Climate Change Impacts on Surface Runoff and Farmers' Perceptions of Climate Change: A Case of Mundeni Aru Lower River Basin in Sri Lanka

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ABSTRACT
Sri Lanka is one of the Asian countries that is mostly affected by climate change. The prime objectives of this research study were to examine the climate change impacts on surface runoff of Mundeni Aru lower river basin in Sri Lanka and to investigate farmers' perceptions of climate change. Data which include rainfall, soil data, land use and land cover and antecedent soil moisture condition of the study area were collected from natural resource management center, Department of Agriculture, FAO website and department of meteorology. Further, primary data for perception of climate change was collected through focus group discussions and in depth interviews with key informants of eighty two respondents in lower Mundeni Aru river basins. To analyze the surface runoff, the Soil Conservation Service-Curve Number method has been used. Descriptive statistics were analyzing using SPSS statistical packages for qualitative data and coefficient of variation for seasonal rainfall. NASA Earth Exchange Global Daily Down scaled Projections of 6 General Circulation Models were used for future projections of climate change. This research findings reveals that Mundeni Aru river basin is sensitive to climate change and decreases annual surface runoff by 8%, 10.5% in 2050, 2080 years scenarios respectively but increase annual surface runoff by 2% in 2030 scenario. Moreover, qualitative study finding shows that majority of the respondents agreed that climate change is occurring in the focal area. The calculated coefficient of variation for seasonal rainfall was 0.37 for the last 20 years and compatible with qualitative findings.

Index Terms: Mundeni Aru, Curve Number; Runoff, River basin.

1. INTRODUCTION

One of the important sustainable development goals is climate action. Natural disasters tend to increase in frequency and intensity in climate change context of Eastern province of Sri Lanka. Eastern province of Sri Lanka is vulnerable to climate change specifically in terms of droughts and floods and Agriculture and water sectors are the most vulnerable sectors to climate change. Out of 103 river basins in Sri Lanka, Mundeni Aru river basin is one of the larger and important basin in the dry zone. The systematic analysis of flood runoff estimation is a pre requisite for water resources system planning & development and framing of water management strategies. Rainfall and temperature are the most important components contributing significantly to the hydrological cycle as well as climate change. A rainfall - runoff model is actually helpful in the case of calculating discharge from any basin. There are number of methods available for rainfall runoff modeling such as hydrologic models, empirical equations and data driven techniques. Mundeni Aru lower river basin is an ungauged river basin. For an ungauged river basin, Artificial Neural Network (ANN), SCS Curve Number model, and Geo-morphological Instantaneous Unit Hydrograph are commonly used. However, estimation of runoff with a simple method is essential for water professionals as well as researchers. Soil Conservation Service Curve Number (SCS-CN) is an index, developed by the Natural Resource Conservation Services of United States Department of Agriculture (USDA) has been used to analyses the potential for storm water runoff of this study because of its simplicity and easy for understanding. Perception of climate change among the prime stake holder is important for designing adaptation and mitigation of climate change impacts of the basin. General Circulation Models with down scaling techniques were used for climate change prediction of the river basin under study. Moreover, rainfall is mainly experience by this watershed is the North-East monsoon during the period of December to February and forcing the catchments to undergo several drying and wetting stages due to rainfall is limited in seasons for a particular year. Runoff volume and distribution data provides valuable information for effective and efficient decision making of a river basin.

2. STUDY AREA DESCRIPTION

The catchment area of Mundeni River Basin is 1300 square kilometers and the length of the main river is 70 km with a slope of 0.11 × 10−2. This river basin originating in Moneragala district and passing through Ampara district and reached Batticaloa district of Batticaloa lagoon and Valaichenai lagoon. It is located in the coordinates 7^{0} 15' N, 81^{0} 8'E and 7^{0}50'N, 81^{0}36'E respectively. Morphologically, the Mundeni Aru river basin is divided into the upper, middle and lower basins. Rainfall is mainly governed to this river basin by the North-East monsoon during the period of December to February. The average annual rainfall over the basin is 1,902 mm. Further, this river basin is covered by Paddy lands, Grass Lands, Savannas, Wetlands and forests. Savannas and grass lands are taken place a major area cover in this land cover. There are five Major and medium water reservoirs enclosed into this river basin namely Rambakan Oya, Borapola wewa, Tembitiya, Rukam, Kithul Tank.

