Spatial Management Planning for Restoration of Small Tank Cascade System in Sri Lanka

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Abstract

Long drought condition is a common weather phenomenon in Sri Lanka. This regime in the weather condition adversely affects the livelihood of the farmer population specifically and the rest in the dry and transitional climatic zones of the country. As many studies pertaining to small tank cascade system emphasized its importance in its hydrological system to give relief to the livelihood of these drought affected areas. Small tanks formed and activated by the natural topographical formation which generates the gravity flows and storage of rain water. The indigenous settlements are evolved in a compatible manner with the ecology and the hydrology. This was an impetus to design their agro-culture based livelihood which leads into traditions and its embraced vivid cultural norms and standards. Accordingly natural forest and the soil catena have been well maintained in carrying out their activities. The village layout of this indigenous village is a testimony to fame as an indigenous knowledge which exists in the country. This has led to manage the natural assets which derived from the ecology and its biodiversity and the natural hydrology. This planned small tank eco hydrology driven village settlement has its layout plan determined by the physical formation of the location. However, at present this cohesion was destroyed by the haphazard development plans throughout the country. Due to this destruction, hordes of environmental, social and economic issues emerged in Sri Lanka. This research focus on studying the spatial management of villages with the tank cascade systems, which was once successful in ancient time periods. To analyze the possibility of rearranging the current villages to overcome the existing issues due to drawbacks of haphazard developments at present, Kurunegala district of Sri Lanka was selected. Landsat Satellite images from 1978 to 2018 of Rambukkan Oya catchment area were used to map out the small tank cascades and to find out the change over the time. Findings clearly show the interruption of current development pattern with the traditional cascade systems breaking the gravitational water flow to the small tanks. It causes to dry out most of the tanks in the study area..

Keywords: eco-hydrology, indigenous, restoration, small village tanks, spatial management

1. Introduction

Sri Lanka has different agro ecological zones; Dry Zone is one of them. Dry Zone receives a mean annual rainfall of less than 1 750 mm with a distinct dry season from May to September. The mean minimum temperature ranges between 20 – 26 ^{0}C and maximum temperature varies between 29- 38 ^{0}C. The DZ is limited to the low-country, with elevation below 300 m. Dry zone has a rich soil to cultivate a verity of crops however, and water availability is the main limiting factor of Dry Zone controlling its flourishing nature.

The civilization of Dry Zone is said to be started around natural water bodies. Gradually people learnt to harvest rain water for their requirements. There are three factors that influenced the evolution of the water resources management system in the dry zone. They are: the morphology of the landscape, the amount and distribution of the rainfall, and the nature of the substratum (Institutional Framework for Integrated Water, 2015).

In order to overcome the harsh weather condition ancient people thought about a unique method of collecting and storing rain water and recharging ground water of the area. It is the cascade system. Madduma Bandara, 1985 defines "A tank cascade is a connected series of tanks organized within a meso catchment of the Dry Zone landscape, storing, conveying and utilizing water from an ephemeral rivulet". This system has been recognized as a Globally Important

Agricultural Heritage System (GIAHS) by the FAO (FAO, 2018). Figure 01 displays a schematic diagram of a tank cascade system.

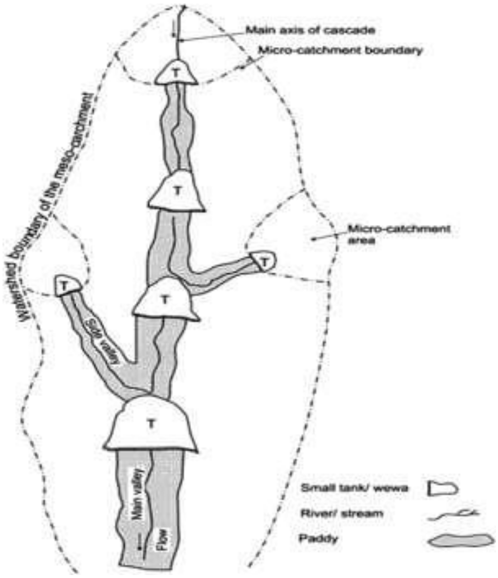

Figure 01: Schematic Diagram of a Tank Cascade System
Source: Panabokke et al. 2002, p.6

Panabokke, et.al, 2002 explains that these cascades are common in mini basins with second order or first order ephemeral streams. These cascades were refined over and over to match with the geomorphological landscape and the rainfall pattern of the Dry Zone. Cascade has three main components; the watershed boundary of the meso catchment, the individual micro catchment boundaries of the small tanks, the main valley and side valleys in the cascade (Panabokke, et.al. 2002).

