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Research Article

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Evaluation of the groundwater active recharge trend in the coastal plain of Dar es Salaam (Tanzania)

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ABSTRACT

This paper deals with a part of the preliminary results of three years investigation activity, carried in Dar es Salaam coastal plain (Tanzania), ACC-DAR project, supported by the European Union, in cooperation with Sapienza University of Rome and Ardhi University of Dar es Salaam. Here, they are presented the effects of rainfall data evolution in the last 50 years on the groundwater active recharge, due to land cover evolution. As a matter of fact, in the last fifteen years the Dar es Salaam coastal plan has been involved in a hard increasing of groundwater exploitation, due to increased population. On the on the hand, the groundwater active recharge has been decreased, due to the evolution of land cover. In the framework of the project, the rainfall data have been collected referred to 50 years of observations in the three urban stations of Dar es Salaam. Starting from the data collection of the continuous historical rainfall series, it has been evaluated the groundwater active recharge for different land cover scenarios from remote sensing data. The results have been compared to water demand evolution values, referred to the same temporal range, and it has been outlined that in the last few years the water demand, in this area, has overpassed the groundwater active recharge.

Keywords: Tanzania, groundwater recharge, climate changes, water demand

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INTRODUCTION

The present study is related to the application of the reverse water balance technique (P = ET + R + I) [1] in order to determine the active average recharge (I) of the aquifer in the coastal plain of Dar es Salaam (Tanzania). The management of the large available quantity of figures asked the application of a Geographical Information System (ESRI ArcGIS10), to set up a distributed parameters mathematical model.

The United Republic of Tanzania is a country in Sub-Saharan Africa and Eastern Europe. It borders the Kenya to the North and the Uganda, Rwanda, Burundi and the Democratic Republic of the Congo to the West while the Zambia, Malawi and Mozambique to the South. The area under study covers all the urban and the periurban zones of Dar es Salaam and it is selected starting from the natural hydrogeological boundaries. The geological setting of the study area comprises unconsolidated sediments, which are classified by their geological age into two major periods: Quaternary and Neogene deposits [2]. The Quaternary deposits consist of three geological layers: alluvial, coastal plain and coral reef limestone deposits (Fig. 1).

The alluvial deposits and coastal plain deposits are of Pleistocene to Recent age and are found mainly moving from the coast towards the mainland within the river valleys [4]. The main part of the study area corresponds to such a valley. These deposits consist of sand, clay, gravels and pebbles. Fine to coarse-grained sands occur widely within valleys creeks, deltas and mangrove sites of the Mzinga, Kizinga and Msimbazi Rivers. Msindai (1988) reported on limestones, which are mainly coralliferous and are found along the coastal strip. They are generally weathered and normally covered on the surface by white buff sands or reddish brown soil. The present study deals with the elaboration of the rainfall data (from 1960 – 2010) in order to assess the active recharge of the aquifer system in coastal plain of Dar es Salaam (Tanzania).

