TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 7805 - 7811

Investigation of issues and Corresponding Sustainable Solutions for Water Resource Management across Ken sub-basin of India

[*1]Gurusamy B T, [2]Vasudeo A D, [3]Gautam N R and [4]Godbole S P
[1]Research Scholar, Department of Civil Engineering, VNIT, Nagpur, India
[2]Associate Professor, Department of Civil Engineering, VNIT, Nagpur, India
[3]Assistant Professor, Civil Department, Priyadarshini Bhagwati College of Engineering, Nagpur, India
[4]Assistant Professor, Dr. Ambedkar Institute of Management Studies and Research, Nagpur, India
[*]Email: guru19april2009@gmail.com

Article Info
Volume 83
Page Number:7805 - 7811
Publication Issue:
May-June 2020

***Abstract*:**
This Paper reviews various issues in the Surface and Ground Water Resources across Ken Sub-basin of India. The spatio-temporal variation of water balance parameters across the Ken sub-basin have been analysed and presented. The estimates about the availability of Surface and Ground Water Resources of Ken sub-basin have been compared with that of Ganga and all India Basins. The decreasing trend of Per Capita water availability across the Ken sub-basin have been graphically presented. The Capacity of Ken sub-basin to provide water, required for diversion towards Betwa sub-basin based on the proposed Ken-Betwa Link Project as a Peninsular Component of NRLP of India, have been examined. The existence of various Sustainable Water Resource Management Practices that can be applied to solve the Water related issues of Ken sub-basin have been explored to achieve SDGs proposed by UN. Applicability of ASR Technology and Ganges Water Machine Concepts to Ken sub-basin has been reviewed. Based on UN agenda 2030, the achievement of SDGs across Ken sub basin have been analysed using the index score parameters defined and monitored by the Government of India.

Article History
Article Received: *19 November 2019*
Revised: *27 January 2020*
Accepted: *24 February 2020*
Publication: *18 May 2020*

Keywords
Water Balance Analysis, Ken Sub-Basin of India, Sustainable Water Resource Management, Ganges Water Machine, Aquifer Storage and Recovery Technology

Introduction

The increase in awareness of Sustainable Development has started with the decreasing trend of the Natural fuel resources supporting the Mechanized life style of the ever growing Population. With the depletion of natural fuel energy resources, the Mechanized life style of the people will become a Question. The increase in Energy demand of population of India has created sharp increase in Installed Power Capacity. Even though there is decreasing trend of Solar Power cost, the development of Natural fuel exploiting Thermal power capacity is consistently observed nearly twice that of Renewable power capacity as shown in Figure 1. The effect of this exploitation also causes climate change impact having influence to bring down the Water Resources Potential. The effect of population growth to reduce per capita water availability across Ken basin is shown in Figure 2.

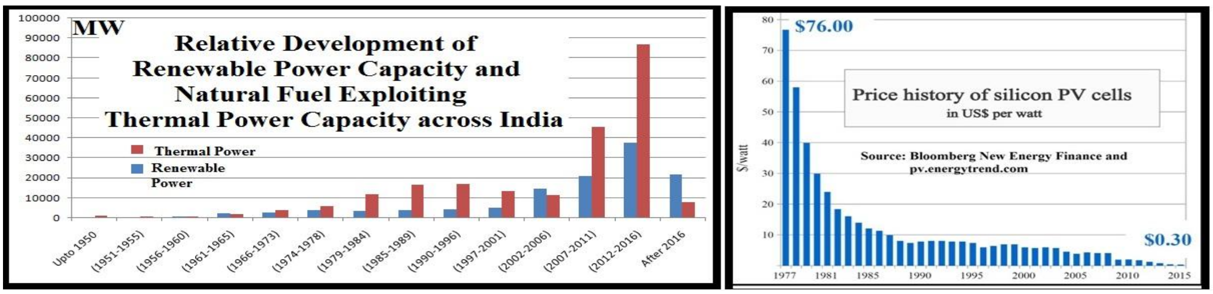

Figure 1 Development of Thermal Power Capacity relative to Renewable Power Capacity across India (CEA)

