ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/283719542

Zonation of water pans for surface water harvesting using GIS in Marigat division, Kenya

Article *in* Journal of Geomatics · October 2015

CITATIONS
0

READS
119

3 authors, including:

R. J. Magut
3 PUBLICATIONS **0** CITATIONS

SEE PROFILE

Emmanuel Chessum Kipkorir
Moi University
70 PUBLICATIONS **1,212** CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Project VLIR-UOS Moi Unversity CSE project View project

Project PhD research on Seasonal and Spatial Assessment of Agro-climatic Parameters for Maize Crop Farming (Case of Lake Victoria Basin Kenya) View project

All content following this page was uploaded by Emmanuel Chessum Kipkorir on 12 November 2015.

The user has requested enhancement of the downloaded file.

Journal of Geomatics Vol 9 No. 2October 2015

Zonation of water pans for surfacewater harvestingusingGISin Marigat division, Kenya

Rebecca Magut[1], Emmanuel C. Kipkorir[2] and Fatuma Daudi[1]
[1]School of Environmental Studies, University of Eldoret, P. O. Box 1125-30100, Eldoret, Kenya
[2]School of Engineering, University of Eldoret, P. O. Box 1125-30100, Eldoret, Kenya
Email: Becky.magut@gmail.com

(Received: Feb 11, 2015; in final form: Oct 09, 2015)

Abstract: Water is essential for human survival, food security, environment and sustainable development. Marigat division experiences water shortages during the dry seasonsdespite the area receiving torrential rain during the raining season that go waste as surface runoff thatoccasionally cause flood disasters. With use of storage facilities, it is possible to harness the surface runoffwhen it rains for use in domestic, livestock and environmental improvement. Harvesting of surface water runoff in water pans provides a direct solution especially in rural and drought prone areas and is one rapid way to improve water storage inrural areas. In this study Geographical Information System (GIS) was used to determine the suitable sites for constructing water pans for harvesting surface runoff. Several criteria were used such as creating buffers around the agricultural areas, roads, rivers and settlements.Weighted overlay suitability analysis within GISwas used to site the potential sites of water pans, weightages were assigned to each criterion depending upon their relative significance.From the analysis, results indicate that there are varied levels of suitable sites for construction of water pans in the study area.

Keywords: Runoff, Site selection, Weighted overlay suitability model

1. Introduction

Potable water is an essential element for human survival and well-being (Ahiablame et al., 2012). Water covers majority of the earth's surface. Still, scarcity of potable water is a major problem in many parts of the world. Globally, 1.4 billion people lack daily access to sufficient amounts of potable water. The demand of water has been increasing for both human and animal needs, partly due to the rapid population increase that the world is mainly experiencing presently in the developing countries and also due to the rising affluence of the population (Huston et al., 2012). The world's population is expected to grow from 6.2 billion today to at least 8 billion by the year 2025, with about 90% of the increase being added to the developing world and to over 9.4 billion by 2050 (Sipes, 2010). As population increases and development calls for increased allocations of groundwater and surface water for the domestic, agriculture and industrial sectors, the pressure on water resources intensifies, leading to tensions, conflicts among users and excessive pressure on the environment (FAO, 2007; Cassardo and Jones, 2011; Godskesen et al., 2013).

Kenya is among the water scarce countries of Africa (Futi et al., 2011; www.nema.ke.org) and has also seen her water storage per capita deteriorate with time to critical levels of 8 m^3 (Futi et al., 2011). Surface water resources are also limited, covering only two per cent of Kenya's total surface area. Rainfall is unevenly distributed throughout the country, with less than 200 mm/yr falling in northern Kenya (KWAHO, 2009; UNEP, 2010).

The erratic climate brings about frequent droughts as well as floods. Kenya's current per capita water availability of 792 m^3. This is below the scarcity threshold of 1000 m^3 and the projected population growth will further exacerbate the pressures on the already limited water supply (UNEP, 2010). To respond to water scarcity, rainwater harvesting techniques provide a direct solution, especially in rural and drought prone areas (NWP, 2007). Kenya with a population of about 40 million is capable of meeting the water needs of six to seven times its current population. The rainwater harvesting potential in Kenya is estimated at over 12,300 m^3 per person compared with the current annual renewable water availability of just over 600 m^3 (UN-Water, 2006; Futi et al., 2011).