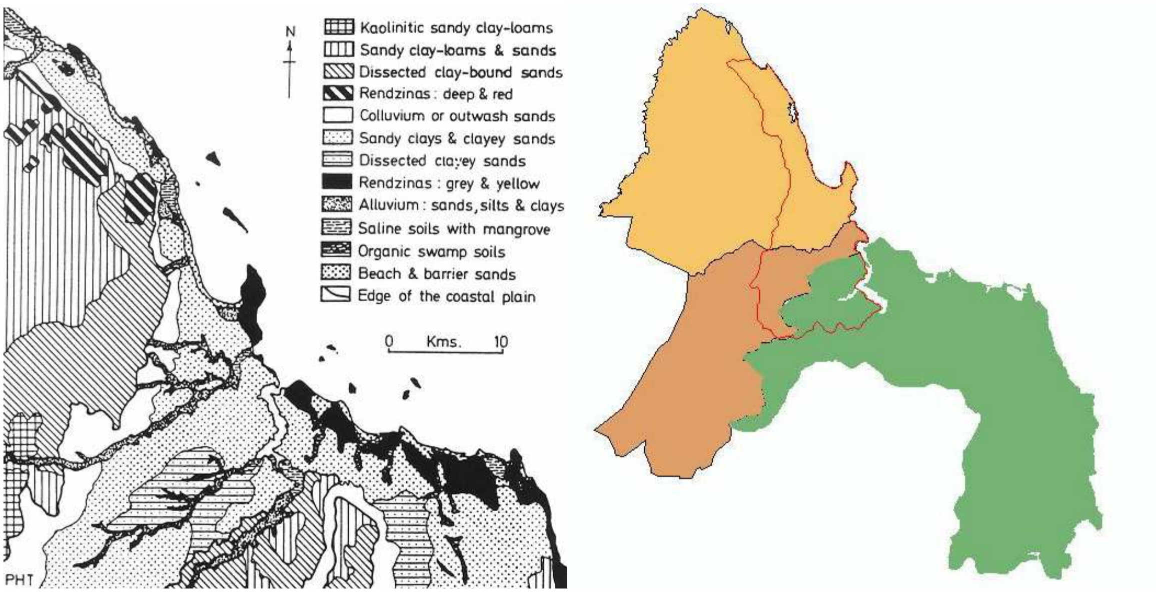

Fig. 1: The study area ([3] modified)

EXPERIMENTAL SECTION

They were available 50 years of rainfall observation (1960 - 2010), related to three different stations (Jnia, Wazohill, Ocean Road), and so all these data have been adapted to certain probability distributions (Fig. 2).

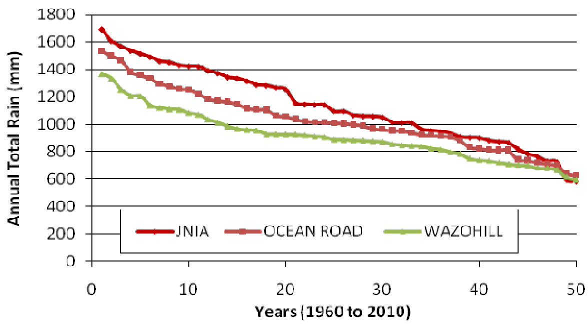

Fig. 2: Rainfall data for the three different urban stations of Dar es Salaam

Since some of these rainfall observations were not a complete data series, it has been applied a well known statistic elaboration process in order to create the lacking data. To fill these data three different methods have been used: (i) Between-station method based on the average between the previous and the following data; (ii) Within-station method based on the average between the data registered in different stations; (iii) Regression based on a important result, the difference or ratio between values of a given element observed in a different stations can be established from corresponding sums or mean values. The adjustment was obtained with the method of moments, calculating firstly the parameters of the distributions (Gauss, Galton, Gumbel, Frechet), equating theoretical moments with one of the distributions (it is assumed that the statistical parameters coincide with those of the sample). In order to determine the setting more representative of the statistical distribution, two different statistic tests have been verified: Pearson and Kolgomorov Smirnof Test. Only the Gaussian distribution has passed both tests (Fig. 3).

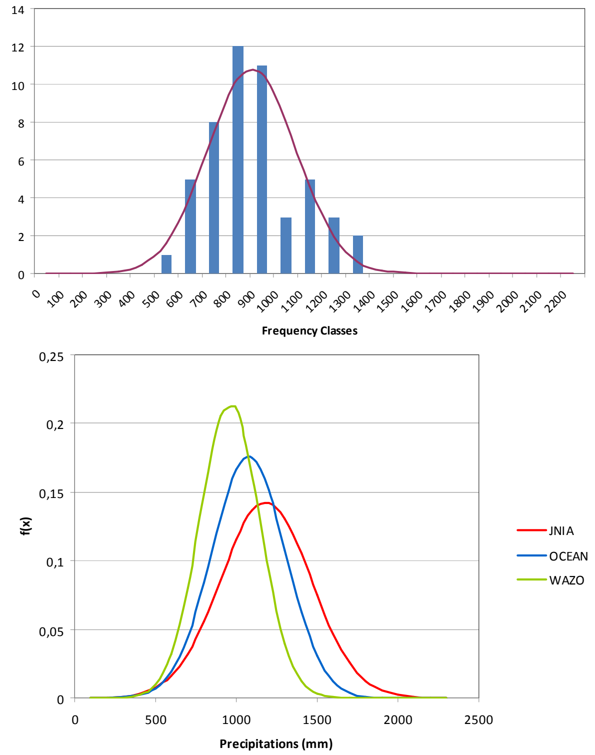

Fig. 3: Gaussian distribution

Consequently, they have been chosen the rain values, referring to one with 70% of probability of happening (Tab. 1).