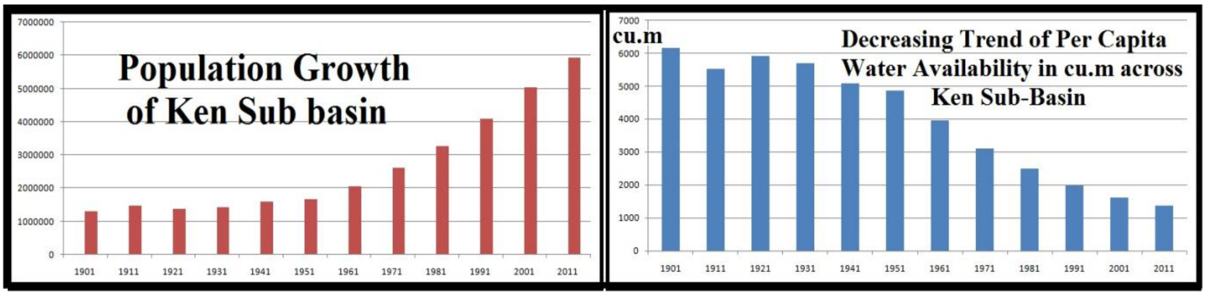

Figure 2 Decreasing trend of Per Capita water Availability across Ken sub-basin (CWC)

To maintain equilibrium and self-sustained Global life pattern, the efforts of United Nations (UN) have created awareness of Sustainable Development in order to achieve Agenda 21 proposed by UNCED (1992), Millennium Developments Goals (MDGs) proposed by UNDP (2006) to be achieved by 2015. UN based Sustainable Development Goals (SDGs) introduced by 2015 in the form of Global Agenda 2030 have replaced the earlier versions. The fundamental rights of human beings for Food, Freedom, Education, etc have also been considered as Natural Resources which should not be exploited for the purpose of economic development. Accordingly the Zero Hunger, No Poverty, Education, Inequalities etc have been included in the SDGs proposed by UN. When we exercise or enjoy the Fundamental Rights, it is expected that we are supposed to adhere with Fundamental Responsibility which is also mentioned in SDG 17 with the objective of Partnership for the Goals (NITI, 2018). Hence any Water Resources Management practices should be Sustainable in order to achieve UN Global SDG Agenda 2030 across all sectors of development using the principle of Integrated Water Resources Management (IWRM) as proposed by WHO (2003). Any discrepancies in this process need to be monitored and corrected in the form of Continuous Improvement Process (CIP) of Development (ASQ, 2015). Organizing a Sustainable Development Conference can be considered as a contribution towards Continuous Improvement Process (CIP) of Development where the ideas originates from the bottom and propagates towards the top (Imai, 1986).

Materials and Methods

This Review Paper does not contain any Primary data except for the organisation, interpretation and logical reasoning of the information about Ken Sub-basin collected from various literatures with the purpose of finding the existing water related issues and the corresponding Sustainable Solutions in order to achieve SDGs across the Ken River Basin (KRB). The location and Watershed delineation maps of KRB as published by CGWB (2014) are shown in Figure 3. The Pattern of Land administration, Land use and Land drainage of KRB by different districts of MP and UP states of India as published by Bhuvan Ganga (2015) are shown in Figure 4.

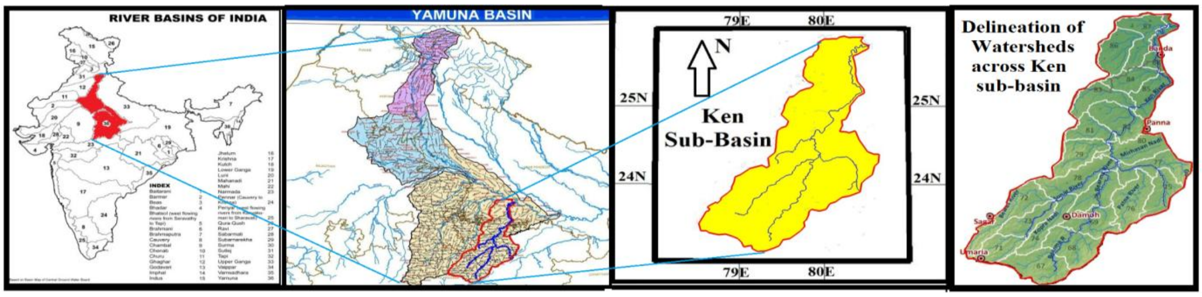

Figure 3 Location and Watershed Delineation of Ken Sub-Basin (CGWB, 2014)