The ancient people in the Dry Zone carefully and systematically allocated the space to serve the humans, other living beings with minimum damages to the nature. They lived with nature in so harmonious manner in enriching the nature with their existence. Figure 02 explains the sustainable ancient spatial management system woven around small tanks.

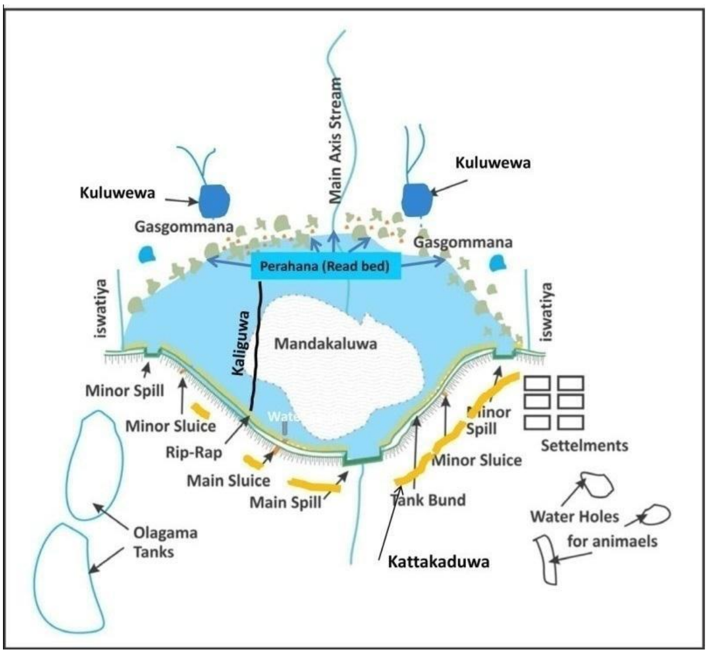

Figure 02: Spatial Management around Small Tanks in Villages of the Dry Zone
Source: Tennakoon, 2015a.

The small tank is the main element of this system. Most of these tanks were built during Anuradhapura kingdom. The tank is the main ecosystem with diverse functions. Same tank was used for drinking, bathing, washing and for the requirements of the animals. However, the locations of these functions were in different places avoiding harmful effects to the users. Terminalia Arjuna (Kumbuk) trees were grown around the water drinking place to purify the water and to give a cooling effect to water. This place was an open area to have enough wind to make waves on the water. It also purified the water. (Abeysinghe, 2018). In this manner, ancient people used the same tank water for different purposes safely.

However, over the time with the development of mankind and after being colonies of foreign countries, our ancient sustainable spatial management approaches were destroyed and neglected. Current development trends give higher benefits for short time periods and their adverse outcomes will destroy the nature and will remain unchanged for longer time periods causing hordes of damages to whole ecosystem. Unfortunately people think about the short term benefits rather than the long term damages continuing their harmful alterations to the ecosystem. Thus the Dry Zone of Sri Lanka is facing frequent variations in weather patterns causing severe water scarcity in the zone causing threat to the living beings of the area.

The main aim of this research is to map out the devastations happen to the small tank cascade systems of Dry Zone over the time due to unplanned development activities of the area and to check the feasibility of relocating the ancient spatial management approaches in the Dry Zone as a solution for the water scarcity currently aggravating with unplanned development activities took place over the last decades. The study was undertaken in a sub catchment of the Deduru Oya Basin.

