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Outstanding Student & PhD candidate Presentation contest

Groundwater recharge restoration in urban area using LID/BMP: Study case of Benin, West Africa

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Introduction

- GW resource is the main source of water usage in Benin. This precious resource is subject to significant changes either due to seasonal dynamic or anthropogenic activities. In Benin, the majority of the population works in or depends on the agricultural sector. Because of the increasing population, LuLc planning is important to preserve water resource and prevent conflicts.

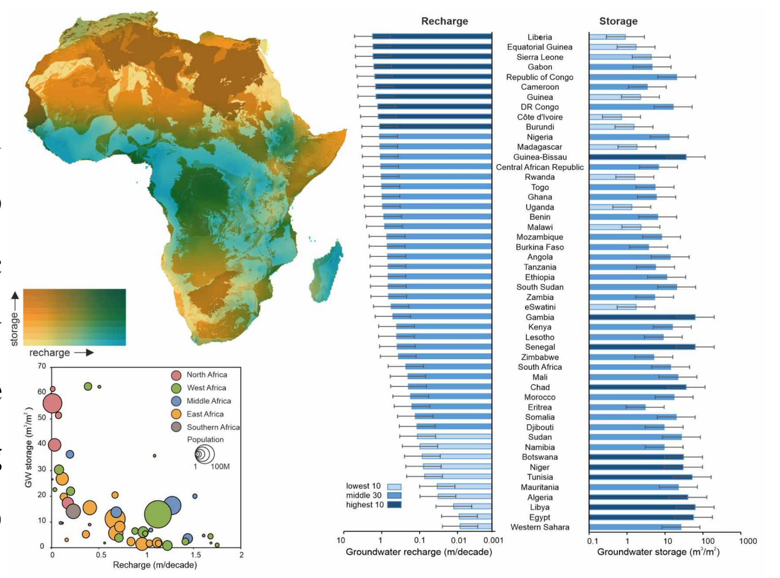


Fig 1: GW storage and recharge in Africa (Source: Makoni, M. (2021))

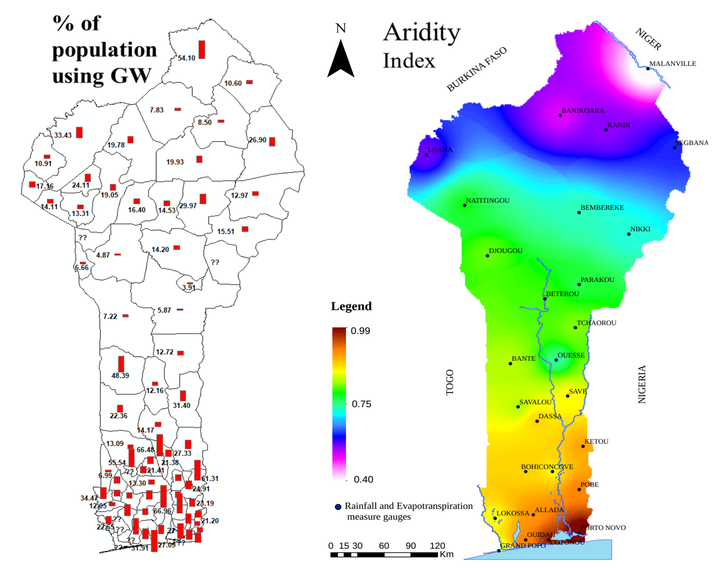


Fig 2: GW use and aridity index of Benin

- First, the present study aims to evaluate GW recharge variation in the interval of 10 years considering land use land cover change from 1975 to 2020. Second, the study aims to develop a tool specially for the township of Abomey-calavi, region with high urban changes for GW recharge estimation and restoration (Best Management Practice: BMP).

Study area

- The study area is located in the south of the republic of Benin (west Africa)
- The climate of the area is marked by two rainy seasons (long rainy season from April to July; short rainy season from September to November) and two dry seasons (long dry season from December to mi-March; short dry season in August)
- The study area contains GW pumping station of Ouédo and Godomey which are the biggest stations used to supply the city of Cotonou and surrounding cities in drinking water. The aquifer of the area is the Continental Terminal.