Marigat division is one of the arid and semi-arid districts in the country. There is water scarcity in the area especially during the dry periods. Lack of vegetation cover causes flood even with moderate rain as the water rushes down unprotected slopes. When heavy rains come, it causes disasters (BDVS 2005-2015). Unlike big dams which collect and store water over large areas, small-scale water harvesting project lose less water to evaporation because the rain or run-off is collected locally (Futi et al., 2011) and can be stored in water pans.

Instead of allowing rainwater to flow over the surface of the earth and cause environmental disasters such as floods, landslides and soil erosion, it is possible to harness it for use in domestic, agriculture, industrial as well as for livestock and environmental improvement. The objective of this study was to identify potential locations of water pans, using GIS techniques, for

© Indian Society of Geomatics

storage of surface rainfall runoff by communities in Marigat division.

2. Methodology

2.1 Study area

Marigat division is one of the fourteen divisions in Baringo county. The county lies between latitudes 0° 12’ and 1° 36’ N and longitudes 35° 36’ and 36° 30’ E. There are two seasons of rainfall. The long rains start from the end of March to the beginning of July, and the short rains from the end of September to November (BDVS 2005-2015).

The major topographical features in the study area are river valleys, plains and the floor of Rift valley. The study area is located on Loboi plain (Figure 1) and is characterized by rolling slopes that range from 5% to 25% towards downstream of the rivers.

Figure 1: Location of the study area

2.2 Siting of potential sites for water reservoirs

Hand held GPS was used to identify the geographic location and the spatial distribution of existing water points within the study area. The collection of data was done by taking the GPS’s points of boreholes and tracks of water pans. GPS technology is very useful for enhancing the spatial accuracy of the data integrated in the GIS (Balakrishnan et al., 2011). Various features such as rivers, streams, dams were obtained from topographical maps and satellite images.

In this study, GIS technique was used to identify potential water reservoir sites. The data sets used in the analysis included topography, land use, roads, rivers, slope and soil type. The analysis was done by creating buffer zones around geographic features (Table 1) to be protected and to be excluded in the list of possible sites.

2.3 Thematic layers for analysis

The topographical maps were digitized with a resolution of 20cm contour intervals and a scale of 1:50,000 were used to develop the Digital Elevation Model (DEM). The DEM is key in deriving a slope map, which gives information about slope angle and topography of the study area. From the DEM (Figure 2), the slope map was derived (Figure 3). The slope map is important in defining the direction of flows within a catchment to potential reservoir sites, a slope of <2% was used. Other factors critical to siting the reservoir were considered based on published literature and expert opinion.

Table 1: Water reservoir site selection criteria and the proposed buffer zones

Criteria	Suitability buffer (m)
Roads	50
Rivers	30
Pit latrines	100
Agricultural lands	150
Houses	30

Source: Modified from the Water Act, 2002

Land use maps (Figure 4), which describe the human activities, were used for delineating agricultural lands like Perkerra irrigation scheme, urban areas and houses. It is the principle factor that determines the rainfall runoff yield from the considered land unit (Harshi et al., 2010).