2. Objectives

With the above background following objectives were set to achieve through this research.

1. To map out the changes happen to the small tank cascades over the time in the study area
2. To examine the effect of the land use changes to the abandonment of the small tanks of the cascades
3. To check the feasibility of restoring the cascade systems to rejuvenate the water management system in Dry Zone

3. Study Area

Deduru Oya river Basin was selected for this study. Deduru Oya basin is located in the North Western province of Sri Lanka. Deduru Oya basin consists of number of catchments. Out of them, Rambukkan Oya catchment was selected for the detail study. Location of the study area is displayed in the figure 03.

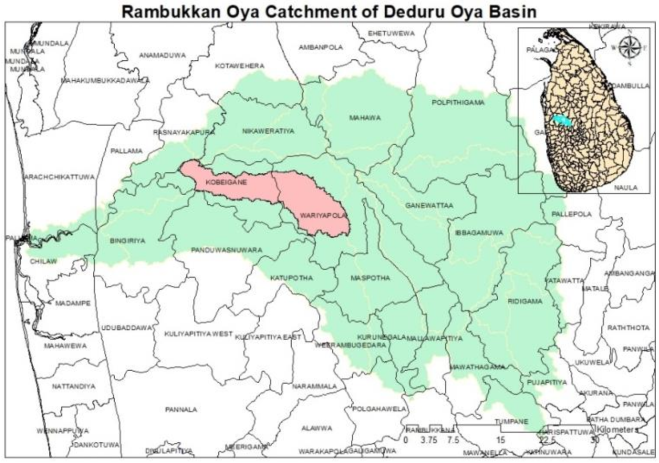

Figure 03. The Study Area

Deduru Oya river basin is the fourth largest river basin of Sri Lanka. The extent of the catchment is 2687 km^2. Annual precipitation is around 1200-2600 mm and average temperature varies around 27 to 31 ^{0}C. It consists of 12 sub watersheds. The basin consists of 4 major reservoirs and 2408 minor reservoirs. Out of them 1598 small tanks located as cascades. From this river basin average annual runoff flows to the sea is around 1180 million cubic meters (Mohanarajah, 2015). The Deduru Oya basin is known as an area of high climatic variability that invariably resulted in the highest density of small tanks (one tank per 1.2 km2) in Sri Lanka (Panabokke et al., 2002).

4. Methodology

The dynamics of small tank cascades of the Rambukkan Oya sub watershed was visualized from 1978 to 2018 through Landsat images. The same images were utilized to assess the land use changes over the time with the help of QGIS software. Meantime the population density of the study area was map out to find out the relationship between land use change and the population increase of the area. The selected Landsat images were 1978.12.31 Landsat MSS, 2005.3.17 Landsat TM and 2018.2.17 Landsat 8 images. All images represent the dry season of the Deduru Oya basin. Thus the affect of the weather for the demarcations were in minimum level. The dynamics of the cascade systems were verified with the help of Google Earth images.

Since the selected watershed was lacking with water inflow and discharge information, secondary data from other two streams of the same river basin was utilized to explain the relationship between population increase, land use change and the reduction of water inflow to the small tank cascades of the study area.

5. Results and Discussions

5.1. Distortions to small tank cascades in Rambukkan Oya watershed Area

Deduru Oya watershed has been subjected to changes since 1960 due to various tank rehabilitation and other development activities took place over the time (Panabokke, et.al. 2002). Rambukkan Oya watershed also faces these changes and it caused to disfigure the small tank cascade chains. Figures 04, 05 and 06 show the spatial pattern of cascades which could be observed in the study area from 1978 to 2018 Landsat Satellite images respectively.

