International Journal of Water Resources and Environmental Engineering

Volume 8 Number 7 August 2016

ISSN-2141-6613

Academic Journals

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International Journal of Water Resources and Environmental Engineering

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academicJournals

Vol. 8(7), pp. 81-91, August 2016
DOI: 10.5897/IJWREE2015.0599
Article Number: 5FBA24959682
ISSN 2141-6613

http://www.academicjournals.org/IJWREE

International Journal of Water Resources and Environmental Engineering

Full Length Research Paper

Hydrological classification of the Besease inland valley bottom in Ghana for crop production using the water table fluctuation method

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Received 14 July, 2015; Accepted 4 July, 2016

The shapes and forms of piezometric hydrographs arising from the recharging and discharging of unconfined aquifers offer a hydrological tool for the classifications of inland valley bottoms in Ghana for crop production. A two-year measured water table fluctuations at Besease wetlands were plotted on a reference scale of time in months on the x-axis and hydraulic head on the y-axis. The water table fluctuation method was used to evaluate the seasonal and annual variations in the water level rise and to estimate the groundwater recharge. The monthly slopes segment of the water table fluctuations were used as a base for the classification of the heads. Results from the study showed that the estimated recharge for the study area ranged from 133 to 467 mm for the fourteen (14) piezometers, representing 9 to 31% of 2009 annual rainfall and 47.6 to 427.9 mm in 2010 representing 4 to 34% of the annual rainfall. The Results also showed that most of the piezometers had their monthly slopes dominated by the acute segment followed by the obtuse segment, flat segment and right-angled segment in that order. It can be inferred that most of the piezometric areas dominated by acute forms become relatively dry during the dry season; however, these areas may still have some water to support crops. The hydrograph representation of the monthly slopes were employed to classify the studied Inland Valley Bottoms into three hydrological regimes as a management tool for developing wetlands for crop production. The regimes were Water table fluctuation (WTF) Class I - acute slopes segment varying from 0 to 30%, WTF Class II - acute slopes segment varying from 30 to 45% and WTF Class III - acute slope segment > 45%. It is concluded that a controlled water table offers a distinguishing criterion for the development of Inland Valley Bottoms for year round crop production in Ghana.

Key words: Water table fluctuation, hydrological regimes, inland valley bottoms, slope segments, crop production.

INTRODUCTION

Small land holding farmers along the Oda River catchment in Ejisu-Besease in the Ashanti Region of Ghana practice inland valley bottom cultivation as a form of supplementary irrigation. The Government of Ghana through the Agricultural Sector Rehabilitation Programme of the Ministry of Food and Agriculture (MoFA) and the Crops Research Institute (CRI) are actively encouraging floodplain cultivation, which can be practiced in the dry season using pumped water as a source of irrigation. Wetlands hold a lot of water in its phreatic zone which alternate under variable recharge conditions from rainfall, runoff from uplands and rivers and seepage from streams. In the wet seasons, the water tables fluctuate close to the ground surface when rainfall inputs are high. However, they also fluctuate at lower depths in the dry season and at times installed piezometers and wells go dry (Bradley, 2002).

West African inland valley bottoms which are under utilisation for crop production receives surface water through irrigation canal in the dry season. Thus, when the water table is expected to fall, it would rather be rising due to induced groundwater recharge from the canal. On the other hand, water table which is expected to rise would be observed to be falling under a considerable groundwater abstraction due to pumping. Therefore, understanding the temporal and spatial hydrological processes of inland valley bottoms is key to capturing the behaviour of the catchment (Nyarko, 2007). Initial storage, antecedent moisture, volume and intensity of rainfall and surface cover will help further understand the water table fluctuations of unconfined aquifers. The watertable fluctuations even under normal conditions of dry and wet periods or when subjected to management scenarios depicts different forms and shapes of piezometric and well hydrographs which can be used to classify wetlands hydrologic regimes.

Raj (2004) classified well hydrographs based on their shapes and forms from slopes made by water table fluctuations of the wells over more than one hydrological cycle in south eastern Peninsular India. He further reported that the differences in the shapes of the hydrographs were attributed to changes in the climatological pattern, reflection of the underlying aquifer characteristics and lithology and also management practices. Ogban and Babalola (2009) also classified inland valley bottoms on the basis of their drainage densities according to their watertable depths in the dry season in Ayepe, South Werstern Nigeria as design criteria for crop production. Knowledge about the shapes and forms of piezometric hydrographs is therefore necessary in the hydrological classification of inland valley bottoms. This aids in the optimal estimation of groundwater table elevation due to an available weather forecast in order to determine an adequate irrigation depth for maximum crop yield (Serrano and Unny, 1987). Kyei-baffour et al. (2013) estimated groundwater recharge from the water table fluctuation method as recharge input into a numerical MODFLOW model to simulate groundwater hydraulic head at the Ejisu-besease inland valley bottom.

This study sought to analyse the hydrological regimes of water table fluctuations in the Besease inland valley bottom catchment as a management tool for crop production.

Study area

Besease is a farming area in the Ejisu-Juaben Municipal District of the Ashanti Region in Ghana. The site lies within Latitude 1°15' N and 1°45' N and Longitude 6°15' W and 7°00' W. The study area covers about 72 ha of the valley bottom lands at Besease (Figure 1). The climate of the study area is mostly related to the semi-decedious type. The region is characterised by two distinct seasons, the wet season which begins from March and ends in November while the dry season extends from the month of November to March. The wet seasons can be categorised less than two rainy seasons.

The major rainy season which ranges from mid-March to July and the minor rainy season starts from September to mid- November. The mean annual rainfall is 1420 mm; mean monthly temperature is 26.5°C, the relative humidity ranges from 64% in January to 84% in August. The average monthly maximum and minimum evapotranspiration (ET_O) for the study area were 127.5 mm and 64.7 mm, and has an annual ET_O of 1230 mm. The area is drained by the Oda River which is seasonal and whose basin is about 143 km² (Kankam-Yeboah et al., 1997).

The study area is located in the moist semi-deciduous forest zone. Grass species prominently found in the valley bottom are *Santrocema trifolia, Chromolaeve ordorata, Imperata cylindrical, Mimosa pigra,Ceiba patendra, Centrosema pubescens and Mariscus flabelliformis*. Plant species like *Raphia hookeri (Raphia palm), Alstonia boonei, Malotus oppositifolius and Pseudospondias microcarpa* extends along the margins of the Oda River. Soils of the Ejisu- Besease can be found in the soil map of Kumasi area. The study area lies in the Offin soil series which are grey to light brownish grey, poorly drained alluvial sands and clays developed within nearly flat but narrow valley bottoms along streams. The series have very slow internal drainage, very slow runoff, rapid permeability and moderate water holding capacity. The geology of the watershed is relatively heterogeneous and mainly composed of phyllites, quartzite, shale, Tarkwain and Voltaian-sandstone and limestone.