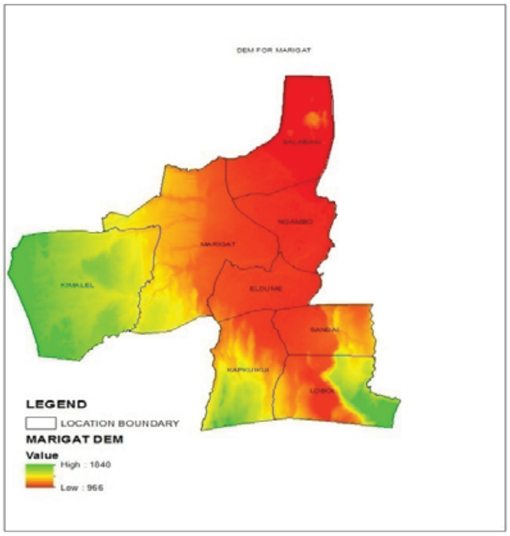

Figure 2: Digital Elevation Map (DEM) for Marigat division

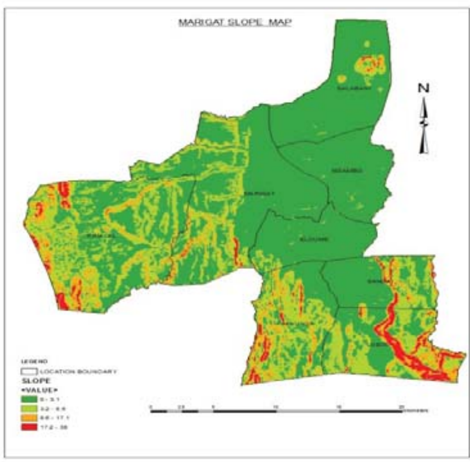

Figure 3: Slope map derived from the DEM map

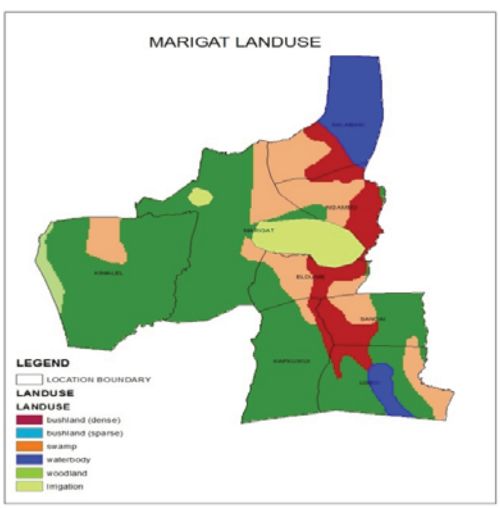

Figure 4: Land use map for Marigat division

Runoff harvesting into water pans depends also on soil type and geology, especially to avoid seepage problems. Soil types have been useful to determine suitability of water pans although seepage can be controlled in water pans/pond through different interventions. Soil was categorized in terms of amount of clay since clay proportion determines the seepage rates. If the soil is very clayey, then it is highly suitable for creation of water pans because it has low seepage rate of water. Figure 5 shows the soil map of Marigat division.

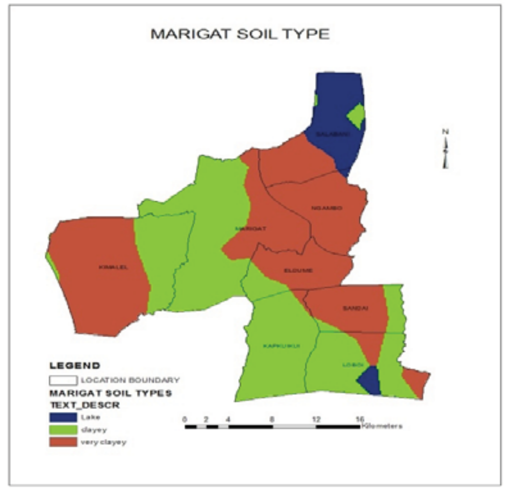

Figure 5: Soil map for Marigat division

2.4 Weighted overlay suitability model

A weighted suitability model is developed using GIS techniques depending on a number of thematic layers (Riad et al., 2011). The weighted overlay tool is used for overlay analysis to solve multi-criteria problems such as site selection and suitability models (http://help.arcgis.com). Such models are used for applying a common measurement scale of values to diverse and dissimilar inputs in order to create an integrated analysis. Additionally, the factors of the analysis may not be equally important. Each individual raster cell is reclassified into a common preference scale such as 1 to 10, with 10 being the most favorable. An assigned preference on the common scale implies the phenomenon's preference for the criterion and then multiplies them by a weight to assign relative importance to each and finally add them together for the final weight to obtain a suitability value for every location on the map (Riad et al., 2011; Sener et al., 2011; http://help.arcgis.com). All the thematic layers were integrated in ArcGIS platform in the study, in order to prepare a map depicting suitable sites for water pans. This can be interpreted by equation (1) (Riad et al., 2011).

$$S = \Sigma w_i x_i \quad (1)$$

where,

w_i = The weight of ith factor map

x_i = Criteria score of class of factor i

S = Suitability index for each pixel in the map

Suitability analysis steps consisted of the following methods: -

i. The first step in the spatial analysis involved the creation of raster data. All thematic layers had to be converted from vector to rasters before the Spatial Analyst could be used to perform any type of analyses. The conversion of vector data to raster layers was completed using the Spatial Analyst conversion tool.

ii. Distance Buffers: The second step comprised of creating multiple ring buffers for some of the layers. Distance buffers were created for the major roads, agricultural lands, houses and rivers as given in Table 1.

iii. Reclassifying Values: Once all the data sets were buffered and converted to raster data, data sets werereclassifiedusingthe reclassify tool. The suitability values ranged from high to low and a value of 10 was assigned to the most suitable range and 1 to the least suitable range.A summation of the values for every raster cell was calculated.

iv. Weighing Data: To establish a logical assessment of optimal suitability, there were certain features that were considered to be more important than others in the suitability model. The ranks were given for each parameter of each thematic map and the weight assigned based on its importance. To find the suitable sites the data was calculated using the weighted overlay suitability model. Figure 6 shows the flow chart of the methodology.