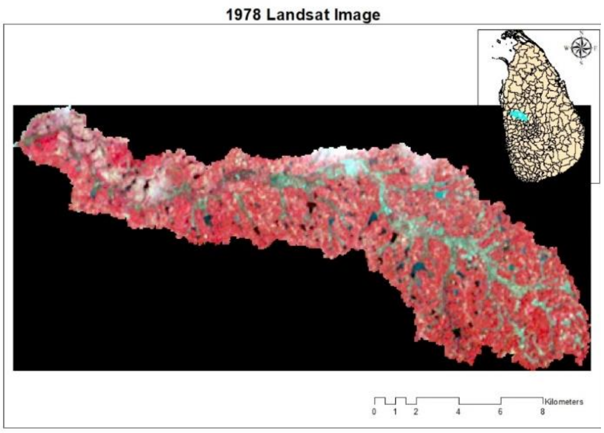

Figure 04. 1978 Satellite Image

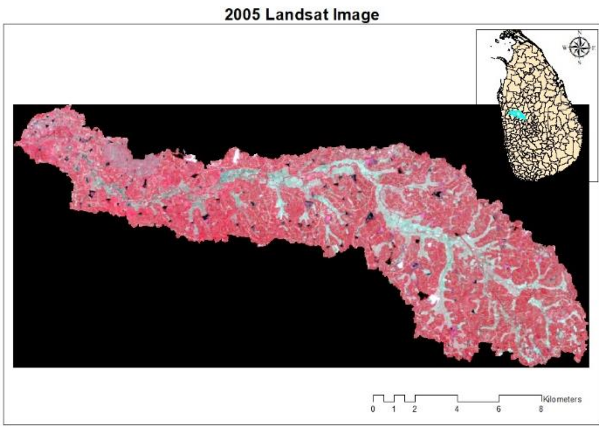

Figure 05. 2005 Satellite Image

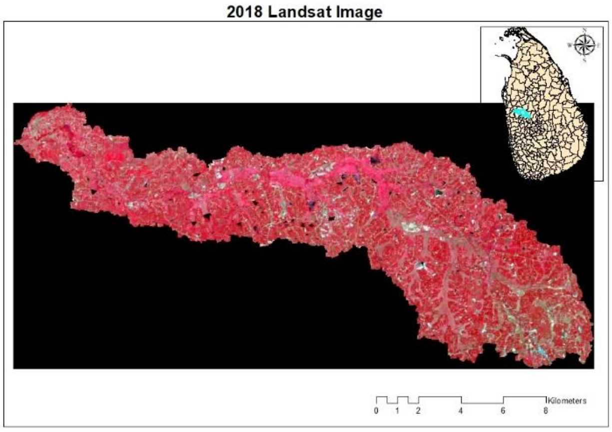

Figure 06. 2018 Satellite Image

The images itself shows the deformation happen to the spatial patterns of the cascades over the time. In 1978 the cascade patterns were very clear and the flow path of the cascades was not obstructed with exterior influence. When it comes to year 2005, the patterns were still remained as 1978 in prominent tank areas with higher volume, however, the small tanks at the start of the streams were not visible as 1978. The present condition is too intricate causing difficulties in identifying the flow patterns of the small tank cascades. It is very clear that the ancient spatial patterns of the cascades were altered during past decades.

The spatial pattern changes were verified using Google earth images during same time period. Figure 07, 08, 09 and 10 display few example areas showing the incursion of humans to the ancient cascade patterns.

Figure 07. Google Earth Image in 2002.4.29

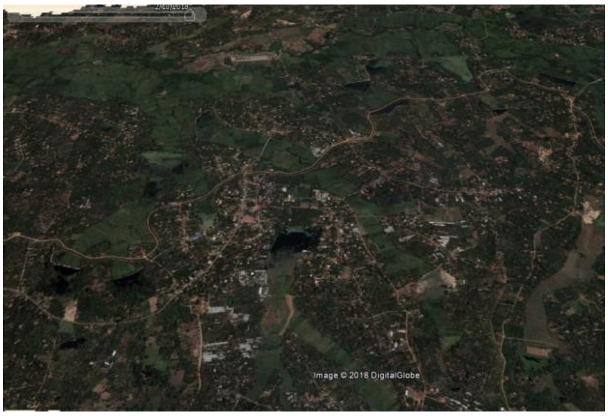

Figure 08. Google Earth Image in 2018.2.10

Figure 09. Google Earth Image in 2002.4.29

Figure 10. Google Earth Image in 2018.2.10

The Google Earth images prove the detachment of some small tanks from the cascade systems due to unplanned land use changes.

