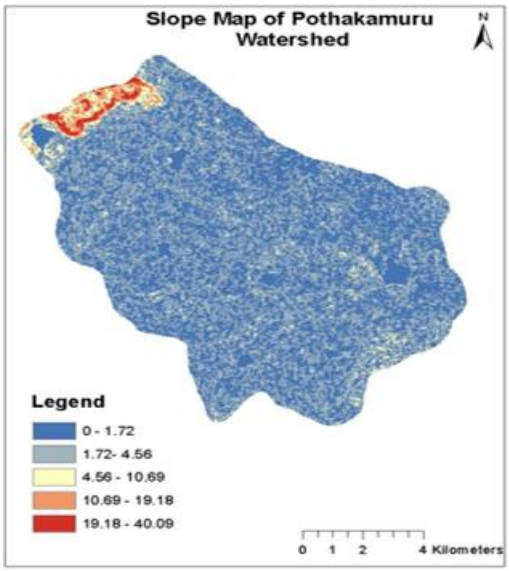

Figure 3: Slope map of study area

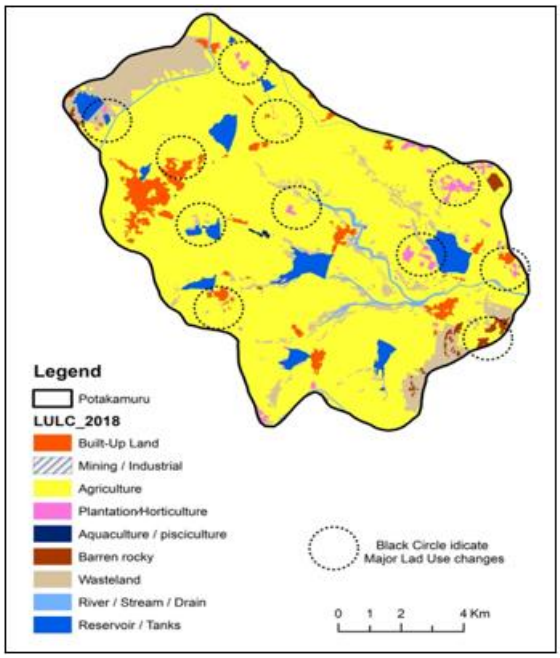

Figure 4: Land use land cover map of study area

2.4 Land use land cover map

"Land cover refers to the physical and biological cover over the surface of land, including water vegetation, bare soil and artificial structures" [3]. Land use refers to the use of land by humans for the purpose of agriculture, building construction etc. Land use land cover map is an important parameter for the determination of areal distribution of different type of land use. There are different types of classification which follows different criteria. Land use land cover classification being used for the estimation of area under different land use in different season, spatial and temporal variation of distribution of agriculture and water body.

Land use land cover map of Pothakamuru watershed for the year 2017 - 2018 was created in ERDAS IMAGINE from Sentinel 2 satellite image as shown in Fig.4. Total area was classified into eight classes namely, cropland, plantation, river/stream/drain, wasteland, mining & industrial, aquaculture/pisciculture and build - up cropland, plantation, water body, river/stream/drain, wasteland, mining and industrial, aquaculture/pisciculture and built - up land. [4]

2.5 Decision rules for soil and water conservation measures:

Soil and water conservation measures may be agronomical structures or practices or engineering
Structures that will prevent degradation of soil and water bodies. Efficiency of conservation measures depends on different factors such as slope of the land, drainage pattern and drainage density of area, land use and land cover etc. Soil conservation structures and water conservation structures can be treated separately. Certain rule should be coined for the suggestion of conservation measures which are decision rules. Soil conservation measures were decided by talking slope and land use into account. Soil conservation measures that can be selected in accordance with the slope and land use are presented in the table 1 and table 2.

Table 1: Decision rules for soil conservation structures

	Slope	land use		**Soil conservation measures**
	Nearly level sloping 0 - 1%	Forest		Drainage disposal + forest restoration
		Agriculture	Cropland	Strengthening existing field bund+ drainage disposal
			Plantation	Gap plantation +drainage disposal
		Scrub		Crop cultivation/plantation + compartmental bund with drainage network. Drainage disposal
	Very gently sloping 1 - 3%	Forest		Boulder bund Boulder bund + forest restoration
		Agriculture	Cropland	Contour bund and levelling with grassed water way
			Plantation	Farm pond + gap plantation
		Scrub		Bush clearance + contour bund/land shaping
	Gently sloping 3 - 5%	Forest		Shallow trench cum boulder bunds Forest restoration
		Agriculture	Cropland	Contour bunds + farm ponds
			Plantation	Contour bund + farm pond +silt application + gap plantation
		Scrub		
	Moderately sloping 5 - 10%	Forest		Staggered trench+ forest restoration
		Agriculture	Cropland	Contour bund+ silt application+ cover/strip crop
			Plantation	Contour bund+ silt application+ cover/strip crop + gap plantation
		Scrub		Bush clearance + removal of boulders + contour bund + silt application
	Moderately steep slope 10 - 15%	Forest		Staggered trench + foot hill contour trench Forest restoration + foot hill contour trench
	Steep slope 15 - 35 %	Forest		Internal trench cum boulder bund (half moon terrace) + Foot hill contour trench
		Scrub		Internal trench cum boulder bund (half - moon terrace) + Foot hill contour trench
	Very steep slope >35%	Forest		Pit planting + Foot hill contour trench Foot hill contour trench + forest restoration
		Scrub		Pit planting + Foot hill contour trench Foot hill contour trench