The phyllites which underlie 59% of the area consist of upper and lower Birimian rocks. Very few rock outcrops were encountered in the survey as the rocks are deeply weathered. The weathered phyllite is soft and easily broken, with recognizable pieces and is

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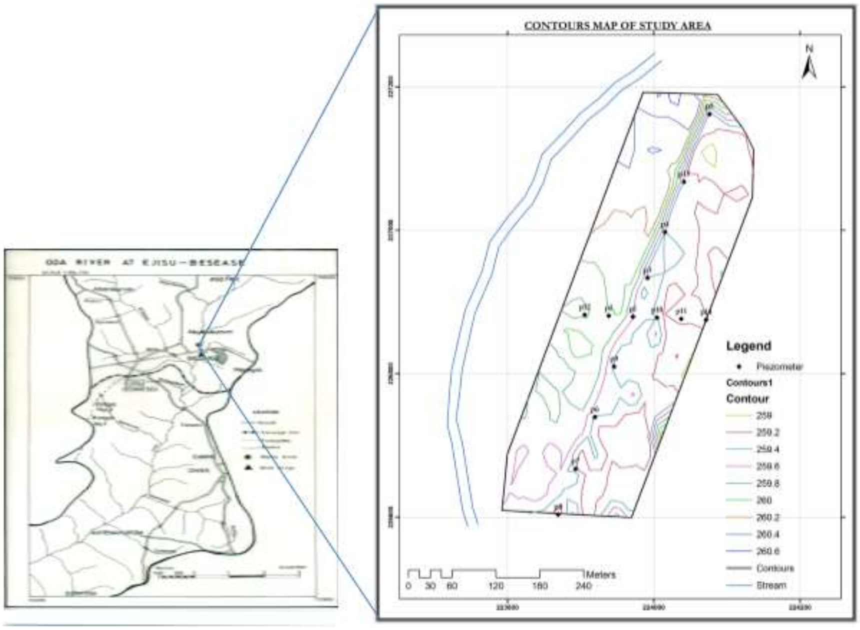

Figure 1. Map of Besease project site showing piezometric network (Source: Kyei-baffour et al., 2013).

typically found at 2 to 3 m below surface. Soils found within the Oda River catchment are grouped as those derived from granites, sandstones, alluvial materials, greenstone, andesite, schist and amphibolities. Specifically the soils are Orthi-ferric Acrisol, Eutric Fluvisol, Gleyic Arenosols, Eutric Gleysols and Dystri-Haplic Nitisol. The Besease aquifer is composed of heterogeneous sequence of layers which is dominated by sand, clayey sand and silts. The valley bottom is developed by small land holding farmers who cultivate rice in the wet season and also grow vegetables like cabbage, lettuce, sweet pepper, cauliflower, cucumber and okra and other cereals like maize in the dry season when the water table is low.

MATERIALS AND METHODS

Groundwater level monitoring

The water table fluctuation method (Meinzer, 1923; Hall and Risser, 1993; Rasmussen and Andreasen; 1959; Healy and Cook, 2002; Risser *et al*, 2005) was used for estimating recharge. This method was based on the premise that the rise in groundwater levels in unconfined aquifers was due to recharging water arriving at the water table. Recharge was calculated using the formula:

$$R = S_y \frac{\mathrm{dh}}{\mathrm{dt}} = S_y \frac{\Delta h}{\Delta t} \tag{1}$$

where, R= Recharge (mm/month), Sy= Specific yield, dh or Δh = Change in water table height
(mm), dt or Δt = Time interval (month).

Wetland groundwater level fluctuations was monitored through a network of 14 piezometers installed using a hand auger along a longitudinal and transverse transect at the Besease site as shown in Figure 1. The piezometers consisted of PVC pipes of 7.62 cm diameter screened over the bottom 20 cm with holes of 0.3 cm diameter. The depth of the pipes ranged from 1.8 m to 3 m. Sand was packed around the screens and the rest of the annulus hole was backfilled with auger cuttings and then grout placed on the top to prevent surface water entry. The cup covering the top of the pipes were not hermetically closed to prevent build up of pressure in the piezometer during phases of groundwater rise. Depth to water table was measured for every two days with greater frequency during rain events by inserting a measuring tape down into the piezometers and observing when it encountered the water surface. The elevations of the piezometers were surveyed to benchmarks to allow adjusting the water levels in the wells to the local datum.

Piezometric hydrograph

Shapes and classifications of piezometeric heads

Two-year measured water table fluctuations were plotted on a reference scale of months on the x-axis and hydraulic head on the y-axis. Hydrographs plotted to this scale were divided into monthly segments and the slope of each segment was then used as a basic element for classification of hydrographs. According to Raj (2004), slopes are classified as flat (segment's inclination < 20°), obtuse (segment's inclination between 20° and 45°), acute (segment's inclination between 45° and 80°), right angled (segment's inclination between 80° and 90°) and homoclinal (when the hydrograph cannot be divided into rising and falling segments and are either rises or falls during one complete water year). Homoclinal segments showing a rise are suffixed as rising, while homoclinal segments that show a fall are referred to as homoclinal-falling. Figure 2 shows

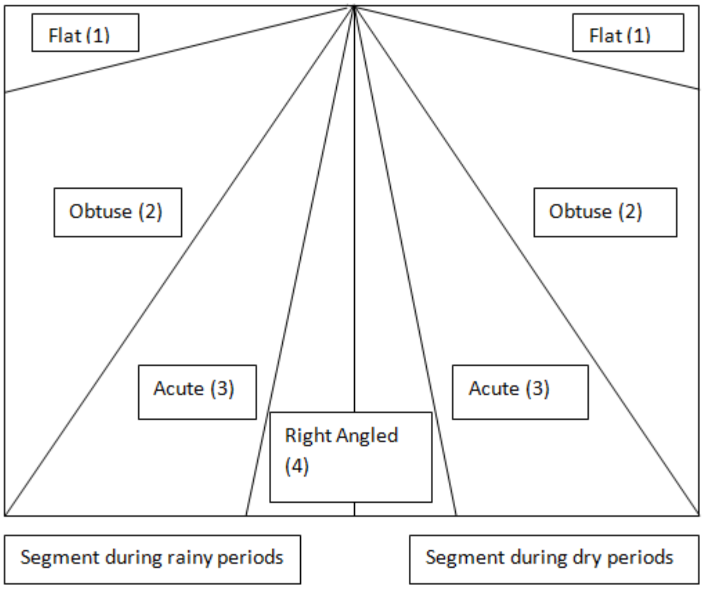

Figure 2. Classification scheme of hydrograph (Source: Raj, 2004).

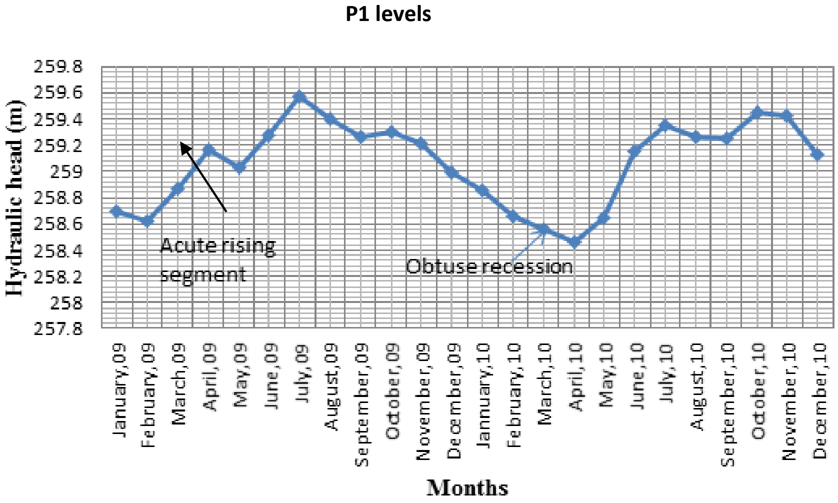

Figure 3. Hydrograph of P1 dominated by acute slopes.

the elements of this classification. Slopes joining at a point would either have the same rising and falling segment which can be acute - acute or different shapes in the form of acute-obtuse, obtuse-flat, right angled-flat. Slopes forming these segments were counted for each month and grouped under flat, obtuse, acute and right angled segments.

RESULTS

Slopes of piezometric hydrographs

Summarised results from Table 1 show that most of the piezometers had their monthly slopes dominated by the acute followed by the obtuse, flat and right-angled segments. There were also sharp rises of water in the months of March in 2009 and May in 2010 with acute and right-angled slope segments. These can be seen in the detailed hydrographs from Figures 3 to 8. Piezometers experienced an acute rising–acute recession form of segment mostly in the quarter of June to August indicating a high recharge surge in June and low or no recharge in August which also reflects the rainfall pattern.