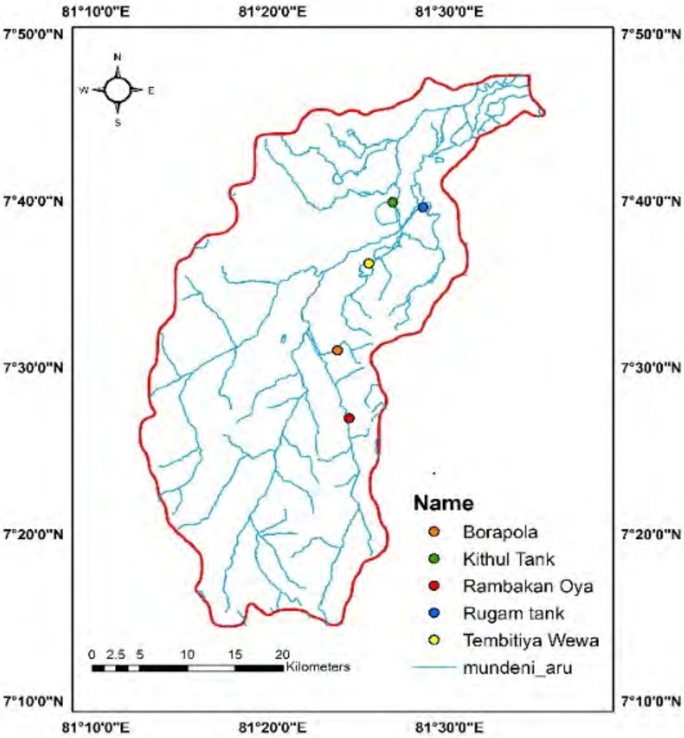

Figure 1: Locations map of Mundeni Aru River

3. MATERIALS AND METHODS

3.1 Research Methodology

Mixed methods of research has been carried out to achieve the objectives. Soil Conservation Service-Curve Number (SCS-CN) method developed by United States Department of Agriculture (USDA) has been used to estimate surface runoff. This method combines the watershed parameters and climatic factors in one entity called the Curve Number (CN). Although the method is designed for a single storm event and for United States, it can be scaled to find average annual runoff values to any basins all over the world. This approach involves the use of simple empirical formulas, standard available tables and curves for estimation of runoff for an ungauged watershed of Mundeni Aru river basin of Sri Lanka. Darshika et al.(2028) used NASA Earth Exchange Global Daily Downscaled Projections of 6 GCM models (CanESM2, CNRM-CM5, CSIRO-MK3-6-0, GFDL-CM3, MRICGCM3and NCAR-CCSM4) with 25km grid spacing which is more applicable to Sri Lankan context. This GCM models were used for future projections of climate change in terms of rainfall-runoff prediction for this river basin by the researchers. The methodologies have been differentiated only based on downscaling the results from global scale models. According to the IPCC, RCP 4.5 requires that carbon dioxide (CO_2) emissions start declining by approximately 2045 to reach roughly half of the levels of 2050 by 2100. Hence only RCP 4.5 has been applied considering South Asian context. Further, primary data for perception of climate change was collected through Focus group discussions and in depth interviews with key informants of farmer organization leaders of 82 respondents in lower Mundeni Aru river basins.

Normally the Soil Conservation Service-Curve Number model computes direct runoff with the help of following relationship (Hand book of Hydrology, 1972)

$$S = (24500/CN) - 254 \quad \text{--------------} \quad (1)$$
$$Q = ((P - 0.2S)^{2})/ (P + 0.8S) \quad \text{-------------} \quad (2)$$
$$CN = (\sum (CNi \times Ai))/A \quad \text{------------------} \quad (3)$$

Where, CN = weighted curve number. CNi = curve number from 1 to any number
Ai = area with curve number CNi, A = the total area of the watershed.
Q = actual direct runoff in mm; P= total storm rainfall in mm;
S = the potential maximum retention of water by the soil in mm.