As the next step using the satellite imagery analysis techniques Normalized Difference Vegetation Index (NDVI) for the identified images were calculated. The Near Infrared (NIR) and Red bands were used in the following combination to perform the NDVI (1) analysis. The NDVI analysis was carried out using ERDAS NDVI modeling environment.

$$NDVI = \frac{NIR-RED}{NIR+RED} \qquad (1)$$

In general, the index values vary between -1 and +1 where the following value rages (Table 01) represent the nature of vegetation in the ground context (Gunawardena 2016).

Table 01. NDVI Values

NDVI Value based Category	NDVI Value
Water	-1.000 – -0.046
Cloud and snow	-0.460 – 0.025
Bare ground	0.025 – 0.090
Moderate Vegetation	0.090 – 0.140
Dense Vegetation	0.140 – 0.500
Highly Dense Vegetation	0.500 – 1.000

The NDVI classification was used to identify the vegetation pattern in the study area based on the ground verification through Google Earth. Figure 11, 12 and 13 shows the NDVI images for 1978, 2005 and 2018 years respectively. The NDVI images were categorized into Water and Non water categories based on the NDVI values for comprehensible visualization and interpretation.

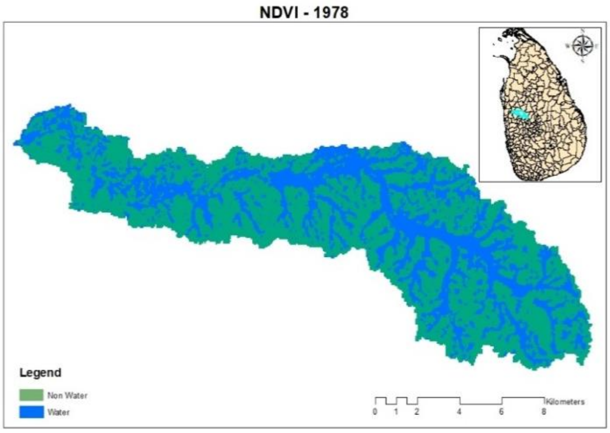

Figure 11. NDVI Image 1978

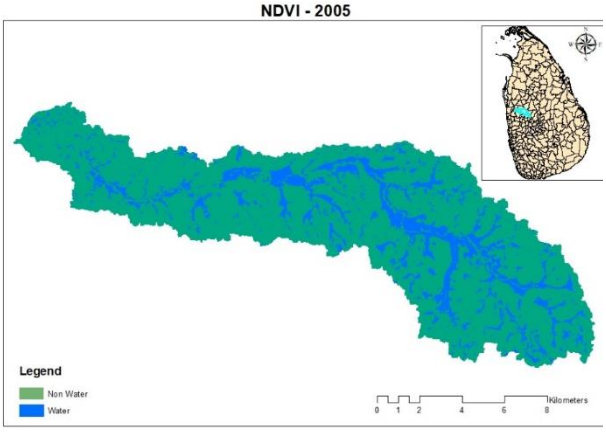

Figure 12. NDVI Image 2005

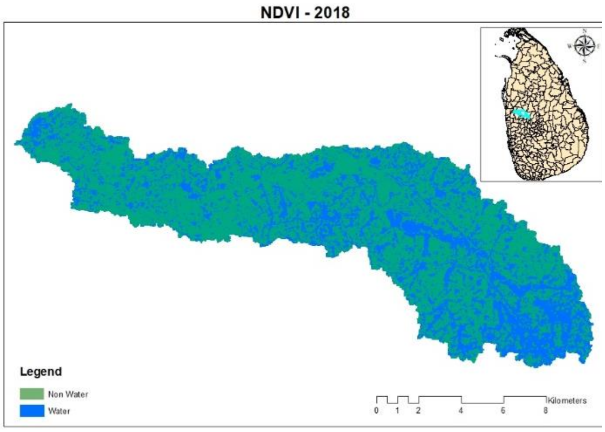

Figure 13. NDVI Image 2018

NDVI images further verify the change of spatial patterns of small tank cascades. The NDVI values of 1978 image range from -0.8 to +0.2, and 2005 values range between -0.5 to +0.5 and in 2018 image NDVI value rage is -0.2 to +0.6. Thus high negative values in 1978 image implies there was no or less water scarcity during 1978 in the study area. In 2005 the value rage increased towards +1 showing the increase of other types of land uses or reduction of surface water content and water related activities of the study area. In 2018 the area shows very less amount of water and water related activities with the low percentage of negative values. Thus the land has altered causing deadly damages to the ancient water retention technology.