Tab. 1: 70% probable annual rainfall data

Jnia	$\mu+\sigma$	1410,6 mm
	$\mu-\sigma$	854,2 mm
Ocean Road	$\mu+\sigma$	1249,9 mm
	$\mu-\sigma$	801,2 mm
Wazohill	$\mu+\sigma$	1091,9 mm
	$\mu-\sigma$	727,8 mm

The Inverse Distance Weighting (IDW) method, which is a deterministic one for multivariate interpolation, starts from a known scattered set of point data, in order to spread them on an area (Fig. 4). In this aim the area under study has been divided in meshes of 500 mt of dimension.

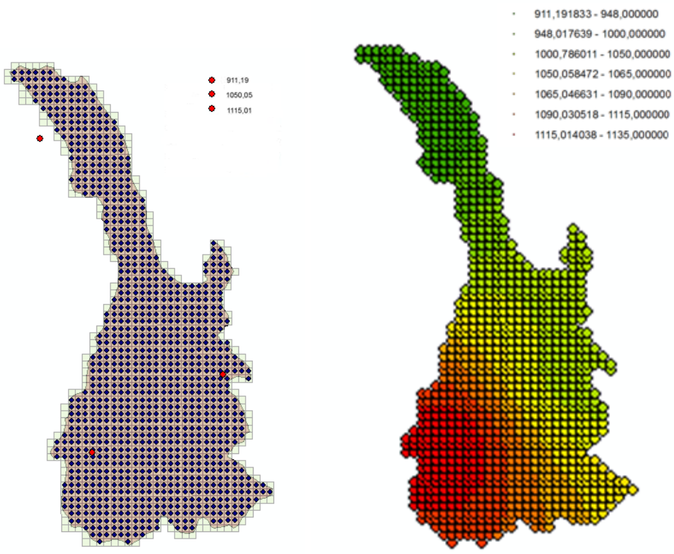

Fig. 4: Application of the Inverse Distance Weighting method to the study area

RESULTS AND DISCUSSION

Over the last ten years, the changes of the area have seen a significant growth of discontinuous and continuous urban land [5]. In the course of time, the consequences of this transformation have influenced the recharge areas extension, and groundwater active recharge have been decreased (Fig. 5).

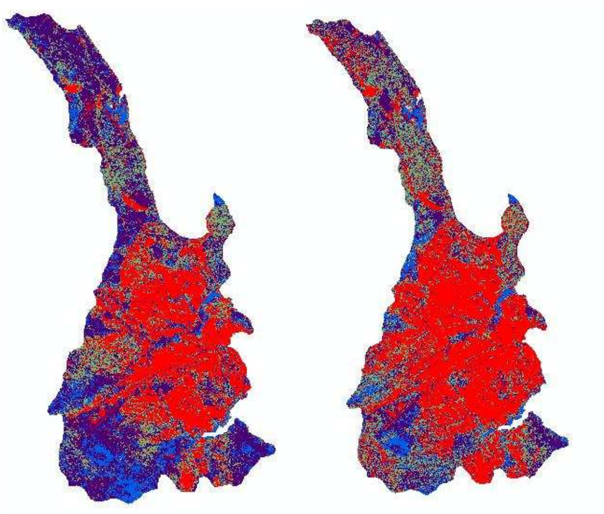

Fig. 5: Land cover distribution in 2002 and 2011

The graph shows (Fig. 6) the changes concerning the land cover between the 2002 and the 2011. It is important to underline that the percentage of continuous urban soil doubled over less than ten years.