The secondary data of rainfall, temperature, types of soil and hydrological soil group, area map, land use and land cover, treatment or practice in relation to hydrological condition, antecedent moisture condition with 5-day antecedent rainfall were collected from Departments of Census, Department of provincial Irrigation, Department of Survey, Natural resources management center, Department of Agriculture Department of meteorology, Food and Agriculture Organization and Soil Grid.Org web site. Preparation of Land use/Land cover information of the study area were obtained from Google map as well. Further, primary data for perception of climate change was collected through Focus group discussions and in depth interviews with key informants of farmer organization leaders of eighty two respondents in lower Mundeni Aru river basins.

3.2 Hydrological Soil Group (HSG)

It is obvious that soil properties highly influence the amount of runoff. Soil Conservation Service-Curve Number has defined soil groups as A, B, C & D represent as high, moderate, low and very low according to their infiltration capacity and water transmission rate when thoroughly wetted. Group A having high infiltration rates when thoroughly wetted and a high rate of water transmission. Group B having moderate infiltration rates when thoroughly wetted and a moderate rate of water transmission. Group C indicates soils having low infiltration rates when thoroughly wetted and a low rate of water transmission. Group D indicates soils having very low infiltration rates when thoroughly wetted and a very low rate of water transmission.

According to this grouping it can be further classified as group A: low runoff potential, group B: moderately low runoff potential, group C: moderate high runoff potential and group D: high runoff potential.

3.3 Types of Soil Texture in the Mundeni Aru river basin

The study area covered with Immature Brown Loams, Reddish Brown earths, Non calcic Brown soils and Low Humic Gley soil and small extent of Regosol, Old alluvial, Grumusol, Solodized Solonetz. It is noteworthy to mention that majority of the soils with clay enriched subsoil and low activity clay. So the Mundeni Aru river basin soils were classified according to the Hydrological Soil Groups to use Soil Conservation Service-Curve Number model. Accordingly, soils of Mundeni Aru river basin belonging to Hydrological Soil Group of B and C based on soil texture and illustrated in Table 1.

Table 1: Soil types in the Mundeni Aru river basin

Description of soil type	Percentage of soil in the Mundeni Aru river basin	Hydrological Soil Group
1.Immature Brown Loams	**37**	**B**
2.Reddish Brown Earths (RBE)	**21**	**B**
3.Non-Calcic Brown (NCB) Soils	**18**	**C**
4.Low Humic Gley (LHG) Soils	**13**	**C**
5.Regosol, Old alluvial, Grumusol, Solodized	**11**	**B**

3.4 Average annual rainfall data

The rain gauge stations within and adjacent to the river basins are shown in Table 2. The average rainfall for the entire river basin was calculated using Thissen method and calculated average rainfall was 1902mm.

Table 2: Rain gauge stations with 25 years of average annual rainfall in the Mundeni Aru river basin

Rain gauge station	Average annual rainfall (mm)
1. Galode	1779
2. Maha oya	2182
3 Ruham.	1460
4. Unnichchai	1725
5. Mathuru oya	1620
6.Senanayake Samudra	2641
Average rainfall	**1902**

3.5 Land Use or Land Cover

The entire river basin has been classified into seven categories namely Scrub land, forest, paddy, Homesteads, garden, coconut, chena & other cultivation, water resources, built up area and rock and shown in Table 3.These land use or land Cover play major role for the causation of runoff.

Table 3: Land Use or Land Cover for the Mundeni Aru river basin

Land Use	Area (Ha)	Percentage (%)
1. Scrub land	65,100.0	50.08
2.Forest	20,120.0	15.48
3. Paddy	15,697.0	12.07
4.Homesteads/Garden,Coconut Chena	19,676.0	15.14
5.Water resources	5282.0	4.06
6.Built up area	573.0	0.44
7.Rock	3,552.0	2.73
Total	**130,000.0**	**100.00**

For the data analysis, area weighted composite curve number method for various conditions of land use & land cover and hydrologic soil conditions were used. NASA Earth Exchange Global Daily Downscaled projections of 6 GCM models were used for future projections of climate change in terms of rainfall-runoff prediction for this river basin. Descriptive statistics of mean, coefficient of variation were analyzed using SPSS statistical packages for qualitative data of perception of climate change parameters and rainfall data. The variability of temperature and rainfall data were analyzed by trend analysis for a period of 1991 to 2019 with coefficient of variation.