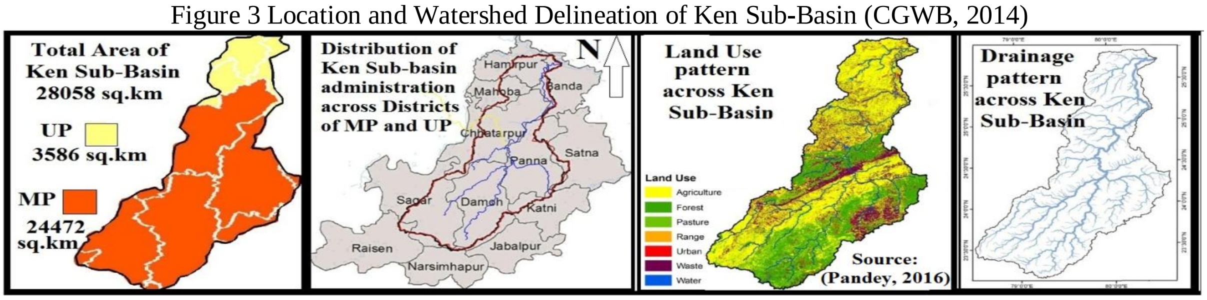

Figure 4 Pattern of Land Administration, Land Use and Land Drainage across Ken Sub-Basin (Bhuvan, 2015)

Even though the data provided by the Water Resources Organizations such as CGWB, CWC etc are district wise, they have been converted into basin wise using the factor which is the fraction of District lying inside the basin. GIS software has been used to determine this factor. Accordingly Ken Population has been calculated. The Qualitative Land Use pattern reported by Pandey (2016) as shown in Figure 4 delineates the relative measure of arable land and Forest Land Use in order to emphasize the need of efficient Water Management system to handle the arable land. The quantitative measure of Ken Land Use details has been reported and used by NWDA (2010) towards the estimation of Economic benefits of the Proposed Ken-Betwa Link Project. Anyhow no attempt has been made for the Economic evaluation of any proposed Sustainable Water Resources Management Strategies explored in this Review Paper. Water Resources Assessment of the Yamuna River Basin provided by Rai (2012) has been used to compare the Water Balance of Ken with that of other basins.

Investigation of Distribution of Water demand across KRB is also not included in this Review Paper Work. The equation (Total Rainfall Inflow=Surface Runoff outflow + Groundwater Recharge + Evapotranspiration) based on simple Water Balance Model has been used to determine the annual Evapotranspiration. The values of district wise percentage Stage Ground Water Extraction as defined, monitored and published by CGWB (2019) have been used to determine the applicability of Ganges Water Machine Strategy across the KRB.

Results and Discussion

One of the major water related issue is the highly seasonal characteristics of Rainfall pattern across the Ken sub-basin as shown in Figure 5. To keep the surface water available during non-monsoon season, the actual process of development of Live Storage Capacity across KRB is shown graphically in Figure 6.

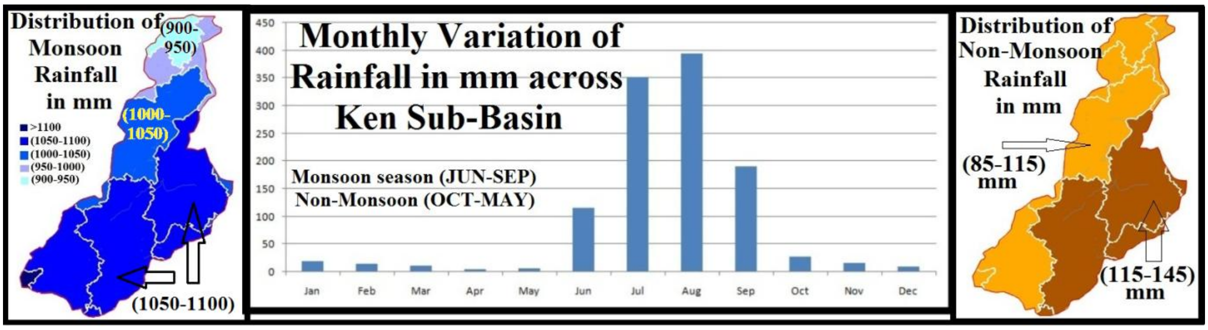

Figure 5 Spatio-Temporal Variation of Monsoon and Non-Monsoon Rainfall across Ken Sub-Basin (Jain,2015)