This was noticed in 2009 more than 2010. Obtuse rising-Obtuse recession segments were present in months with moderate rainfall and not too intense evaporation. Flat segments were visible in the months of

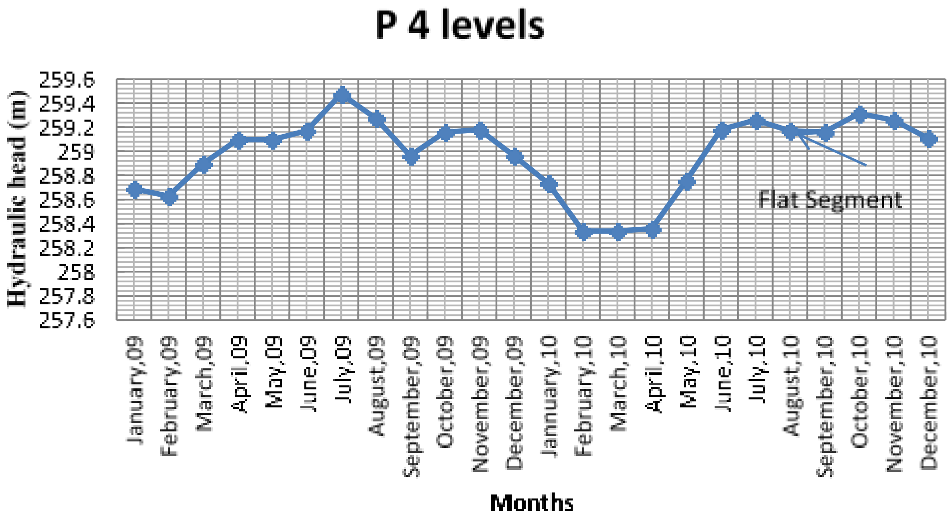

Figure 4. Hydrograph of P4 dominated by acute slopes.

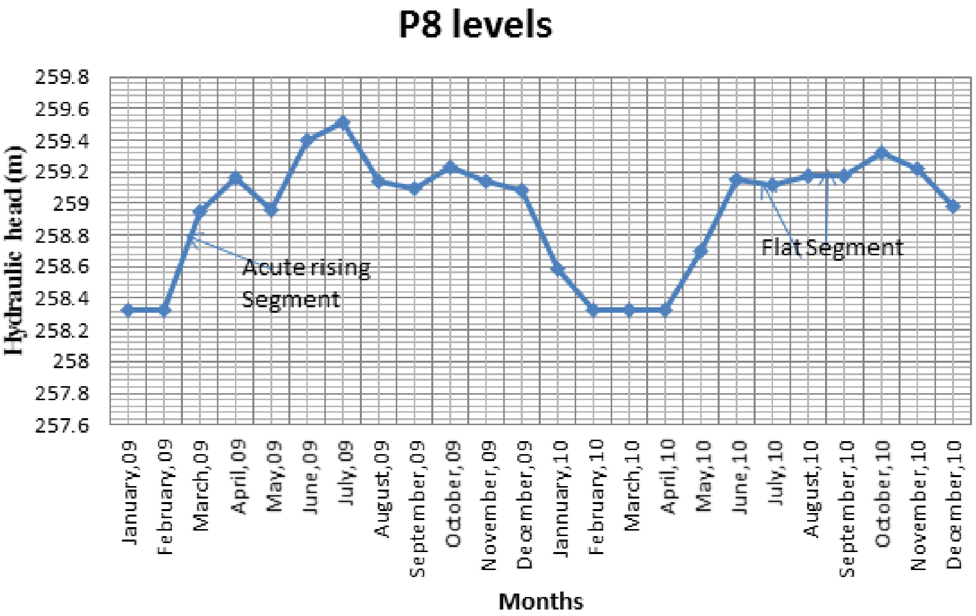

Figure 5. Hydrograph of P8 dominated by acute slopes.

August-September in 2010 water year. P11 and P14 had the lowest acute form of hydrograph representation of 13% and 30%. P12 and P13 had the highest form of acute slopes representing 75 and 61%. Also P11 had the highest obtuse segment of 57% and the lowest (Table 1) was recorded at P12 and P4. The highest form of flat segment was recorded at P14 representing 40% of the slopes in the hydrographs followed by P10 and P4. P3 was the only piezometer which showed a right-angled segment slope. Summing the obtuse and the flat segments revealed P11 and P14 recording 87 and 70% respectively as the highest slopes from the hydrograph presentation. However P12 and P13 had the lowest form of the combination of obtuse and flat of 25% and 39% respectively. The piezometric point twelve (P12) which is closer to the river became empty in most of the dry season possibly due to the lithology of the strata.

Water level rise

When one takes into account all observation

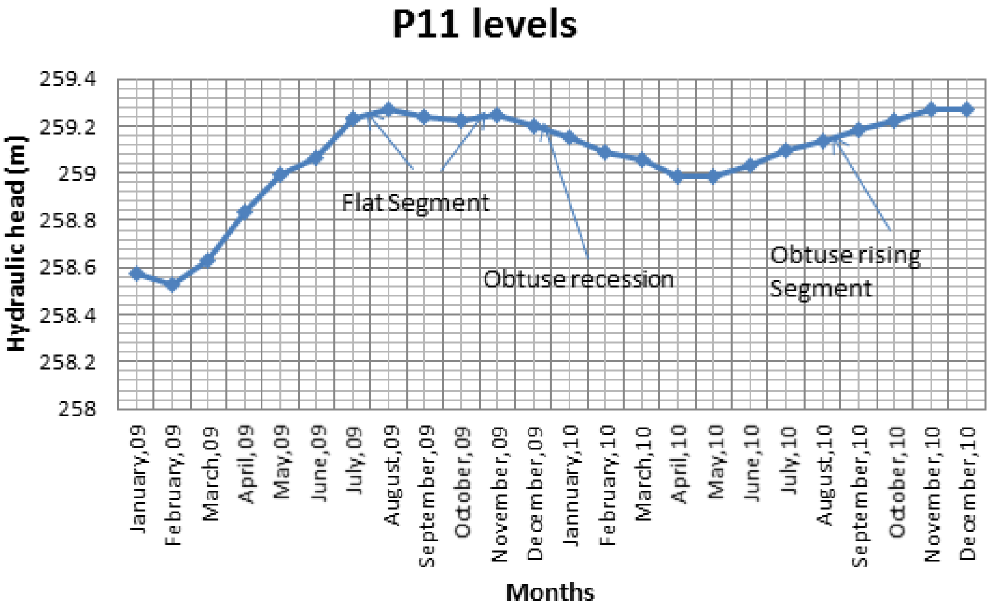

Figure 6. Hydrograph of P11 dominated by obtuse slopes.

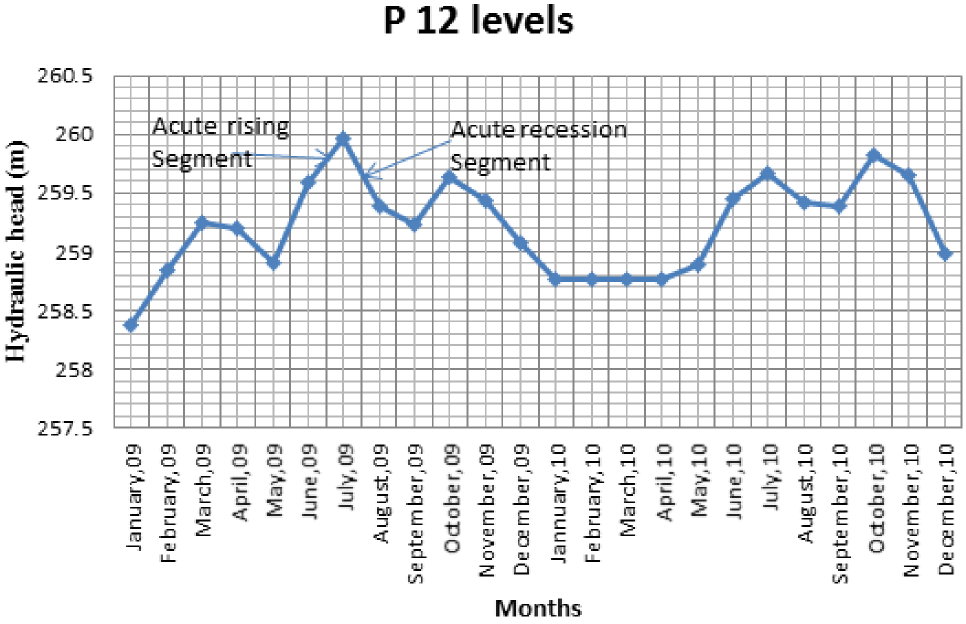

Figure 7. Hydrograph of P12 dominated by acute slopes.