4. Results and Discussions

It is very important for selection of curve number which is the outcome of combined map of Land use or cover and treatment or practice to hydrological condition, Antecedent moisture condition and Hydrological Soil – Cover Complex.

4.1 Hydrological Soil- Cover Complex

The common factors used to determine curve numbers are hydrological soil group (types of soil), hydrological conditions, land use and land cover, and treatment or practices but slope is not one of the above parameters. Moreover, during the process of overlapping the land use and land cover with hydrological soil group with hydrological conditions, curve number could be selected from the standard Table with class I slope and results are shown in Table 4. Sprenger (1978) iterated that five classes to qualify the slopes were introduced to integrate and to find curve numbers. Accordingly the current study has taken as class I, due to sloping watershed area of the river basin is less than 1% (flat).

Table 4: Curve Number for HSG, Land use or cover and Class I slope under AMC II Conditions as per Soil Conservation Service, 1972.

S.N	Land use or cover	Area in Ha	Area in Percentage	Hydrological Condition	Soil Group	Curve Number
1	Scrub land	65,100.0	50.08	Poor	B	74
2	Forest	20,120.0	15.48	Good	C	71
3	Paddy	15,697.0	12.07	Good	C	79
4	Homesteads/Garden, Coconut	19,676.0	15.14	Good	C	78
5	Water resources & Swamps	5282.0	4.06	-	C	0
6	Built up area	573.0	0.44	-	D	92
7	Rock	3,552.0	2.73	-	D	89
Total		**130,000.**	**100.00**			

4.2 Antecedent Moisture Condition (AMC)

Antecedent moisture condition is a crucial factor for deciding the final CN value. Antecedent moisture condition refers to the amount of water present in the soil at a given time (Mishra et al., 2004). Three antecedent soil moisture conditions namely AMCI, AMCII & AMCIII were developed by the SCS according to conditions of the soil and precipitation limits for inactive and growing seasons. This study has taken AMC III condition to determine the curve number value considering growing season of Maha in Batticaloa district of Sri Lanka.

Table 5: Seasonal rainfall limits for AMC classes (Soil Conservation Service 1972)

Antecedent Moisture Condition (AMC)	Condition	5 - day antecedent rainfall (mm) /Total Rain in Previous 5 days		
		Dormant Season	Growing Season	Average
I	Dry soil but not the wilting point	Less than 13 mm	Less than 36 mm	Less than 23 mm
II	Average conditions	3mm- 28 mm	36 mm – 53 mm	23 mm- 40 mm
III	Saturated soils, heavy rainfall or light rainfall	Greater than 28mm	Greater than 53 mm	Greater than 40 mm

4.3 Calculating Weighted Curve Number Value

CN = (∑ (CNi X Ai))/A -------------------- (3)

= (74 x 50.08) + (71 x 15.48) + (79 x 12.07) + (78 x 15.14) + (92 x 0.44) + (89 x 2.73)/100

= 72.23, Weighted Curve Number Value is Say 73

The calculated CN value of 73 for study area is for average conditions of antecedent moisture condition class II. The CN values for AMC II can be converted into CN values for AMC III by using the SCS (Soil Conservation Service) Standard conversion Tables. To determine which AMC Class is the most appropriate in relation to the study area, rainfall data of 2019 of Rugam of Batticaloa district was used. The 5-day rainfall prior to the event date was determined from rainfall data and it was AMC III.

Table 6: Conversion Tables for curve Numbers from Antecedent Moisture Condition Class II to AMC Class III (After Soil Conservation Service, 1972).

Curve Number of AMC II	Curve Number of AMC I	Curve Number of AMC III
72	53	86
74	55	88
73	54	87

From Table 6, Weighted Curve Number of AMC II is of 73 and Weighted Curve Number of AMC III is 87 and Weighted Curve Number of AMC I is of 54.

4.4 Estimation of runoff depth and runoff volume in terms of rainfall

After generating the CN of 87, the next step was to calculate maximum potential retention (S). The runoff was estimated by knowing the antecedent moisture condition III and the curve number with rainfall in accordance with the following graph or ascertained for each rainfall event by using equation 2 of $Q = ((P - 0.2S)^2)/ (P + 0.8S)$. This shows in the following Figure 2 and Table 7.