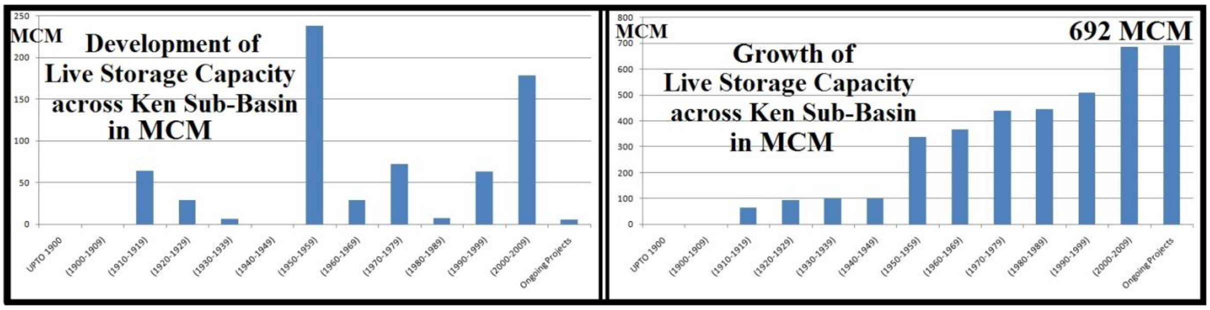

Figure 6 Development of Surface Water Live Storage Capacity across Ken Sub-Basin (Rai, 2012)

Table 1 Comparison of Water Availability of Ken with that of Ganga, Betwa and All India Basins (CWC, 2017)

Name of the Basin	Rain Fall (BCM)	Surface Water Availability or Natural Runoff (BCM)	Replenishable Ground Water Potential (BCM)	Evapotranspiration (BCM)	2011 population Per Capita Surface Water availability (cu.m)	2011 Population in Lakh	2011 Population Density per sq.km	Live Storage Capacity in BCM & % of Rain	Per Capita Surface Water Live Storage Capacity in cu.m	Density of Surface Water Availability (MCM per sq.km)	Geographical area (sq.km)

All India	3880 (100%)	1914 (49.3%)	452 (11.7%)	1514 (39%)	1580	12102	374	304 (7.8%)	252	0.59	3234496
Ganga (India)	914 (100%)	525 (57.4%)	172 (18.8%)	217 (23.8%)	1595	3292	382	56 (6.1%)	171	0.61	861452
Betwa basin	47.2 (100%)	11.8 (25%)	5.7 (12.1%)	29.7 (62.9%)	960	125	282	4.4 (9.3%)	350	0.27	44335
Godavari Basin	365 (100%)	117 (32 %)	47 (12.9%)	201 (55.1%)	1604	730	234	44 (12%)	603	0.37	312812
Ken basin	32.6 (100%)	8.1 (24.8%)	3.1 (9.5%)	21.4 (65.7%)	1364	60	214	0.7 (2.1%)	115	0.29	28058

The Annual Water Balance and Water Availability of Ken sub-basin is analysed and compared with that of Betwa, Godavari, Ganga and all India basins as shown in Table 1.

The next issue observed from the Table 1 is the relatively high Evapotranspiration(ET) of KRB having more than 65% rainfall while that of Ganga Basin and Godavari basin average ET is respectively about 24% and 55%. Anyhow based on the Water Balance Analysis across KRB, carried out by Murty (2014) using 25 years data (1985-2009) it has been reported that out of the annual average rainfall of 1132 mm (31762 MCM), 23% (7305MCM) has been observed as runoff loss and 4% (1271 MCM) for Ground Water replenishment and the remaining 73% (23186 MCM) has been accounted as Evapotranspiration. In order to utilise the observed average annual runoff loss of about 7394 MCM, NWDA (2010) had proposed a project called as Ken-Betwa Link as shown in Figure 7. Using the Link Canal, 1074 MCM water has been planned for transfer to Betwa Basin so that the Bundelkhand Region of UP and MP will get benefitted.