piezometers, rise of water level in the study area is almost entirely from the seasonal rainfall, since water level rise occurred mostly in the rainfall period. Though there were some accumulations of recharge in the dry season possibly due to regional flow of groundwater, this was very small. The annual and spatial variations in water level were quite high as shown from the groundwater hydrographs (Figures 3 to 8). The total annual water level rise for the piezometric networked ranged from 1105 to 3115 mm for an annual rainfall of 1544 mm in 2009 and 397-3070 mm for an annual rainfall of 1248 mm in 2010 respectively. The degree to which water levels fluctuate in the piezometers varied considerably within the study area. The variability in water-level rise exhibited by these piezometers was mostly the result of the location of the piezometers. The

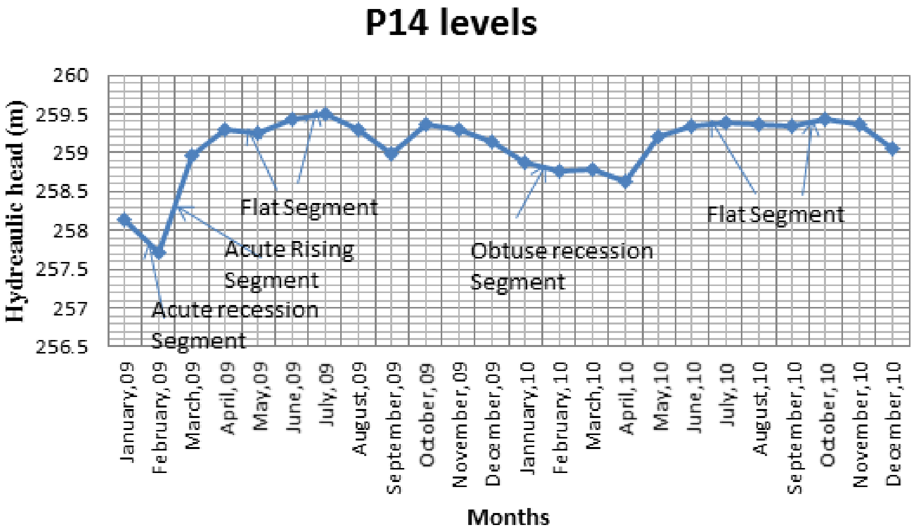

Figure 8. Hydrograph of P14 dominated by flat slopes.

Table 1. Slopes exhibited by the hydrographs.

Piezometer	Acute	Obtuse	Flat	Right-angled
P1	52	35	13	-
P2	57	30	13	-
P3	48	35	13	4
P4	57	17	26	-
P5	43	48	9	-
P6	57	43	0	-
P7	52	35	13	-
P8	50	25	25	-
P9	52	43	5	-
P10	44	30	26	-
P11	13	57	30	-
P12	75	15	10	-
P13	61	35	4	-
P14	30	30	40	-

highest and lowest water level rises in the piezometers were recorded at P 6 and P11 respectively for 2009 and that of 2010 was recorded at P7 and P11 respectively. The water level rise measured at P12 and P2 were rather high and may have been influenced by lateral flow due to its close proximity of 33 m and 66 m to the Oda River and P 14 at a low topographic height also experienced a high water level rise (Figure 1).

DISCUSSION

Groundwater recharge estimation

The groundwater recharge rate for each of the observation wells was calculated by multiplying the water level rise with the specific yield values (Table 2). The estimated recharge for the study area ranged from 133 to 467 mm for the 14 piezometers, representing 9 to 31% of 2009 annual rainfall and 47.7 to 427.9 mm in 2010 representing 4 to 34% of the annual rainfall. The overall mean groundwater recharge in the Ejisu-Besease Oda River basin of Ghana was estimated to be 316 mm in 2009, representing 22% of the mean annual rainfall for that year and 238 mm in 2010, representing 21% of the mean annual rainfall. The difference in the recharge values for the two study years could be attributed to the variability in the annual rainfall distribution and intensity. The recharge estimate obtained in this study is similar to estimates from groundwater studies done elsewhere in the world, using the water table fluctuation method.

Sibanda et al. (2009) estimated the recharge rate of

Table 2. Recharge values in the Ejisu-Besease Oda River Basin of Ghana, in 2009/2010.

Piezometer number	Soil texture	Specific yield	Year	Water level rise h(mm)	Recharge (mm)	Rainfall (%)
P1	Sandy loam	0.12-0.18	2009	1933	232-348 (290)	15-23 (19)
	Sandy loam	0.12-0.18	2010	1519	182.3-273.2 (227.9)	15-22 (19)
P2	Sandy loam	0.12-0.18	2009	3055	366.6-550 (458.3)	24-36 (30)
	Sandy loam	0.12-0.18	2010	2835	340.2-510.3 (425.3)	27-41 (34)
P3	Sandy loam	0.12-0.18	2009	2288	247.5-411.8 (343.1)	16-27 (22)
	Sandy loam	0.12-0.18	2010	1950	234-351 (292.5)	19-28 (24)
P4	Sandy loam	0.12-0.18	2009	1624	194.9-292.3 (243.6)	13-19 (16)
	Sandy loam	0.12-0.18	2010	1464	175.7-263.5 (219.6)	14-21 (18)
P5	Sandy loam	0.12-0.18	2009	2495	299.4-449.1 (374.3)	20-29 (25)
	Sandy loam	0.12-0.18	2010	2734	328.1-492.1 (410.1)	26-40 (33)
P6	Sandy loam	0.12-0.18	2009	3115	373.7-560.6 (467.2)	24-37 (31)
	Sandy loam	0.12-0.18	2010	2205	264.6-396.9 (330.8)	21-32 (27)
P7	Silt loam	0.10-0.14	2009	3070	307-429.8 (368.4)	20-28 (24)
	Silt loam	0.10-0.14	2010	2853	285.3-399.4 (342.4)	23-32 (28)
P8	Silt loam	0.10-0.14	2009	2784	278.4-389.8 (334.1)	18-25 (22)
	Silt loam	0.10-0.14	2010	1623	162.3-227.2 (194.8)	13-18 (16)
P9	Sandy loam	0.12-0.18	2009	2725	327-490.5 (408.8)	21-32 (27)
	Sandy loam	0.12-0.18	2010	2223	266.8-400.2 (333.5)	21-32 (27)
P10	Silt loam	0.10-0.14	2009	2230	223-312.2 (267.6)	14 -20 (17)
	Silt loam	0.10-0.14	2010	2154	215.4-301.6 (258.5)	17-24 (21)
P11	Silt loam	0.10-0.14	2009	1105	110.5-154.7 (132.6)	7-10 (9)
	Silt loam	0.10-0.14	2010	397	39.7-55.6 (47.7)	3-5 (4)
P12	Sandy loam	0.12-0.18	2009	2995	359.4-539.6 (449.3)	23-35 (29)
	Sandy loam	0.12-0.18	2010	2435	292.2-438.4 (365.3)	23-35 (29)
P13	Sandy loam	0.12-0.18	2009	2125	255-382.6 (318.8)	17-25 (21)
	Sandy loam	0.12-0.18	2010	1636	196.3-294.5 (245.4)	16-24 (20)
P14	Silt loam	0.10-0.14	2009	2650	265-371 (318)	17-24 (21)
	Silt loam	0.10-0.14	2010	1421	142.1-198.9 (170.5)	11-16 (14)

Nyamandhlovu aquifer in Zimbabwe to be 0.4 and 9% of the long term annual precipitation. Also Obuobie (2008) applied the method to the Southern part of the White Volta Basin of Ghana and estimated recharge to range from 28.0 to 150.0 mm in 2006, representing 3.5 to 16.5% of the mean annual rainfall and from 32.0 to 204.0 mm in 2007, representing 2.5 to 16.0% of the mean annual rainfall with a specific yield range of 0.01 to 0.05.