5.2. Land use dynamics of Ranbukkan Oya Catchment

Land use changes are inevitable in any place of the world with the development of mankind and the technology (Gunawardena 2011, 2017). Thus it is apparent phenomenon in Ranbukkan Oya catchment as well. The changes should be methodical with minimum effects to the balance of the ecosystem.

Measuring land use change in the Rambukkan Oya watershed is essential to identify the impact of land use change on the cascade system and irrigation water availability. Thus the land use change and the simulation for future was undertaken in combined of several systems. QGIS open source software was used to classify the Landsat images and topographical maps were used for the verification of the analysis. Figure 14, 15 shows the land use maps for 1983 and 2010 years.

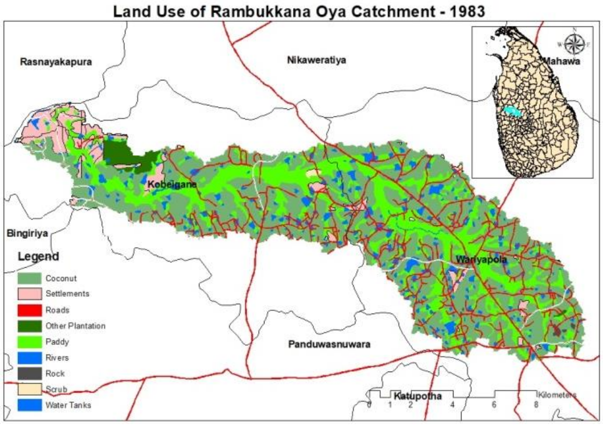

Figure 14. Land use 1983

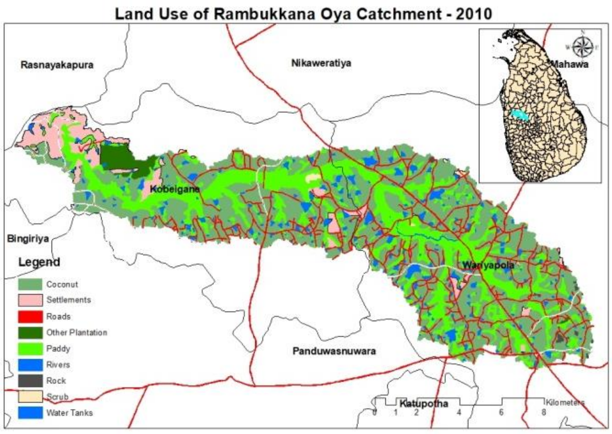

Figure 15. Land use 2010

Land use change during 1983 to 2010 was estimated and displayed in table 02.

Table 02. Major land Use Extends

Major Land use	1983 (Sq m)	As a %	2010 (Sq m)	As a %	Change %
Paddy	3272.329	0.247	3310.805	0.250	0.003
Coconut	7257.362	0.547	7225.110	0.545	-0.002
Settlements	879.529	0.066	914.631	0.069	0.003
Other Plantation	268.668	0.020	253.959	0.019	-0.001
River	13.586	0.001	12.050	0.001	0.000
Tanks	724.890	0.055	703.859	0.053	-0.002
Roads	764.863	0.058	764.863	0.058	0.000
Rocks	34.173	0.003	34.173	0.003	0.000
Scrub	48.442	0.004	44.391	0.003	0.000
Total	13263.841	1.000	13263.841	1.000	

According to the classification the paddy cultivation of the area has increased while water decreases. During the considered time period the land use changes were not obvious, however, after 2010 the area has faced considerable alterations due to various development activities. The population density was analyzed to prove the increase of population with the land use change. Figure 16 and 17 shows the population density maps for year 1981 and 2012.