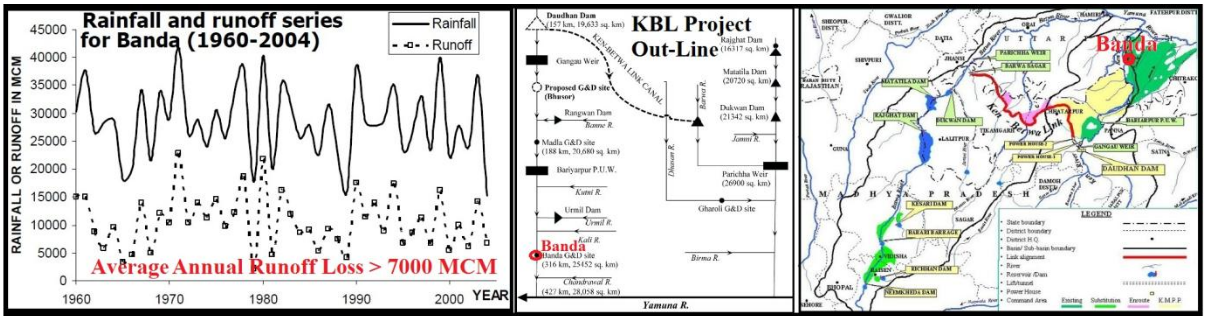

Figure 7. Observed Annual Runoff Loss and Proposed Water Management Strategy across Ken Basin (NWDA)

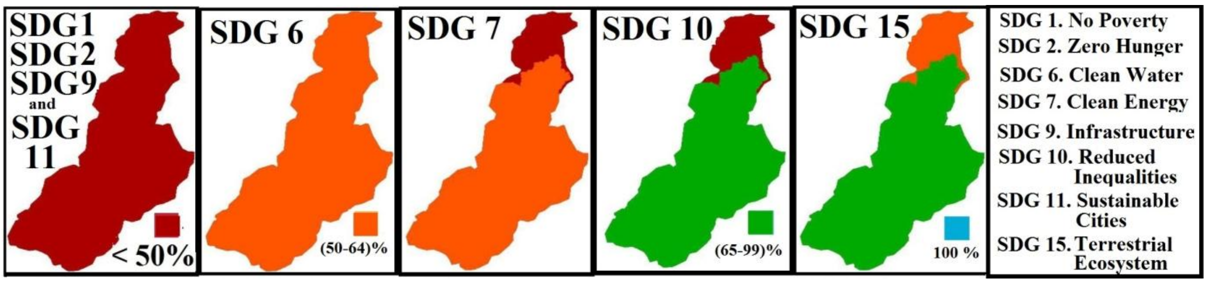

Figure 8 Achievement of SDGs across Ken Sub-Basin using index score defined & monitored by NITI (2018)

Even though the name is Ken-Betwa Link (KBL) Project, more than 85% benefits of the project is being utilised by the Ken basin and less than 15% benefit is credited to Betwa basin using the water Transfer. The original Project name was Ken Multi Purpose Project (KMPP). There is an issue in the form of submergence area of KBL project lying inside Panna National Park. According to the report of NITI (2018), as shown in Figure 8 the level of achievement of SDG towards terrestrial Ecosystem is somewhat better than that of SDGs towards No Poverty, Zero Hunger, Water, etc applicable for KRB. Hence the submergence of less than 8% Panna Tiger Reserve (PTR) area due to the proposed Storage structure can be tolerated towards the benefit of storing more than 2800 MCM water to achieve the purpose of irrigating the downstream area of KRB.

According to USACE (2015), large volume of water can be stored and recovered beneath a relatively small surface footprint using properly designed Artificial Recharge Structure located preferably adjacent to large and flowing water bodies to enhance the capacity of the system similar to rechargeable battery. This Concept had been named as Aquifer Storage & Recovery (ASR) Technology. CGWB (2007) had developed a Manual for Artificial Recharge as a standard for the Efficient Implementation and Operation of ASR System to enhance the performance of increased Recharge in order to bring down the impact of Flood and Drought. Owusu, (2017), has reported about the successful adaptation of various ASR system to bring down the Flood level for the flood-prone areas of northern Ghana in west Africa and to achieve dry-season irrigation.