Similarly Sandwidi (2007) used this method for the Kompienga Dam Basin in Burkina Faso near Ghana, and estimated the recharge to be from 5.3 to 29.4% of the annual rainfall. Similarly, Martin (2006) applied the method in the Atankwidi catchment, Ghana and estimated the recharge to vary from 1.8 to 12.5% of the annual rainfall in 2003 and from 1.4 to 10.3% of the annual rainfall in 2004. It can be concluded that differences in estimate of specific yield causes large relative differences in estimated recharge. Cumulative rainfall in January to February 2010 could not recharge the groundwater. This time lag occurred because rainfall takes some time to reach the groundwater table. That implied the rainfall infiltrated to replenish soil moisture deficit.

Recharge rate in the month of March 2009 was very high in the entire observational piezometric network. The highest recharge rate of 160 mm occurred in P 14 which is located at a relatively low topographic height (Figure 1) with a shallower water table. However, the water table fluctuation estimated recharge rate increases. One possible reason for this increase in recharge rate may be that it takes proportionately less time for water to travel through a thinner unsaturated zone, thus bringing the water to the saturated zone before it can be transpired by plants. The topographic low height at the site of P 14 coupled with the horizontal movement of subsurface groundwater (West-East) at the location of piezometer 14 gives the field a better point to locate a well to irrigate the field.

Hydrograph representation

Comparison of hydrographs provides an insight into the nature of the aquifer (Raj, 2004). The most common form of the hydrograph is the acute-obtuse slopes of the quarters. The acute slopes suggest a higher fluctuations surge from high rainfall records whiles that of obtuse indicates a lower fluctuation also from a moderate rainfall. Right-angled rising segments or departures towards steeper-rising segments occur due to high rainfall in a short duration, either in one spell or in several closely spaced precipitation events (Raj, 2004).

The shape of the rising limb is influenced by the intensity, interval and duration of precipitation. Rainfall appears to primarily determine the shape of the rising limb, as even a hydrograph of a borehole in a good aquifer in an alluvial tract shows an acute or right-angled (steep) rising limb during a period of particularly good rainfall and conversely well hydrographs tend to be obtuse in a poor raining year which is also a characteristic of the aquifer. A higher percentage of acute recession slope segments with either acute rising segments or right-angled rising segments is due to relatively poor unconfined aquifers. These are observed in aquifers comprising weathered residual of vispar, gneisis and shale which gives off gritty or coarser grained sand.

The dominant flat segment slopes are noted in aquifers with low hydraulic conductivity, high silt and clay, and low topographic site of the study area and aquifers with granites and sandstones rocks weathered to give fine grained sand. The dominant obtuse recession and rising slopes reflect characteristics like that of the flat segment which is often accompanied by poor rainfall amount in a water year. Also linear recession in the flat segment slopes could be due to rapid discharge from the aquifer. In the drying periods the dominant recession slope segment was the acute which suggest a sharp decrease and a higher fluctuation depth and in most cases leads to the drying of the borehole.

Water table slopes segment fluctuation and areal extent

The small size of the inland valley bottoms (IVBs) is attributed to deeper incision of the landscape and convex nature of the valleys. The amount of water flowing into the valley depends not only on rainfall amount but also on catchment size. Killian and Teissier (1973) have reported that water capture would be too small for a catchment size less than 400 ha. Therefore, the extent of the study area of 72 ha suggest that much of precipitation runs off the surface resulting in flooding of shallow depth and short duration. However, despite the topographic condition and the high drainage density and texture, the rainwater does infiltrate and readily recharges the groundwater, causing a sharp rise in the regional groundwater table and seepage flows, resulting in the seasonal or perennial wetness condition which prevails in Inland Valley Bottoms (Ogban and Babalola, 2009).

Watertable fluctuation and classification of inland valley bottom

Time series of the hydrograph shows seasonal variations in the observations among the boreholes of the study sites. About 14 % of the area had their monthly slopes from 13 to 30% of the acute segment. This was observed in P11 and P14. Also, 14% of the area had their slopes ranging between 40 to 45% acute segment which occurred in P10 and P5.

However, 72% of the monthly slopes had their acute slopes greater than 45% in the aerial domain. It can be explained that most of the piezometric areas dominated by acute forms become relatively dry during the dry season; they may, however, still have some water to support crops. These results also point to some management practices in Inland valley bottoms in developing them for crop production. Figure 6 and 8 shows that the water table (WT) is at or near the soil surface for more than 6 months in the valley system IVBs with the monthly segment slopes dominated by obtuse and flat forms of 70 to 87%. This also indicates that with higher records of monthly rainfall amount, water table would fluctuate near the ground surface for a longer period of time in the wetlands.

According to Ogban and Babalola (2009) high watertables fluctuating near the ground surface are also attributed to poor surface and subterranean drainage outlets. Hekstra and Andriesse (1983) and Andriesse (1986) have reported that IVBs in the West African sub-region have excellent conditions for more than one crop

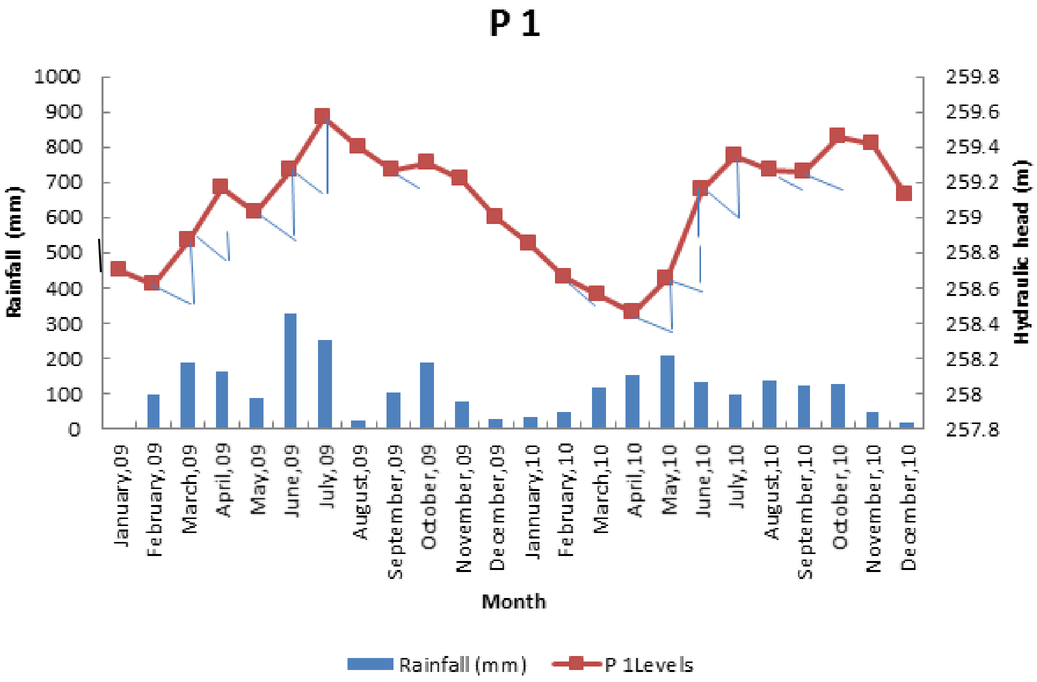

Figure 9. Example of graphical approach for estimating recharge for P 1.

growing season (150 days or more) especially wetland crops, for example, rice. It can be inferred that wetlands hold a rich potential for food production owing to the availability of water coupled with the fertile nature of the inland valley bottoms. On the other hand, the water table recedes in the beginning of the dry season which varies in the inland valley system accounting for high evapotranspiration rates. Effective cultivation can be enhanced by planting dryland crops like maize, cassava, sweet potato and vegetable crops specifically when the water table (Figure 9) has attained its mean lowest depth in February. High evaporation processes and increase in internal drainage reduces the pore water pressure, extends or pushes the phreatic surface downwards and improve aeration for crops with aerobic edaphic requirements.