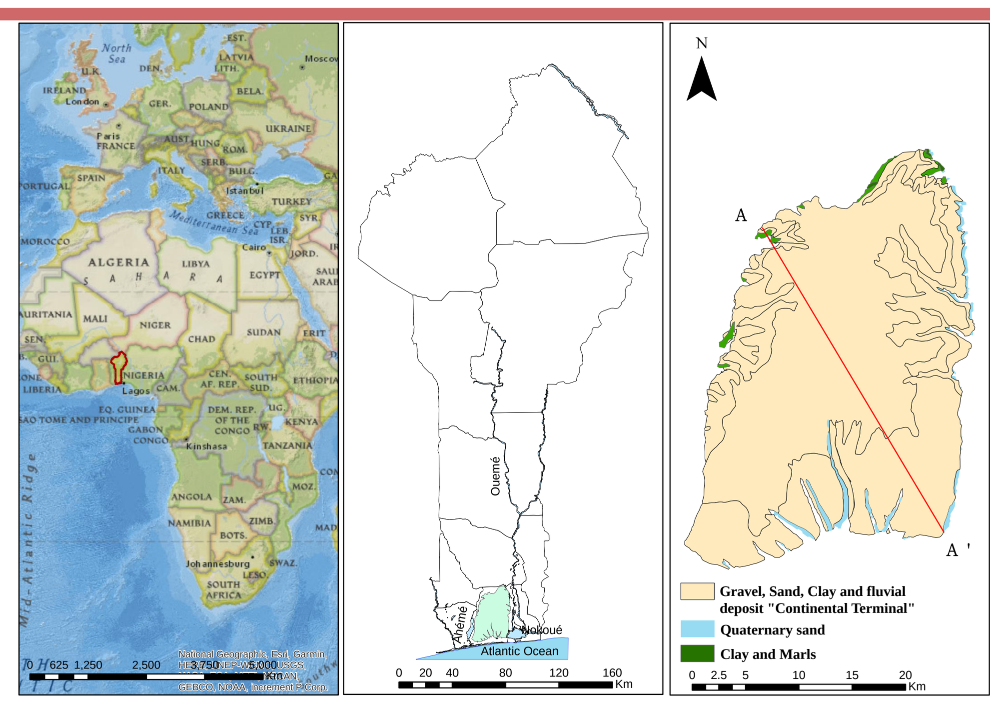


Fig 3: Study area geographical location and geologic units

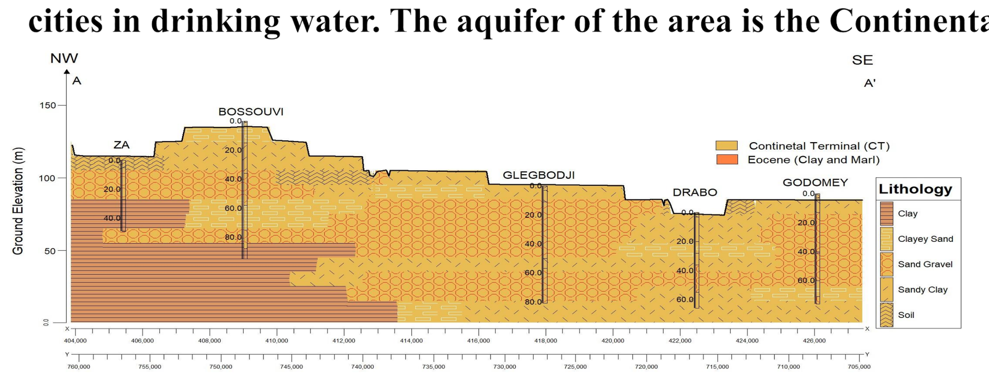


Fig 4: Geologic units of cross-section AA'

- It is mostly constituted of sand, gravel and clay
- The thickness of the Continental Terminal deposits ranges from 60 m in the north to about 200 m in the south (Cross-section AA')
- Its horizontal transmissivity ranges from 4.10^{-3} to 14.10^{-3} m^2/s