To bring down the impact of Flood and Drought produced by highly seasonal Characteristics of rainfall, a concept called Ganges Water Machine (GWM) was introduced by Revelle (1975). This concept proposes for intensified pumped Ground Water Use before monsoon in order to increase the Sub Surface Storage (SSS) potential of the basin. Proper design of Recharge Structure will restore SSS water availability. Such Pump-Recharge-Pump strategy is having similar behaviour of Reciprocating Machine and hence called as Ganges Water Machine. Conjunctive Use of Surface and Ground water has been defined as a Philosophy of Water Resources Management where efficient allocation of Surface and Ground Water need to be designed for both to satisfy the water Demand of the basin and to bring down the impact of Flood and Drought based on the high variability of Surface Water Availability. Based on the report presented by Muthuwatta (2017), more than 30% contribution of Flood in the Bihar State is from Ghaghara and Yamuna Lower Sub-Basin which includes KRB. Amarasinghe (2016) has reported that the suitability of the basin for the successful implementation GWM concept depends on the Ground Water Consumptive Water Use (CWU) as a percentage of Recharge. The distribution of Ground Water CWU and the Potential for the application GWM concept across the Ganga basin is shown in Figure 9. Accordingly there is reasonable potential for the implementation of GWM across Yamuna Lower Sub-Basin including KRB. According to Khan et al. (2014), proper ground water Management through conjunctive water use strategy in the form of distributed pumping and recharge across Ganga River basin (GRB) with the implementation of GWM can bring down sizable flood volume in UP below Allahabad.

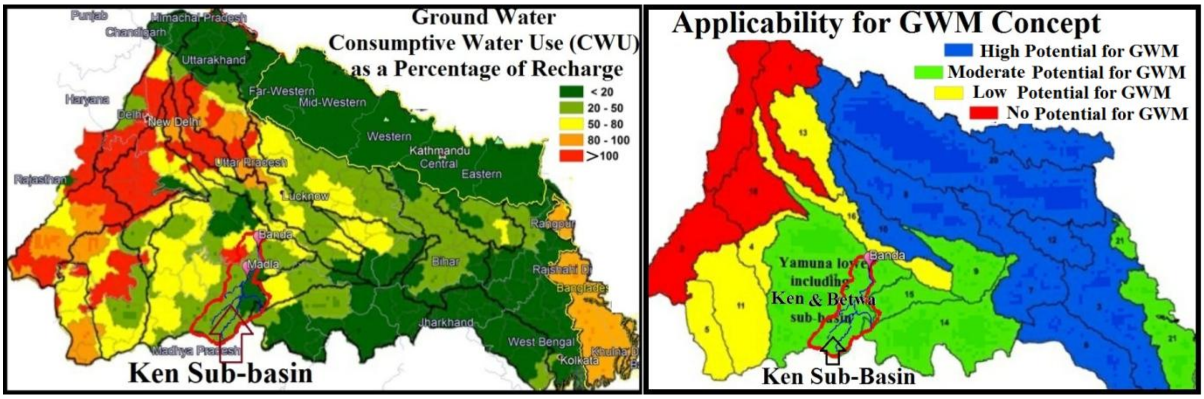

Figure 9 Distribution of Ground Water CWU as % of Recharge and Applicability of GWM Concept across KRB

Conclusions

Even though the observed average annual rainfall over the Ken sub-basin is somewhat above 1000mm, because of the highly seasonal characteristics on rainfall in the form of temporal concentrated over JUN-SEP monsoon season and the relatively high value of Evapotranspiration having value more than 65% of rainfall, the possibility for the occurrence of drought in the Summer season is expected to be high. The drought without sufficient rainfall is reasonable. But the occurrence of drought with average rainfall more than 1000mm will represent the existence of inefficient Water Management Practices across the Basin.

The Live Storage Capacity (LSC) as a percent of rainfall as well as Per capita LSC both are relatively very low for KRB when compared with that of Betwa, Ganga, Godavari etc. Hence even though some fraction of the submergence area lies inside the Panna Tiger Reserve (PTR) area, the Daudhan dam across Ken river with LSC more than 2 BCM as proposed by NWDA in the name of Ken-Betwa Link Project is justified. Getting Storage space in hilly terrain is a good opportunity.

There are more than four dams including Kapur, Muran, Podagada and Indravati to create single Reservoir of GSC 2300MCM across Indravati River of Godavari basin in Odisha State. This shows more enthusiasm to create Storage Space and hence the LSC of Godavari basin is more than 12 % of annual rainfall. The construction of proposed Daudhan dam need to be encouraged to reduce the possibility of drought during summer season in the Bundelkhand region located in the downstream side of KRB.

The adaptation of ASR and GWM System across KRB as a Sustainable water Resources Management Practice, the Climate-Resilient Capacity of the Basin can be increased to counteract the impact of Climate Change and to bring down the possibility of Flood and Drought and also to enhance dry season agricultural productivity.