Thus, a rise in the level of the WT decreases the zone of unsaturation, increases the pore water pressure, reduces the hydraulic gradient and increases the drainage load, and creates waterlogging conditions that inhibit cultivation and crop growth for dryland crops but enhances rice cultivation. On the other hand, the receding water table reduces waterlogging conditions, or creates unsaturated conditions or re-establishes the agricultural zone of the soils for dryland crops. These alternating conditions explain the alternate fallow and farming in the IVBs (Ogban and Babalola, 2009). Consequently, the decrease of the phreatic surface depth in the dry season is a critical predictive criterion because it defines the effective rooting depth (ignoring the extent of the capillary fringe), the soil water storage depth and drainage requirements, and a distinguishing characteristic for classifying the Inland valley bottoms into soil and water management regimes (Ogban and Babalola, 2009). Three hydrological regimes have been developed to classify wetlands from Figure 3 to 8. These regimes are:

WTF Class I Acute slopes segment varying from 0 to 30%,
WTF Class II acute slopes segment varying from 30 to 45%
WT Class III > 45%.

The distinguishable factors describing the fluctuation classes are as follows.

Water table fluctuation classes

Water Table Fluctuation Class I

Acute slopes segment (0 to 30) %.
Water table is close to the ground surface and soil always wet through the annual water year.
Duration of high water table is about 8 months
It is suitable for year round crop production, preferably rice.

Water table fluctuation class II

Acute slopes segment ranges from 30 to 45%. Water table is intermediate between the ground surface and the base of the borehole and piezometric water table recuperates in March in the dry season. Duration of high water table is about 4 months suitable for wetland (rainy season) and dryland (dry season) crop production but with little soil and water conservation getting to the latter part of the dry season using residue mulch in the middle of the dry season for roots to follow the receding WT.

Water table Fluctuation class III

Acute slopes segment ranges > 45%.

Water table is close to the ground in the wet seasons and most of the piezometric water table recuperates in April throughout the water year. Duration of high water table is about two months suitable for wetland (rainy season) and dryland (dry season) crop production but with soil and water conservation using residue mulch together with early planting for roots to follow the receding WT.

Conclusions

Developments of Inland Valley Bottoms of unconfined aquifers for crop production have been classified into three hydrological regimes based on the intensity of their acute slope segments of the water table fluctuations. The regimes for Besease and other IVBs are:

WTF Class I for acute slope segments varying from 0 to 30%
WTF Class II for acute slope segments varying from 30 to 45%
WT Class III > 45%.

The results show that most of the piezometric areas dominated by acute forms become relatively dry during the dry season; they may, however, still have appreciable water to support crops. It was also revealed that a rise in the level of the WT decreases the zone of unsaturation, increases the pore water pressure, reduces the hydraulic gradient and increases the drainage load, and creates waterlogging conditions that inhibit cultivation and crop growth for dryland crops but enhances rice cultivation. The lowest recharge rate in the dry periods of the two study years showed a decrease in groundwater storage which lowered the phreatic water level. It meant that irrigation water should be applied to obtain optimal moisture content and water table levels. It is concluded that a controlled water table will offer a distinguishing criterion for the development of Inland Valley Bottoms for a year round crop production. This study could be extended to other IVBs in the remaining agro-ecological zones in Ghana.

Conflict of Interests

The studies reported in this publication, were supported by a grant from the Ministry of Food and Agriculture (MoFA), Ghana. The author is a lecturer at the University of Energy and natural Resources, Ghana. The terms of this arrangement have been reviewed and approved by the University of Energy and natural Resources at Sunyani in accordance with its policy on objectivity in research.

REFERENCES

Andriesse W (1986). Wetlands in sub-Saharan Africa: area and distribution. In: The Wetlands and Rice in Sub- Saharan Africa. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, pp. 15-30.

Bradley C (2002). Simulation of the annual water table dynamics of a floodplain wetland,Narborough Bog, UK. J. Hydrol. 261:150-172.

Hall DW, Risser DW 1993). Effects of agricultural nutrient management on nitrogen fate and transport in Lancaster County, Pennsylvania. Water Resour. Bull. 29:55-76.

Healy RW, Cook PG (2002). Using groundwater levels to estimate recharge. Hydrogeol. J. 10(1):91-109.

Hekstra P, Andriesse A (1983). Wetland Utilization Research Project.West Africa. Phase 1. The Inventory. Vol. 11. The Physical Aspects. International Institute of Land Reclamation and Development (ILRI) and Soil Survey Institute (STIBOKA), Wageningen, The Netherlands 78 p.

Kankam Yeboah K, Duah AA, Mensah FK (1997). Design and construction of Hund Dug wells at Besease Technical report, Water Research Institute (CSIR), Accra, Ghana. 16 p.

Killian J, Teisseir J (1973). Methodes d'investigation pour l'analys culture et le classement des bas-fonds dans quelques regions de l'Afrique de l'ouest. Propositions de classification d'aptitudes de terres á riziculture. L'Agronomie Tropicale 28(2):156-171.

Kyei-Baffour N, Ofori E, Mensah E, Agyare WA, Atta-Darkwa T (2013). Modelling groundwater flow of the besease inland valley Bottom in Ghana. Global J. Energy Agric. Health Sci. 2(1):52-69.

Martin N (2006). Development of a water balance for the Atankwidi catchment, West Africa. A case study of groundwater recharge in a semi-arid climate. PhD.Thesis. Ecol. Dev. Series No. 41.

Meinzer OE (1923). The occurrence of groundwater in the United States with a discussion of principles. US Geol Surv Water- Supply 489:321.

Nyarko BK (2007). Floodplain wetland-river flow synergy in the White Volta River basin, Ghana. Ecol. Dev. Series Bd. P 53.

Obuobie E (2008). Estimation of groundwater recharge in the context of future climate change in the White Volta River Basin,West Africa. PhD Thesis. Ecol. Dev. Series No. 62.

Ogban PI, Babalola O (2009). Characteristics, classification and management of Inland valley bottom soils for crop production in subhumid southwestern Nigeria. J. Trop. Agric. Food Environ. Ext. 8:1-13.

Raj P (2004). Classification and interpretation of piezometer well hydrographs in parts of southeastern peninsular India. Environ. Geol. 46:808-819.

Rasmussen WC, Andreasen GE (1959). Hydrologic budget of the Beaverdam Creek Basin, Maryland. US Geo. Surv. Water-Supply 1472:106.

Risser DW, Gburek WJ, Folmar GJ (2005). Comparison of methods for estimating ground-water recharge and base flow at a small watershed underlain by fractured bedrock in the eastern United States. US Geol. Surv. Sci. Invest. Rep. 2005-5038.

Sandwidi WJP (2007). Groundwater potential to supply population demand within the Kompienga dam basin in Burkina Faso. PhD Thesis. Ecol. Dev. Series No. 55:2007.

Serrano SE, Unny TE (1987). Predicting groundwater flow in a phreatic aquifer J. Hydrol. 95:241-268.