Methods

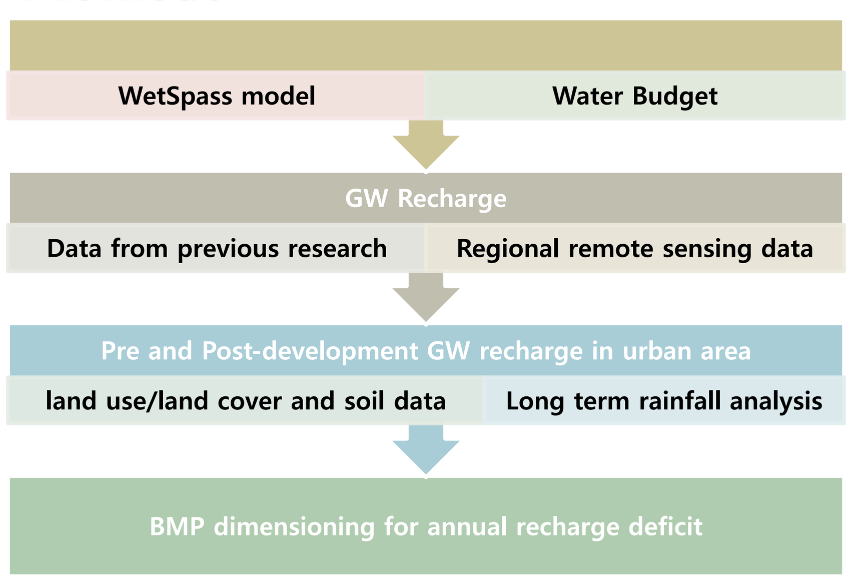


Fig 5: Methodology flowchart

- LuLc change analysis from 1975 to 2020
- Influence of LuLc change on surface runoff and GW recharge
- GW recharge changes in the township of Abomey calavi due to urbanization
- Pre and Post-development GW recharge estimation tool development in excel

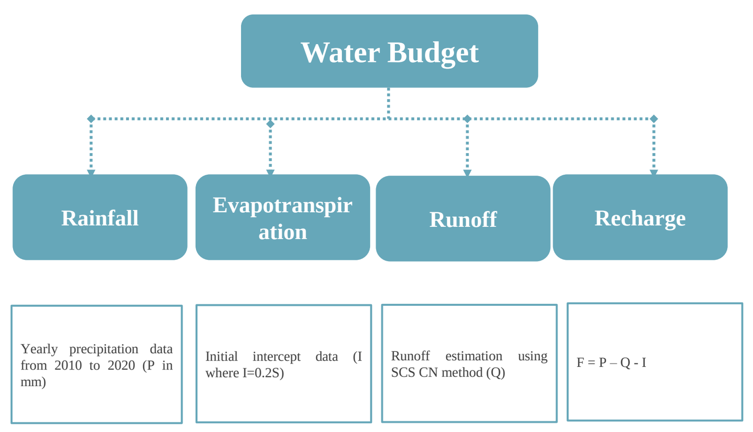
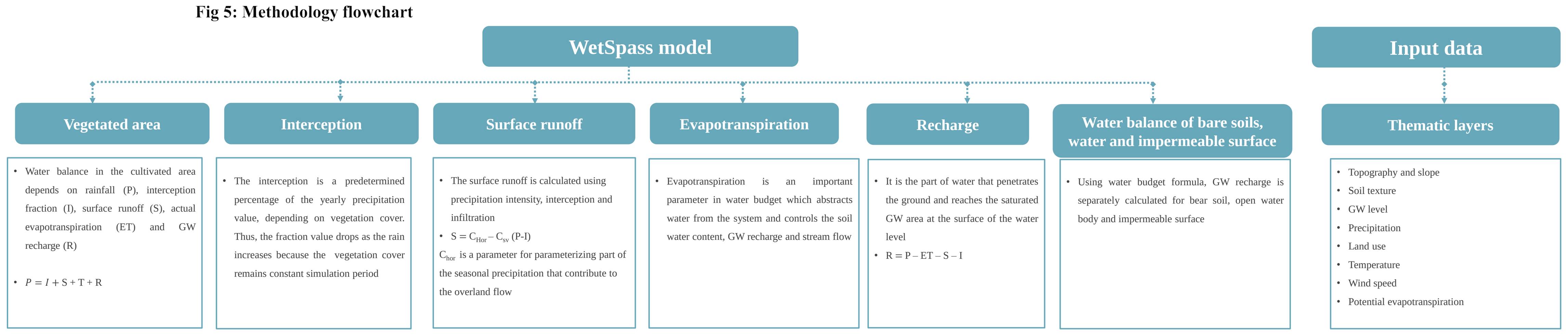


Fig 6: GW recharge estimation using Water Budget



Results

LuLc change

- From 1975 to 2020, LuLc change analysis showed that Forest has decreased by 91%, Shrubland and woodland have decreased by 65.5% and 98%, respectively. At the same time agricultural land has increased by 127%, Cropland and fallows with oil palms has increased by 85.10%; Bareland/Sparse vegetation and Built up areas have increased by 30.6% and 201.69%, respectively.