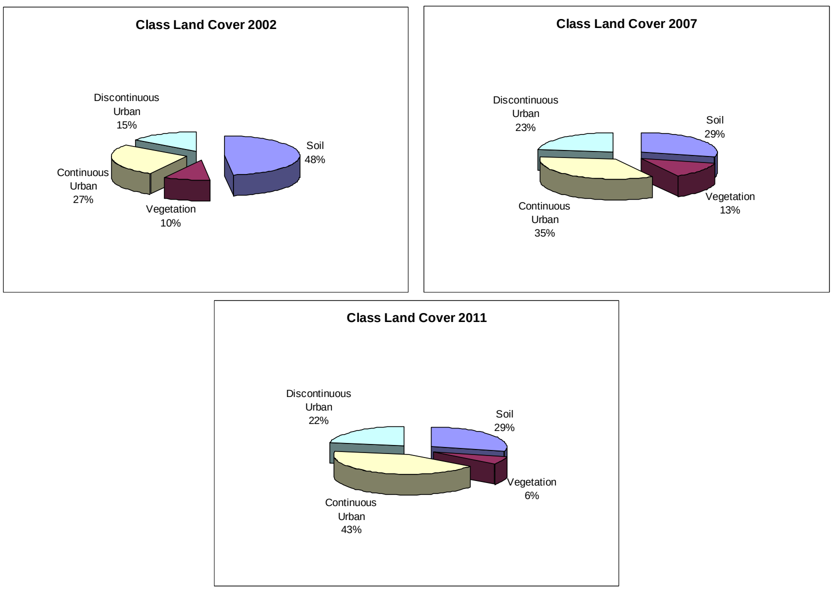

Fig. 6: Land cover distribution from 2002 to 2011

The assignment of the potential infiltration factor χ_s let us to separate the infiltration from rainfall, taking in account runoff and evapotranspiration, which do not contribute to the active recharge (Tab. 2).

Tab. 2: Potential Infiltration Factor referred to the different land cover class

Land Cover Class	Potential Infiltration Factor (χ_s)
Continuous Urban	0,1
Discontinuous Urban	0,2
Vegetative	0,3
Soil	0,4

By this way for each mesh it has been calculated the volume of recharge, through the multiplication of the rainfall (mm) by the factor χ_s (-) and the area (m^2). Adding up all the mesh values, the resulting volume has been compared with the annual water demand (Fig. 7).

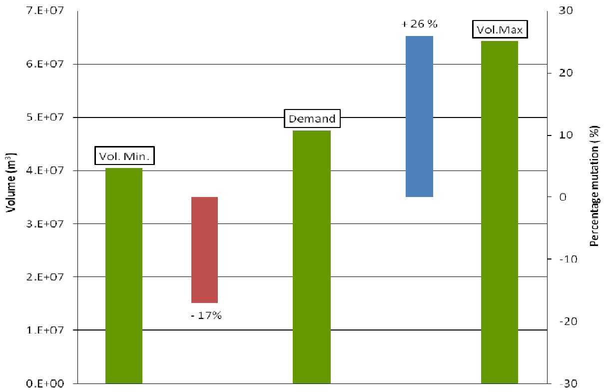

Fig. 7: Annual recharge compared with water demand

According to land cover changing the volume of water is decreased from 2002 to 2011. The bar graph (Fig. 8) shows that the volume of groundwater active recharge in Dar Es Salam coastal plan has decreased by almost 5% for each year.

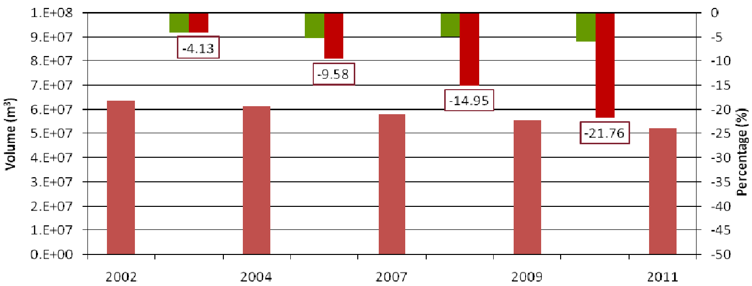

Fig. 8: Volume trend from 2002 to 2011

It true, on the other hand that part of groundwater active recharge in the coastal plan comes form Pugu Hills, but it will be necessary, all the same, to stop the groundwater exploitation, due to new building construction, to reverse the nowadays trend of budget between demand and recharge.

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