Sibanda T, Johannes JC, Uhlenbrook S (2009). Comparison of groundwater recharge estimation methods for the semi-arid Nyamandhlovu area, Zimbabwe. Hydrogeol. J. 17:1427-1441.

academicJournals

Vol. 8(7), pp. 92-96, August 2016
DOI: 10.5897/IJWREE2016.0650
Article Number: 2AE0CD159684
ISSN 2141-6613

http://www.academicjournals.org/IJWREE

International Journal of Water Resources and Environmental Engineering

Full Length Research Paper

Wet and dry spell analysis for decision making in agricultural water management in the eastern part of Ethiopia, West Haraghe

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Received 31 March, 2016; Accepted 4 July, 2016

The objective this study was to analyze the dry and wet spell of the main and small rainy season in the eastern part of Ethiopia, West Haraghe. Markov Chain model was employed to investigate the extent and characteristics of the dry and wet spell in the study sites. Accordingly, the results exhibited that the chance of having wet dekades is relatively higher (greater than 50% of probability of occurrences) during last of June to the start of October for all the study locations (Hirna, Asebe Teferi and Meios). The probability of having wet after wet is also fairly enough that farmers can take significant agricultural operations, like planting during the start of the season, second dekade of June. The probability of having wet during belg is however very low (usually less than 40%). But the soil moisture from the season could help farmers start plough earlier so that farmers can have the full advantage of the main rainy season, without wasting moisture for other activities.

Key words: dry, probability, Markov chain, probability, spell.

INTRODUCTION

Precipitation modeling is very important for planning and management of water resources and has many practical applications in engineering and agriculture. The majority of hydrological methods for precipitation modeling try to represent the generating mechanism of the physical process. They are basically mathematical description of the nature of precipitation and of the structure of the sample time sequence. The purpose of estimating probability with respect to a given amount of rain fall is extremely useful for agricultural planning.

In a growing season decisions have to made based on the probability of receiving certain amount of rainfall during a given decade. The probability of rain during next decade, if rain occurs this decade known as conditional probability of a wet decade preceded by a wet decade (P_{WW}), and the probability of rain next decade being wet, if this decade is dry known as conditional probability of a wet week preceded by a dry decade (P_{WD}). Analogously,

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initial and conditional probability for a dry decade can be defined (Srinivasa et al., 2008). These initial and conditional probability would help in determining the relative chance of occurrence of a given amount of rain fall and the chance of any threshold amount of rain fall depends on the purpose for which the different probability may be computed (Virmani, 1976).

Studies on earth's global climate show an increasing trend on average air temperature. Consequently, the vegetation period is expected to become shorter and even more irregular distribution of rainfall is expected. It has been noted that the long dry spells incur heavy costs to the affected communities. In humid countries the success or failure of the crops, particularly under rainy conditions is highly related with the distribution of dry spells. For achieving maximum benefits from dry land agriculture the knowledge of distribution of dry spells within a year is useful. Dry spells affect not only in agriculture but also other sectors such as fisheries, health, electricity etc. Long dry spells may physically weaken the people which could cause mental degradation due to the lowering of their status. The fish productivity from fresh water is likely to be stricken by longer dry spells. Longer dry spells also interrupt generating electricity using hydroelectric power (Jayawardene, 2005). Therefore, the effects of dry spells in various sectors as described above ultimately have a direct impact on the economy of a country.

Reddy (1990) stated that 3mm rainfall depth per day is the minimum threshold value for crops to satisfy their crop water requirement during a growing season. In his study an average of 30 mm per decade (ten days sum) of precipitation depth was taken as a threshold value for evaluating whether a decade is in a dry or wet spell. A decade with a depth of precipitation below this value as Markov chain model of first order was considered as dry and vice versa for a decade with precipitation value of above the threshold level. In his study Reddy (1990) described wet spell duration as a sequence of wet decades preceded and followed by the dry decades and correspondingly the dry spell duration is the sequence of dry decades followed and preceded by the wet ones.

The information on the length of dry spells could be used for deciding a particular crop or variety in a given location, and for breeding varieties of various maturity durations. Information on dry spell lengths could be used in decision making with respect to supplementary irrigation and field operations in agriculture. Prior knowledge of dry spell studies can be applied to generate synthetic sequences of rainfall and to the estimation of the irrigation water demand. Crops are more likely to do well with uniformly spread 'light' rains than with a few 'heavy' rains interrupted by dry periods. The timing of breaks in rainfall (dry spells) relative to the cropping calendar rather than total seasonal rainfall is fundamental to crop viability. The longest period of several long dry spells is of crucial importance in planning agricultural activities and managing the associated water supply systems (Sharma, 1996). Since drying (the dry period) in one year is not necessarily the same as in another year, thus knowledge of behavior of these patterns has become increasingly important to understand.

For assessing the dry and wet spell distribution, a number of probability models have been developed in many studies to describe the pattern of rainfall distributions (Manning, 1950; Feyerherm and Bark, 1967; Kulandaivelu, 1984; Phien and Ajirajah, 1984; Topalogu, 2002). Aneja and Srivastava (1986, 1999) came up with two-state (with two parameters) and three-state (with five independent parameters) Markov chain models to study the pattern of occurrence of rainfall. Purohit et al. (2008) used two-state Markov chain model to find the probabilities of occurrence of dry and wet weeks. The probability analysis of dry and wet spell distribution is believed to help in support of planning agricultural water management, particularly during the rainy season.

The objective this paper is therefore to explain the characteristics and extent of the dry and wet spells in the eastern part of Ethiopia, West Haraghe.

MATERIALS AND METHODS

In Ethiopia, there are three distinct seasons, namely, bega, belg and kirmet. The definition is presented as in the following;

a) Bega: This is generally the dry season that covers the period from October to January. However, there is occasionally untimely rain over various parts of the country. During this season, most part of the country predominantly falls under the influence of dry and cool northeasterly winds. These dry air masses originate either from the Saharan anticyclone and /or from the ridge of high pressure extending into Ethiopia from Arabian land and from the large high surface pressure over central Asia and, Siberia (NMSA, 1996; Gonfa, 1996).

b) Belg: Belg is small rainy season that covers the period from mid-February to mid-May. However, the rainfall is highly characterized by inter annual and inter seasonal variation. Major systems during the Belg season are the following:-development of thermal low over South Sudan, generation and propagation of disturbances over the Mediterranean Sea, sometimes coupled with easterly waves, development of high pressure over the Arabian Sea, Some of the interaction between mid-latitude depressions and tropical systems accompanied by troughs and the subtropical jet and occasional development of the Red Sea convergence zone (RSCZ) (NMSA, 1996; Gonfa, 1996).

c) Kiremt: Kiremt is the main rainy season that covers the period from June to September. Major rain producing systems during Kiremt season includes; Northward migration of ITCZ, development and persistence of the Arabian and South Sudan thermal low along 20°N latitude, development of quasi-permanent high pressure systems over south Atlantic and south Indian Oceans, development of tropical easterly jet and the generation of low level Somali jet that enhance low level south westerly flow (Tadesse, 1994; NMSA, 1996; Segale and Lamb, 2005).

The analysis of dry and wet spell analysis was carried for the two rainy seasons, belg and kirmet. As Reddy (1990) has already stated that a 3 mm rainfall depth per day is the minimum threshold valued for crops to satisfy their crop water requirement. Accordingly, in this study, a 30 mm per decade of precipitation

Table 1. Standard meteorological decade.

Dekade no	Month	Date
1	January	1-10
2		11-20
3		21-30
4	February	1-10
5		11-20
6		21-30
7	March	1-10
8		11-20
9		21-30
10	April	1-10
11		11-20
12		21-30
13	May	1-10
14		11-20
19	July	1-10
20		11-20
21		21-30
22	August	1-10
23		11-20
24		21-30
25	September	1-10
26		11-20
27		21-30
28	October	1-10
29		11-20
30		21-30
31	November	1-10
32		11-20

depth was taken as a threshold value for evaluating whether a dekade is in a dry or wet spell. A dekade with a depth of precipitation below this value was considered as dry and vice-versa for a dekade with precipitation value of above the threshold level. The following expressions were used in the Markov chain analysis of dry/wet spells in the zone (Reddy et al*.,* 2008)

In a crop growing season, decisions have to be taken based on the probability of receiving certain amount of rainfall during a given decade. Therefore, Markov chain model was used to evaluate the dry and wet spell distributions on dekadal basis using dekadal rainfall.