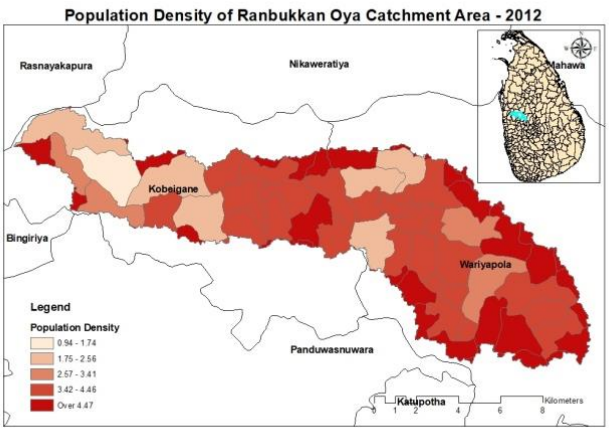

Figure 16 Population Density in 1981

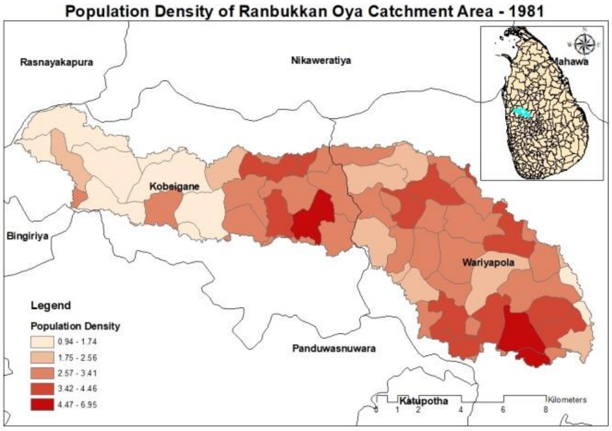

Figure 17 Population Density in 2012

The population density of the area has increased significantly during considered time period. It causes to drastic land use changes and the increase of water demand of the area. The Google Earth images displays the urbanization in some locations and how it detached the small tank cascade chains in the study area.

5.3. Relationship between land use change, reduction of water capacity and the distortions to the small tank cascades in Rambukkan Oya catchment

To understand this relationship it is essential to analyze the Rambukkan oya water discharges and water inflow to the Oya. Due to data constraints it was difficult to prove it through the ground data of the same catchment. However, to find out the relationship, water inflow data from Hakwatuna Oya (Pelpitiya, et.al, 2015) and demand supply graphs of Ridibandi Ela (Sampath, et.al., 2014) were utilized. Figure 18 displays the annual inflow graph of Hakwatuna Oya watershed.

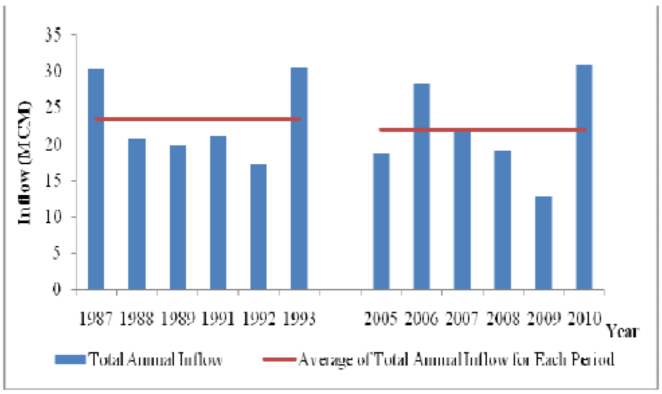

Figure 18. The total annual inflow to the reservoir from 1987-1993 and 2005-2010

(Source. Pelpitiya, et.al. 2015)

According to their analysis, the annual inflow to the watershed has decreased during 2005 to 2010 period. Since the Hakwatuna Oya is also a sub catchment of Deduru Oya basin the same results can be applied to the Rambukkan Oya watershed.