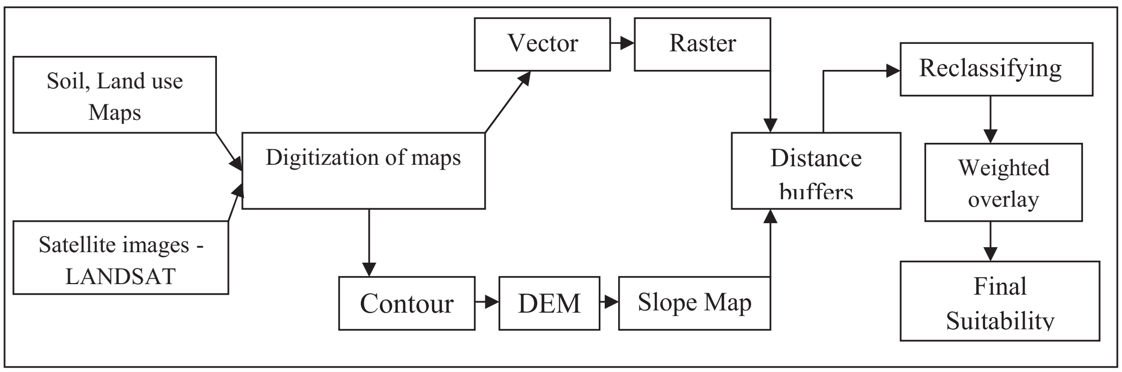

Figure 6: Methodology for potential sites map

3. Results and discussion

In Marigat, there are many sources of water. These sources of water can be categorized into surface water and ground water. Surface water occurs as rivers, streams, pans and lakes as shown in Figure 7. After preparing the thematic layers and assigning weights for suitability model, it was run on ArcGIS. The results of the weighted overlay suitability model indicated that there were several areas that were suitable for siting water pans for rainwater harvesting.

The spatial distribution of the identified suitable sites in Figure 7 strongly reflects the influence of the river network data layer; most suitable sites for water pans were located along the perennial and seasonal streams. Suitable flat to moderate slopes of between 2% and 8% was used, these findings also agree with findings by Harshi et al. (2010), who argue that water reserves are constructed close to streams with slopes where water can easily enter and exit by gravity. In addition, the potential sites also satisfied the criterion used in this study as they are located outside the agricultural schemes and households. This is mainly due to the fact that the weighted overlay is a technique used to apply a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. Riad et al., 2011 also used weighted overlay model to determine the best locations for artificial recharge of groundwater and by comparing it with Boolean logic and recommended weighted model if analysis needs more flexibility, since every location cell has a suitability value.

The soils were mainly clayey to very clayey, making them sticky when wet hence have poor drainage, which makes them more suitable as solid foundations for a water reservoir due to its very low infiltration rate. These soil characteristics also agree with Harshi et al. (2010) who argue that relatively fine soils such as clay have a high water storage capacity and thus are suitable for siting reservoirs. According to Harshi et al. (2010), soils with smaller particles like clay and silt have a larger surface area than those with larger particles and a large surface area allows soil to hold more water. The least suitable sites, slopes were moderate to very steep >8% and the soil were mainly course textured and highly permeable sand and newly weathered and weathering soils and were assigned 0.

Figure 7shows the suitable sites indicating a variation from least suitable to most suitable sites. From the model results, it shows the true presentation on the ground evidenced by the existing water pans that are on moderately suitable to most suitable sites (Figure 7).