Acknowledgement
The research facilities that have been provided by the administration of VNIT Nagpur, water resources data that have been published by Government of India through its organizations such as CWC, NWDA, IMD, CGWB, NRSC and WRIS and Services such as Web, Google Earth, Wikipedia & Search Engines available through internet communications and information about achievement of SDGs from NITI Aayog are acknowledged

References
1. CEA, 2019, "Growth of Electricity Sector in India from 1947-2019", Central Electricity Authority , Ministry of Power, Govt. of India
2. CWC and NRSC 2014. Ganga Basin Report Version 2.0. Central Water Commission and National Remote Sensing Centre, CWC Publications, Ministry of Water Resources, Government of India.
3. UNCED, "United Nations Sustainable Development Agenda 21", United Nations Conference on Environment & Development, Rio de Janerio, Brazil, 3 to 14 June 1992
4. UNDP. 2006. Millennium Development Goals - MDGs. http://www.undp.org/mdg/basics.shtml
5. NITI Aayog, SDG India Index Base Line Report 2018, National Institution for Transforming India, GoI.
6. WHO, "World Summit on Sustainable Development: Key Outcomes, Challenges and Opportunities for Health and Sustainable Development. World Health Organization 2003
7. ASQ, 2015, "Continuous Improvement", American Society for Quality, (http://asq.org/learn-about-quality/continuous-improvement/overview/overview.html).
8. Imai M (1986). Kaizen: The Key to Japan's Competitive Success. McGraw-Hill/Irwin. ISBN 0-07-554332-X.
9. CGWB, 2014, "Watershed Atlas of India", Central Ground Water Board, MoWR, Government of India.
10. Bhuvan Ganga, "Geospatial Support for National Mission for Clean Ganga" 2015, NRSC, Ministry of Water Resources, Government of India. https://bhuvan-app1.nrsc.gov.in/mowr_ganga/
11. Pandey R P, et al, "Assessment of Vulnerability to Drought towards Effective Mitigation Planning: The Case of Ken River Basin in India", Journal of Indian Water Resources Society, Vol 36, No. 4, Oct, 2016
12. NWDA, "Detailed Project Report (DPR) of Ken Betwa Link Project Phase I and II" 2010 and 2014 respectively Ministry of Water Resources, Government of India, New Delhi.
13. Rai R.K. et al., (2012), The Yamuna River Basin, Water Science and Technology Library 66, 13 Springer Science and Business Media B.V. DOI 10.1007/978-94-007-2001-5
14. CGWB, (2019) "National Compilation on Dynamic Ground Water Resources of India, 2017", Department of Water Resources, RD & GR, Government of India.
15. Jain K V et al. , "Comparison of drought indices for appraisal of drought characteristics in the Ken River Basin", Weather and Climate Extremes 8(2015)1–11, Elsevier B.V
16. CWC, 2017 Reassessment of Water Availability In India" Central Water Commission, Govt of India.
17. Murty P, et al. (2014). Application of Semi distributed hydrological model for basin level water balance of the Ken basin of Central India. Hydrological Processes. 28. 4119–4129. 10.1002/hyp.9950.
18. USACE, 2015, "Aquifer Storage & Recovery (ASR) | Regional Study", United States Army Corps of Engineers http://www.saj.usace.army.mil/Portals/44/docs/FactSheets/ASR_FS_June2015_web.pdf

May – June 2020
ISSN: 0193-4120 Page No. 7805 - 7811

19. CGWB, 2007, "Manual on Artificial Recharge of Ground Water" Central Ground Water Board, Ministry of Water Resources, Government of India.
20. Owusu S, et al, 2017. Adapting aquifer storage and recovery technology to the flood-prone areas of northern Ghana for dry-season irrigation. SriLanka. International Water Management Institute Working Paper 176. 35p.
21. Revelle R, Lakshminarayana V (1975) The Ganges water machine. Science 188(4188): 611-616.
22. Muthuwatta L, et al. "Reviving the “Ganges Water Machine”: where and how much?" Hydrol. Earth Syst. Sci., 21, 2545–2557, www.hydrol-earth-syst-sci.net/21/2545/2017/ doi:10.5194/hess-21-2545-2017
23. Amarasinghe U. A, et al.(2016), Reviving the Ganges water machine: potential and challenges to meet increasing water demand in the Ganges River Basin. Sri Lanka (IWMI RR 167). 42p
24. Khan M R, et al (2014), Water resources management in the Ganges basin: A comparison of three strategies for conjunctive use of groundwater and surface water", Water Resources Management 28(5): 1235-1250.