Detachment of small tank cascades in Rambukkan Oya and the reduction of water during 1981 to 2010 period compatible with the results of the Pelpitiya, et.al. 2015 analysis. Thus it is obvious that the change of land use has negatively affected on the water retention capacity of the Rambukkan Oya watershed area and the weakening of small tank cascades system could be one of the reason for the less water retention capacity of the area.

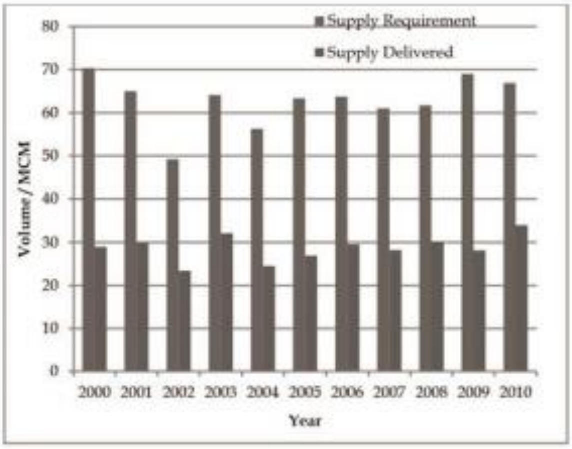

Figure 19. Comparison of Supply Requirement and Supply Delivered in Left Bank Canal Area of Deduru Oya Basin (Source. Sampath, et.al. 2014)

Figure 19 shows the demand and supply of one of the canal in Deduru Oya Basin. According to the analysis during 2000 to 2010 period the demand could not be satisfied with the supply of the canal. Thus it shows the depletion of surface and ground water of the Deduru Oya Basin.

The present study clearly proved that the ancient small tank cascade systems of the Deduru Oya basin have drastically destructed during past decades. The reason behind this is the unplanned spatial alteration occurred during the considered time period.

People do not think about the aftermath of the events they carry out at present, they think only about the instant profit they gain. However, it affect the balance of the ecosystem causing unaltered damages to human as well as other living beings.

6. Conclusion

The research was carried out with the objectives of identifying the change of spatial pattern of small tank cascades of Deduru Oya basin. To achieve this objective Rambukkan Oya watershed was selected. With the help of Landsat satellite images and land use maps the objective could be achieved successfully.

Landsat images covering 1978, 2005 and 2018 showed the obstructions happen to the cascade systems. The small tanks of some locations were isolated and abandoned with the land use changes in the study area. When the pattern of cascade changed, water flow gradient changed and it causes to reduce the water level of some small tanks. Thus these tanks dry out and gradually abandoned. It is one of the reason for less water capacity during recent time periods of the area and the water scarcity.

The land use change analysis in year 1983 and 2010 showed that there is a slight change in land uses. Due to lack of current land use information the land use could not be estimated for year 2018. However, during considered time period the water in the area has decreased. It may be due to poor functionality of the ancient cascades of the study area.

Referring the past researches carried out in Deduru Oya basin, the output of the current research could be verified. The inflow to the Deduru Oya reservoir has decreased during past decades as well as the demand has increased with the developments took place in the area. It causes to aggravate the water scarcity in the study area.

If the business as usual for future, the ecosystem of the Deduru Oya will be in severe danger due to lack of water. The balance of the ecosystem will not be able to regain for decades.

Therefore, it is essential to think seriously about this phenomenon and need to revisit the ancient technology to solve the emerging water scarcity problem in the Deduru Oya basin.

It is essential to think about sustainable spatial management planning to restore the ancient cascade systems to regain the ancient booming ecosystems at the present again.

7. Suggestions

A study about the water balance of the research area is essential to prove the relationship between water scarcity and the distortions to the ancient cascade systems**.** Adding rainfall and temperature analysis to the research will enrich the study.

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