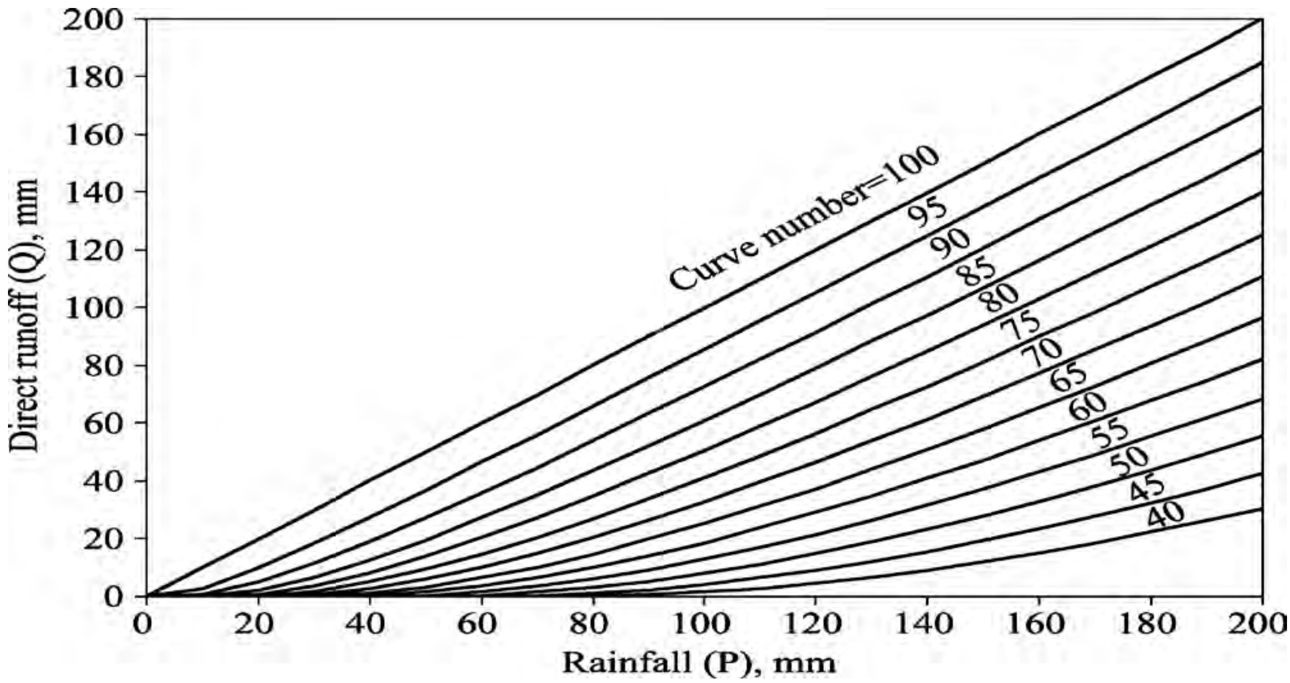

Figure 2: Graphical solution of Equation 2 showing runoff depth Q as a function of rainfall depth P and curve number CN (after soil conservation Service 1972)

Table 7: Rainfall, Curve number and computation of estimated runoff

Rainfall Events for the Months of Year 2019	Rainfall in mm.	Antecedent Moisture Condition	Curve Number	Potential maximum retention in mm	Initial abstraction in mm.(0.2S)	Estimated runoff depth in mm
January	115.30	III	87	27.61	5.52	87.72
February	88.90	III	87	27.61	5.52	62.64
March	117.90	III	87	27.61	5.52	90.22
April	0.00	-	-	-	-	-
May	0.00	-	-	-	-	-
June	5.20	-	-	-	-	-
July	12.00	-	-	-	-	-
August	101.10	III	87	27.61	5.52	74.16
September	80.80	III	87	27.61	5.52	55.08
October	115.00	III	87	27.61	5.52	87.43
November	305.20	III	87	27.61	5.52	274.40
December	614.30	III	87	27.61	5.52	582.37
Total	**1,555.70**					**1314.02**
Total Estimated runoff in Year 2019						**1314.02**