Table 2 Decision rules for water conservation structures

Structures	Slope (%)	Stream order	Catchment area (ha)
Sub surface dyke	0 - 3	>4	>5
Farm pond	0 - 5	1	1 - 2
Percolation pond	<10	1 - 4	25 - 40
Check dams	<15	1 - 4	>25
Gully plugs	15 - 20	1	-

3. Results and Discussion

For leveled land, mostly of slope between 0 - 1%, irrigation water as well as rain water has to be disposed safely to the drainage network of watershed. Conventionally most of farmers are disposing drained water to the natural depressions on the land surfaces. Disposal of drainage water into surface water resources can affect the quality surface water spending on the quality of irrigated water. At some points it is better to install evaporation ponds. Drainage disposal was suggested to the area under agriculture as well as plantation crops and drained water was diposed to near by stream mostly to the firt order steam along the slope. The area with horticulture crop or plantation crop was suggested to cultivate with other crop as inter crops, that will improve the infiltartion capacity of soil. Plane land which is filles with scrubs can be used for cultivation of crops. Drainage density of the area covered with scrubs are less compared with the other area, so that the developed soil conservation plan was included with artificial drainage network for the safe disposal of water. Bunding was included on this area for the safe disposal of runoff water and for increasing the infiltration time.

Developed soil conservation plan for the area with slope 0 - 1% wqas shown in the figure. The paln was developed by considering grids of area 25ha. So that this practices were adopted for that area. Locations for the soil conseravation works were shown in the figure.

In the second catogory, i. e, slope varying from 1 - 3%, crop area was prominent which is mostly cultivated during kharif season. Area on the upstream side mostly came under high runoff region. Downstream area came under low to moderate runoff region. In these area, for the reduction of runoff and increase of infiltration contour bunding has to be implemented. For the safe disposal of water without erosion, grassed water ways should be adopted. Horticulture crop or plantaion crop on the watershed in the second slope category was less. Out of the area gap plantation has to adopted, which is nothing but intercropping in plantation field. Farm ponds can be constructed on these areas, that can be further utilised for safe disposal of drained water from the filed. Scrubs on the second category mostly concentrated on the upstream and

downstream side of the watershed. Drainage density at this region is high. Runoff from this region was varying from moderate to high. So safe disposal of runoff water should be there. Bush clearence and contour bunding can be done on this region. Contour bunding can reduce runoff as well as decrease the slope length.

Third category, land use of the watershed comes under agriculture and plantation. Runoff from this region varies from low to moderate. Area under agriculture was adopted with a combination of farm ponds and contour bunding. Contour bumding was suggested to area with scrubs and plantation. Plantation area can further adopt gap plantation or intercropping which can reduce the runoff. Degradation of the soil can be prevented as well as quality of the soil can be further improved by the application of silt. Silt or tank silt is nothing but fine soil collected from runoff from any watershed which contain crop debris which is deposited as sediment in tanks. Application of tank silt not only improve the infiltration rate of the soil but also increase the fertility of the soil with reduction in runoff. Water holding capacity of soil can be improved by the application of silt to soil.

Fourth catogory which come under high slope spreads on the upstream side of the watershed. As slope of this region is very high, this area was not utilized for agriculture purpose. These regions were covered with scrub. Even though the slope is high, this region has high infiltration capacity and as the land is covered with scrub, runoff from this region was comparatively low. At downstream end, this region has moderate runoff and area was covered with scrubs. These regions can be considered for forest restoration. Internal trench cum boulder bund was adopted for the upstream side of the watershed.