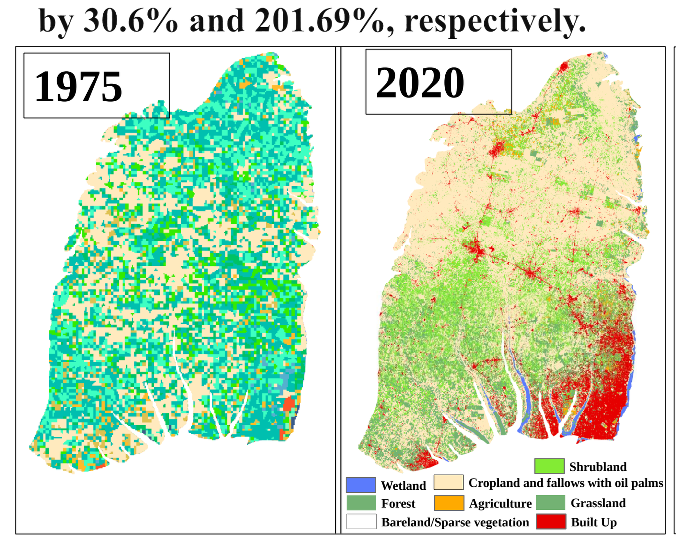


Fig 7: Land use land cover

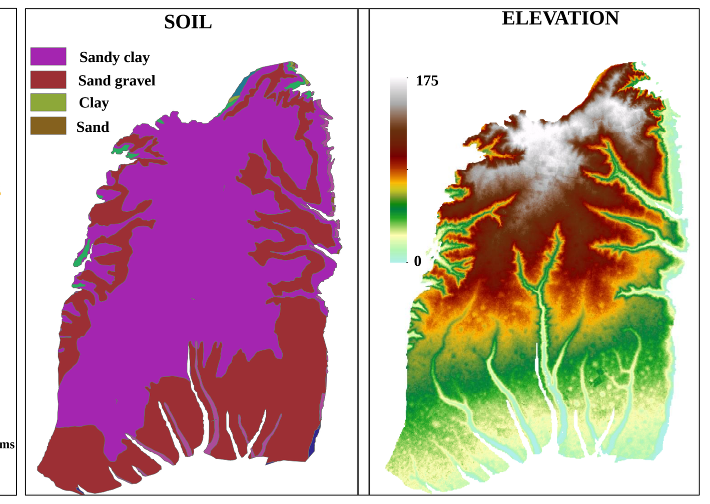


Fig 8: Soil and ground elevation of the study area

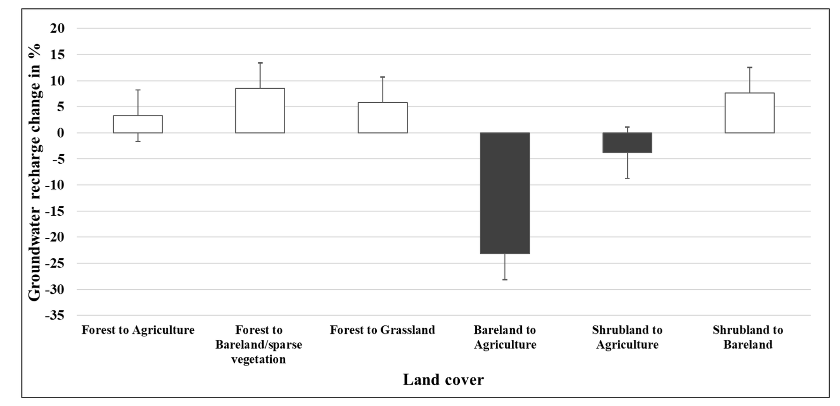


Fig 10: Impact of land use land cover changes on GW recharge

- The study has generated a CN grid of each LuLc combined with hydrological soil group of the study area which was used to estimate the runoff, and GW recharge was calculated using the water budget. The annual recharge deficit is the difference between the total annual recharge volumes for Pre- and Post-Developed Conditions (first excel sheet fig.11).
- The second excel sheet is a sizing tool of GW recharge BMP to provide the desired or required volume of annual GW recharge deficit which is caused by a project development (second excel sheet fig.12). Alternatively, it is used to evaluate the performance of the user-specified recharge BMP.