4.5 Coefficient of variation of rainfall and temperature

Descriptive statistics of mean, trend analysis and coefficient of variation were analyzed using SPSS statistical packages for data of perception of climate change parameters and rainfall data. The variability of temperature and rainfall data were analyzed by trend analysis for a period of 1991 to 2019. The results indicated that trend factor as 0.53 with R^2 value of 0.51 indicates increasing trend for temperature. It can be concluded that the temperature of the project area is increasing and compatible with the farmers interview results. Variability of seasonal rainfall was analyzed in terms of coefficient of variation for the period of 1991to 2019, the results indicates that the coefficient of variation is 0.37 indicates high variability of seasonal rainfall for maha season and survey results are also compatible with analytical results.

4.6 Perception of climate change

Primary data for perception of climate change was collected through Focus group discussions and in depth interviews with key informants of farmer organization leaders to understand the level of perception of climate change among a sample of 82 farmers in lower Mundeniaru river basins in Batticaloa district. Descriptive statistics of the sampled farmers and other analysis were done using SPSS statistical packages. Respondents (82) were asked about their perceptions of climate change items as shown in Table 8.

Table 8: Perception of climate change of farmers.

Perception of climate change items	Frequency		Percentage	
	Yes	No	Yes	No
1.Glabal warming is happening	48	34	58.5	41.5
2.Glabal warming is human caused	47	35	57.3	42.7
3.Experience more droughts	68	14	82.9	17.1
4.Increase in overall temperature	58	24	70.7	29.3
5.Decrease in overall rainfall	69	13	84.1	15.9
6.Increase in variability of rainfall	56	26	68.3	31.7

According to sample of 82 respondents, 44 (53.7%) were male and 38 (46.3%) were female. In response to climate change items as shown in Table 8, Global warming is happening item was reported positively by 58.5 % of respondents, Global warming is human caused item was reported positively by 57.3 % of respondents. Moreover, Experience more droughts item agreed by 82.9% of respondents, Increase in overall temperature item agreed by 70.7% of respondents, Decrease in overall rainfall item agreed by 84.1%, of respondents and Decrease in overall rainfall item reported positively by 84.1% and Increase in variability of rainfall item was reported positively by 68.3% of respondents.

5.0 Findings and Conclusions

This study findings reveals that Mundeni Aru river basin is sensitive to climate change and decreases annual surface runoff by 8%, 10.5% in 2050, 2080 years scenarios respectively but increase annual surface runoff by 2% in 2030 scenario. The Representative Concentrated Pathway (RCP) of 4.5 scenario from the IPCC AR5 2013, representing medium future was adopted with three time periods - 2030s, 2050s and 2080s. RCP 4.5 has been applied considering South Asian context of climate change. The results also indicated that North - East monsoon rainfall anomaly slightly positive in short term projection for the year 2030 and negative trends for long term projections for the years of 2050 and 2080.

This study also reveals that SCS-CN method can be effectively used to estimate the runoff for the basin. Climate change projections are important to decision makers in government and corporate sectors. Moreover, this study finding shows that majority of the farmers agreed that climate change is occurring in the focal area. Farmers perceived that changes in climatic variables such as rainfall and temperature had occurred in their area over the last decades and these farmers have adequate understanding of the causes of climatic changes.

The variability of temperature and rainfall data were analyzed by trend analysis for a period of 1991 to 2019. The results elucidates that trend factor as 0.53 with R^2 value of 0.51 indicates increasing trend for temperature. The results also shows that the coefficient of variation for rainfall is 0.37 indicates high variability of seasonal rainfall for maha season and survey results are also compatible with analytical results. Male respondents have more climate knowledge than female respondents as it depends on social, cultural and religious factors.

According to Puniyawardena et al., (2013) stressed that Batticaloa district has been identified as highly vulnerable to climate change in terms of exposure, sensitivity and adaptive capacity of climate change.

Further study could be done using remote sensing Digital Elevation Model (DEM) and GIS based SWAT model effectively to estimate the runoff from this river basins and of river basins of similar geo-hydrological characteristics for climate change prediction with Shared Socio-Economic Pathways for climate change predictions.

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