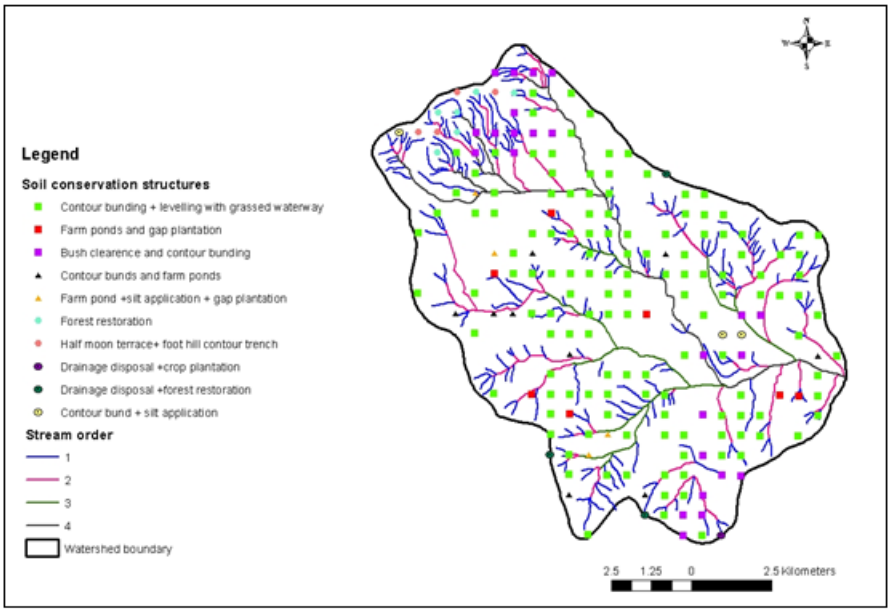

Figure 2: Suitable sites for soil conservation measures

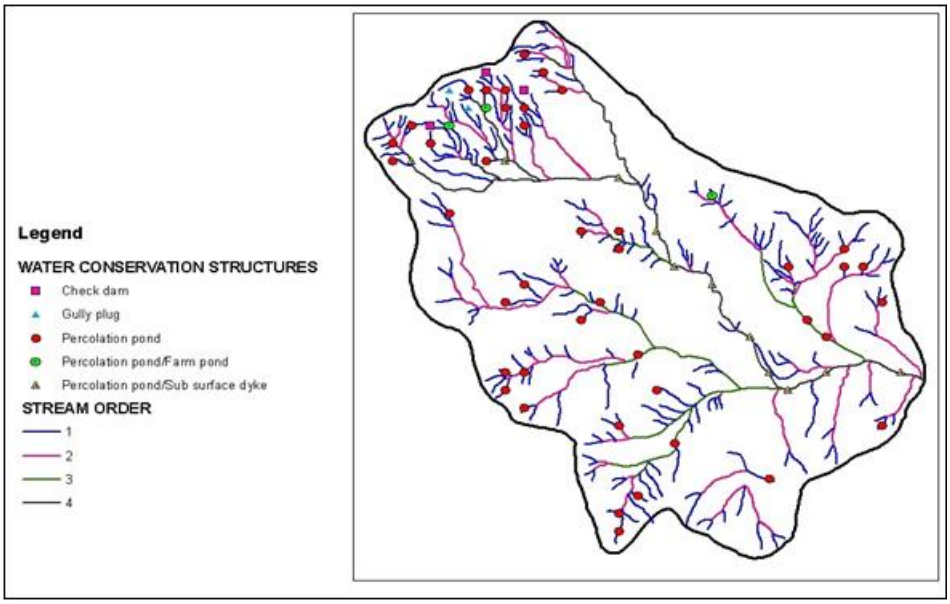

Figure 3: Suitable sites for water conservation structure

Identification of appropriate site for water conservation structures play an important role in water harvesting as well as soil and water conservation. Watershed characteristic is the only criteria that can be utilized for the suggestion of suitable

sites for the structures. We have used different parameters for the identification of suitable sites which includes land use land cover map (obtained from satellite image), slope map (obtained from SRTM DEM), drainage density map.

Water conservation structures selected for the watershed includes farm pond, gully plug, percolation pond and sub surface dyke. At some point combination of structures were also suggested. Farm ponds are constructed along ground or with stream order one. Percolation ponds are constructed on ground as well as on streams from stream order one to four. Check dam is alone constructed on stream with order varying from one to four slope less than 15%. For the study area check dam was suggested to upstream area by considering other parameter like runoff potential, permeability etc. Gully plugs are suggested to the area with relatively higher slope. So that for Pothakamuru watershed, suitable sites for gully plugs lie on the upstream area with stream order one. Sub surface dyke is suggested to the stream having order four or greater than that. In Pothakamuru watershed, suitable sites for sub surface dyke lies from upstream side to downstream side of the watershed. Some areas were suggested with a combination of farm pond and percolation pond. Farm pond are usually suggested for ground, percolation ponds can be suggested in both ground as well as for streams [6].

4. Conclusion and Suggestion

The main aim of development of water resource management plan was to increase the infiltration time and reduction of runoff. For that decision rules were made for water conservation structures and soil conservation structures separately. For soil conservation methods, LULC map and slope map were utilized. Slope of the watershed was more or less stable with 0% to 40% at upstream side of the watershed. Major area was under agriculture. Slope map, drainage order, runoff potential was taken as parameters for selecting the suitable sites for water conservation structures.

Developed water resource management plan for the Pothakamuru watershed included soil and water conservation measures such as gap plantation, contour bunding, drainage disposal, forest restoration, silt application, crop plantation, farm ponds, percolation ponds, gully plugs etc. Soil conservation structures present on watershed were concentrated on the downstream portion of the watershed. Suitable sites for soil and water conservation structures were identified.

By using the high - resolution satellite data and obtaining more time series satellite images during the study period for better map generation.

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