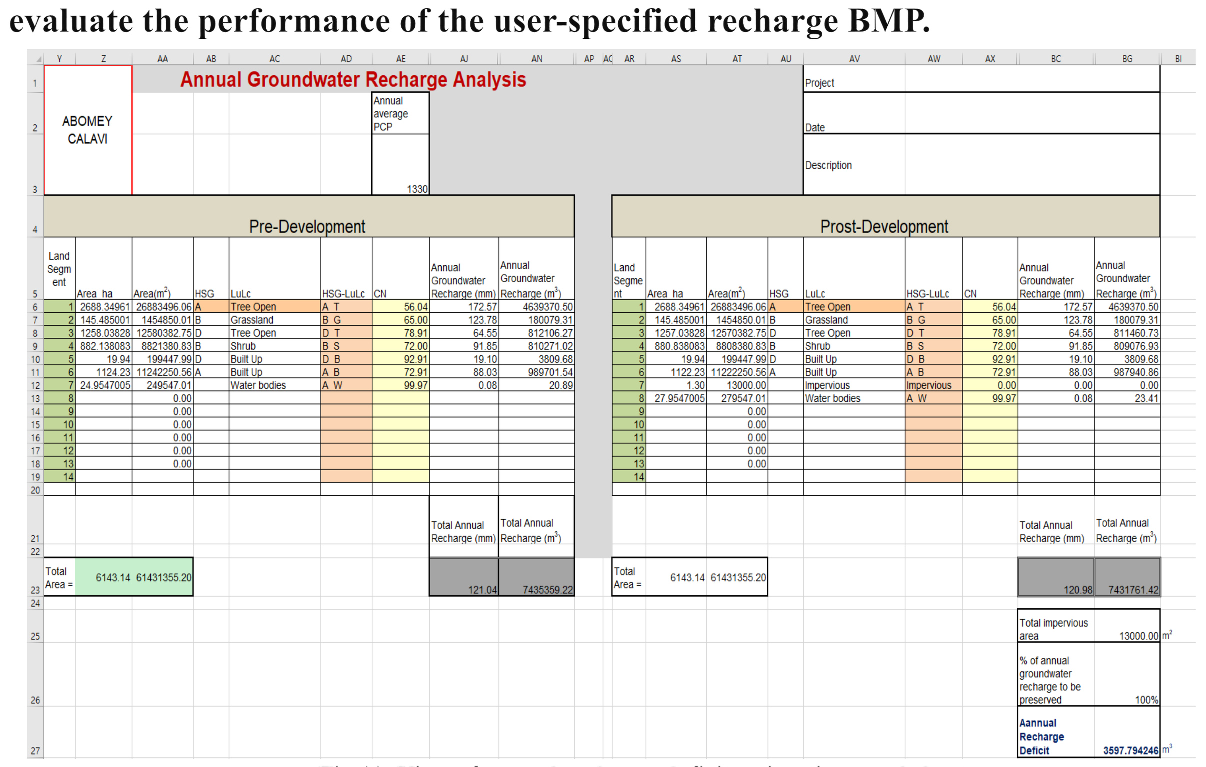


Fig 11: View of annual recharge deficit estimation excel sheet

GW recharge estimation using two different methods

- GW recharge across the plateau of Allada was estimated using two different models. The results produced by both models showed a high spatial correlation of 0.79 but after analysis and validation of each model by comparing the results to GW recharge estimated using Water Fluctuation Method (previous research), the second model (estimate runoff using SCS CN and recharge using water budget) has produced better results. The parameters used and 10 years annual average GW recharge are shown in fig.7,8 and 9.

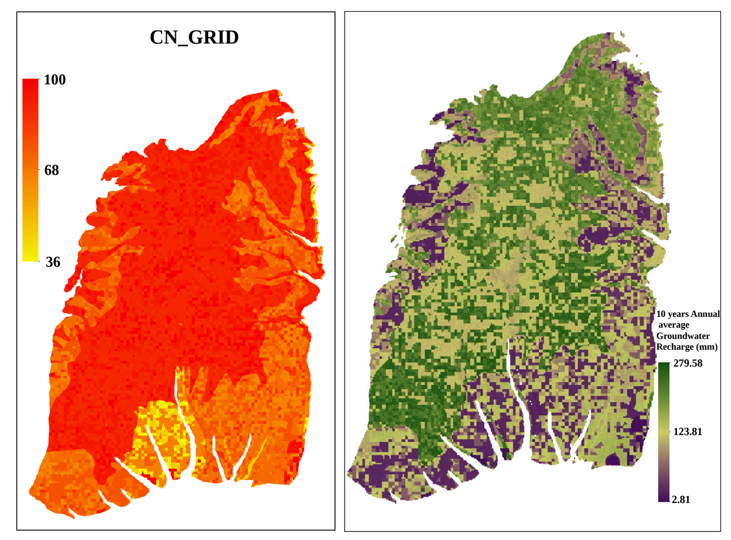


Fig 9: CN grid and 10 Years annual average GW recharge

Impact of LuLc change on GW recharge

- GW recharge across the study area is found to be highly influenced by the LuLc changes.