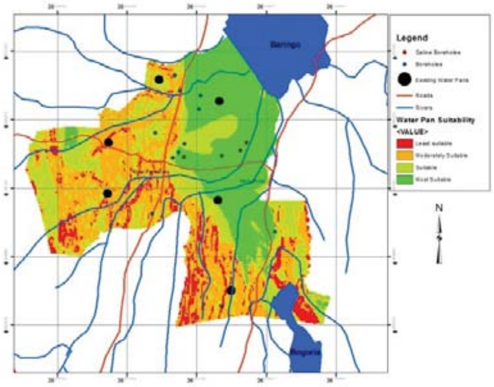

Figure 7: Suitability map showing the sources and the potential sites for water pans

4. Conclusion and recommendation

In the study area, there is water scarcity especially during the dry periods. During the rainy seasons, there is a lot of runoff that goes waste and causes floods - which can be salvaged if stored in water pans and used during the dry periods. The suitable sites for water pans that can be used to harvest rainwater were identified using GIS. Overlay analysis was used to prepare the final suitability map and high to low suitable areas of the study area were determined. From the study, there exist potential sites for harvesting surface water runoff. Therefore, it is recommended that the community should construct more water pans for harvesting surface water for domestic use and livestock to solve their problem of water scarcity. The spatial distribution maps generated could be useful to planners and decision makers for water resource management.

References

Ahiablame, L., B. Engel and T. Venort (2012). Improving water supply systems for domestic uses in urban Togo: The case of a surburb in Lome. Water, 4, 123-134.

BDVS - Baringo District Vision and Strategy: 2005-2015. Kenya.

Balakrishnan, P., A. Saleem and N.D. Mallikarjun (2011). Groundwater quality mapping using Geographic Information System (GIS): A case study of Gulbarga city, Karnataka, India. African Journal of Environmental Science and Technology, Vol 5, No. 12.

Bertone, E. and R.A. Stewart (2011). Framework for enhancing the supply - demand balance of a tri-supply urban water scheme in Australia. Water 3(4), pp. 979-987.

Cassardo, C. and J.A.A. Jones (2011). Managing water in a changing world. Water 2011, 3, 618-628. Italy.

FAO, (2007). Coping with water scarcity: Challenge of the twenty-first century. World Water Day 2007.

Futi, A.P., W.S. Otieno, O.J. Acholla, A.W. Otieno, O.S. Ochieng and M.C. Mukisira (2011). Harvesting surface rainwater – purification using Moringaoleifera seed extracts and aluminum sulfate. Kenya. Journal of Agricultural Extension and Rural Development Vol. 3(6), pp. 102-112.

Godskesen, B., M. Hauschild, M. Rygaard, K. Zabrano and H.J. Albrechtsen (2013). Life-cycle and freshwater withdrawal impact assessment of water supply technologies. Denmark. Water Research, Volume 47, Issue 7, pp. 2363-2374.

Harshi, W., S.A. Uwe and A. Low (2010). Water harvest and storage location optimization model using GIS and remote sensing. Ohrid, Republic of Macedonia.

http://help.arcgis.com

Huston, R., Y.C. Chan, H. Chapman, T. Gardner and G. Shaw (2012). Source apportionment of heavy metals and ionic contaminants in rainwater tanks in a subtropical urban area in Australia. Water Research 46, 1121-1132.

KWAHO - Kenya Water for Health Organization (2009). Enhancing water and sanitation governance in Kenya - Human rights based approach to reforms in the Kenya water sector. Nairobi, Kenya.

NWP - Netherlands Water Partnership (2007). Smart water harvesting solutions: Examples of innovative, low-cost technologies for rain, fog, runoff water and groundwater. Netherlands.

Riad, H.P., H.M. Billib, A.A. Hassan and A.M. Omar (2011). Overlay weighted model and fuzzy logic to determine the best locations for artificial recharge of groundwater in a semi-arid area in Egypt. Nile Basin Water Science & Engineering Journal, Vol.4, Issue 1.

Sener, S., E. Sener and B. Nas (2011). Selection of a landfill site using GIS and multicriteria decision analysis for Beysehir lake catchment area (Konya, Turkey). Journal of Engineering Science and Design. Vol:1, No:3 pp. 134-144.

Sipes, J. (2010). Sustainable solutions for water resources: Policies, planning, design and implementation. John Wiley & Sons Publishers. Canada.

UNEP, (2010). Africa water atlas. Division of Early Warning Assessment (DEWA). United Nations Environment Programme (UNEP). Nairobi, Kenya.

UN-WATER (2006). Coping with water scarcity: A strategic issue and priority for system-wide action.

www.nema.ke.org

View publication stats