BMP design tool

- The most urbanized area (Abomey calavi) in the study region is used to study a GW recharge restoration using BMP.

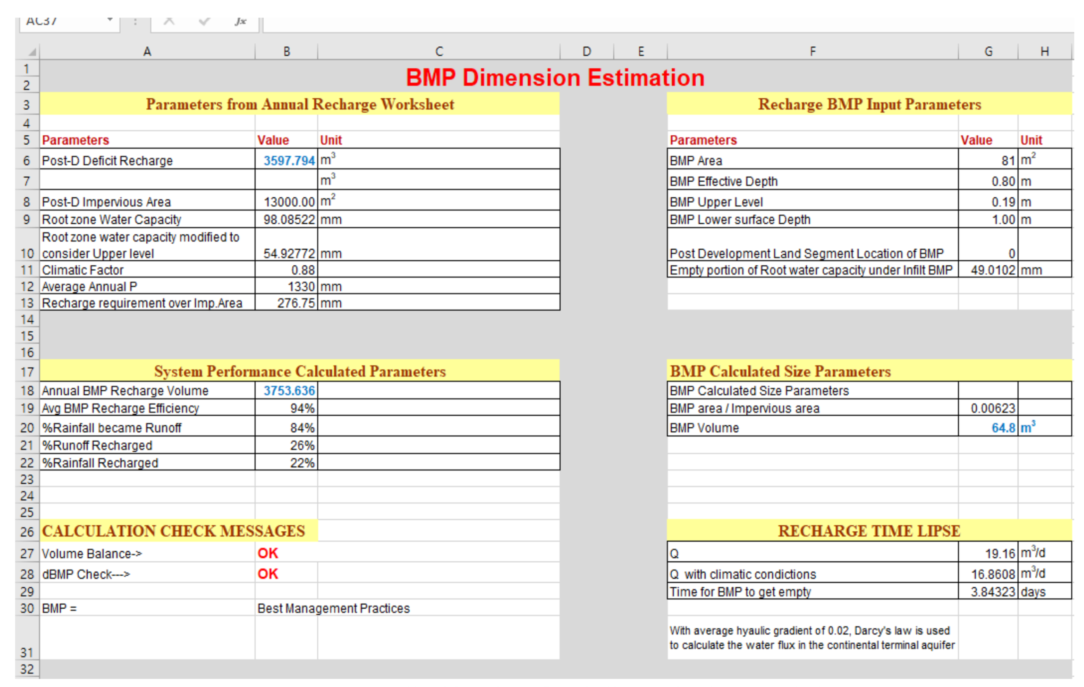


Fig 12: View BMP dimensioning excel sheet

Conclusion

- The present research associated WetSpass model with geospatial tool and SCS-CN method to estimate the spatial and temporal GW recharge in the plateau of Allada (Benin, West Africa). From 2010 to 2020, GW recharge across the study region was estimated using first the LuLc of 1975 and second the LuLc of 2020
- Using the LuLc of 1975 and 2020, the 10 year period GW recharge average is 210mm and 255mm, respectively.
- A spatial and temporal analysis proved that the change of forest to agricultural land has increased annual GW recharge by 5%. While forest is changed to bareland/sparse vegetation and grassland, the annual GW recharge has increased by 10% and 6%, respectively. The change of shrubland and bareland into agricultural land has decreased GW recharge by 25% and 5%, respectively.
- For the township of Abomey calavi, the study has developed a database of the HSG, LuLc and generated CN. The database is used in excel to develop a tool for GW recharge assessment using water budget
- The tool is utilized to estimate a GW recharge deficit caused by urban project development which has increased the impervious area
- From the annual GW recharge deficit the tool is used for sizing a BMP facility (infiltration basin and or dry well) to restore a pre-development GW recharge conditions in urban area .

Acknowledgements

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