The different formulations of Markov chain model which were used in the assessment of distribution of dry and wet spells are presented in the following series of equations.

Description of the study area

The study area is located in West Haraghe zones, Oromiya Regional State, eastern part of Ethiopia, about 405 km east of Addis Ababa. The Harerghe highlands lying in the eastern part of the country are generally known for their rugged topography, mountainous landscapes which govern the variations in regional geomorphology, soil sequences, ecological zones, quantity and quality of plant and animal life (Tamire, 1981). The climatic conditions of the study area exist in all agro-ecological zones. The majority is covered by kola, woyena dega and Dega according to its altitudinal range from sea level.

The climate in West Hararghe is warm and temperate, there is significant rainfall. Even in the driest month there is a lot of rain. This location is classified as Cfb by Köppen and Geiger. The averages temperature of the zone is 17.1°C. On an average about 1026 mm of precipitation falls annually in its zone. It has a latitude and longitude of 9°05′N and 40°52′E and an altitude of 1826 meters above sea level.

Standard dekades

The standard dekades are organized as in the Table 1.

Initial probabilities

$$P_D = \frac{F_D}{n}$$

$$p_w = \frac{F_W}{n}$$

Conditional probabilities

$$P_{WW} = \frac{F_{WW}}{F_W}$$

$$P_{DD} = \frac{F_{DD}}{F_D}$$

$$P_{WD} = 1 - P_{DD}$$

$$P_{DW} = 1 - P_{WW}$$

Where: F_{D}- is the number of dry dekads
F_{W}- is number of wet dekads
F_{DD} -is number of dry dekad followed by another dry one
F_{WW} -is number of wet dekads followed by other wet dekads
P_{D} -is the probability of a dekad being dry
P_{W} -is the probability of a dekad being wet
P_{WW}- is the probability of wet dekad preceded by another wet dekad
P_{DD} -is the probability of a dry dekad preceded by another dry one
P_{WD} -is the probability of a wet dekad preceded by another dry dekad
P_{DW}- is the probability of a dry dekad preceded by a wet one.

RESULTS AND DISCUSSION

Main rain season

The results of initial and conditional probabilities of dry and wet dekads during *Kiremt* season at *Hirna* area are presented in Table 2. These results revealed that the probability of having a wet of greater than 50% occurred during 19th to 25th dekads while probability occurrence of a dry dekad (P_D) with more than 50% probability of occurrences observed to be between 16th to 18th dekade. Conditional probability of wet dekad preceded by a wet dekad [P_{WW}] at *Hirna* is observed to be greater than 50% (50-86%) except for dekads 16 and 18, 28, 29, which had 33, 10, 0 and 20% in their respective orders.

Similarly, only four dekades were observe to have more

Table 2. Dry-wet spell probability distribution of *Kiremt* based on the Markov Chain model *Hirna* station.

Dekade no.	P-W	P-D	P-WW	P-DD	P-WD	P-DW
16	35	65	33	59	41	67
17	19	81	75	81	19	25
18	38	62	10	38	62	90
19	69	31	72	25	75	28
20	77	23	70	17	83	30
21	85	15	86	25	75	14
22	85	15	86	0	100	14
23	85	15	77	0	100	23
24	85	15	82	0	100	18
25	88	12	83	0	100	17
26	77	23	75	33	67	25
27	31	69	50	39	61	50
28	12	88	0	83	17	100
29	19	81	20	67	33	80

Table 3. Dry-wet spell probability distribution of *Kiremt* based on the Markov Chain *Asebe Teferi* station (1985-2014).

Dekade no.	P-W	P-D	P-WW	P-DD	P-WD	P-DW
16	3.00	97.00	00.00	93.00	7.00	100.00
17	13.00	87.00	00.00	73.00	27.00	100.00
18	37.00	63.00	18.20	47.00	53.00	81.80
19	53.00	47.00	31.00	29.00	71.00	69.00
20	57.00	43.00	53.00	38.00	62.00	47.00
21	80.00	20.00	75.00	33.00	67.00	25.00
22	63.00	37.00	58.00	27.00	73.00	42.00
23	63.00	37.00	74.00	55.00	45.00	26.00
24	87.00	13.00	88.00	25.00	75.00	12.00
25	60.00	40.00	56.00	42.00	58.00	44.00
26	63.00	37.00	58.00	27.00	73.00	42.00
27	50.00	50.00	53.00	60.00	40.00	47.00
28	20.00	80.00	17.00	79.00	21.00	83.00
29	13.00	87.00	00.00	81.00	19.00	100.00
30	10.00	90.00	00.00	93.00	7.00	100.00

that 50% probability of occurrences of dry dekades preceded by dry dekades (dekade 16, 17, 28 and 29). Moreover, the probability of occurrence of dry dekad preceded by wet dekad or vice versa (P_{WD} or P_{DW}) was found to be in the range of (17-100%) and (14-100%) respectively for the same location.

The analysis of the results for Asebe Teferi showed that dekade 24 is the wettest while the driest is dekadde 16 (Table 3). The period between dekade 20 and 27 had the highest probability of wet deakde after wet implying the chance of having good soil moisture for panning agricultural operations during those period. In other words, decision making with respect to planting of crops is fairly less risky for farmers. On the other hand, the dekades beyond dekade 27 should carefully be monitored as the plant may suffer from low soil moisture.

At Meiso, the period between dekade 20 and 24 had the highest chance of wet and wet after wet during the main growing season (Table 4). Planning for sowing crops on dekade 20 can be a good decision but during the dekades of October plants could suffer from low soil moisture as the pant may require more water as it developes. Therefore, some soil and water conservation techniques should be exercised during the wettest periods (dekade 20-24) to conserve soil moisture so that it can serve in the later days of the growing season.

Table 4. Dry-wet spell probability distribution of *kiremt* based on the Markov Chain model *Meiso* station (1991-2008).

Dekade no.	PW	P-D	P-WW	P-DD	P-WD	P-DW
16	17	83	0	73	27	100
17	6	94	0	88	12	100
18	17	83	0	73	27	100
19	61	39	55	29	71	45
20	50	50	44	60	40	56
21	78	22	71	25	75	29
22	72	28	54	20	80	46
23	56	44	60	34	66	40
24	61	39	55	43	57	45
25	50	50	33	33	67	67
26	44	56	62	40	60	38
27	28	72	0	62	38	100
28	22	78	50	79	21	50
29	17	83	67	87	13	33

Table 5. Dry-wet spell probability distribution of *Belg* based on the Markov Chain model *Hirna*.area (1985-2010).

Dekade no.	P-W	P-D	P-WW	P-DD	P-WD	P-DW
7	23	77	0	75	25	100
8	38	62	55	69	31	45
9	38	62	40	73	27	60
10	58	42	67	36	64	33
11	62	38	44	30	70	56
12	50	50	46	70	30	54
13	54	46	43	42	58	57
14	46	54	36	57	43	64
15	31	69	25	72	28	75

In general, in the main rainy season, agricultural operations (e.g. planting) enjoy favorable soil moisture conditions during the dekades between 20 to 27 for all the study areas. In the dekases where the chance of having wet after wet could create an opportunity to conserve water so that it could be used in the latter days of the crop development stages when the demand of water is relatively high. In this respect, *in situ* water harvesting can be an option to build soil moisture reserve.

Small rainy season (*Belg*)

The Makov chain analysis of the probability of dry and wet spell of belg season at Hirna exhibited that the driest dekade is dekade 7(23% of wet occurrences) and dekade 11 had the highest probability of getting wet (62%) (Table 5). The highest probability of having wet dekade after wet was obtained at dekade 10, 67% of occurrences. Correspondingly, the start of the season had the highest probability of occurrences of dry dekade, during the dekades 7-9. Similarly, during the same period, dry dekade after dry is highly probable, ranging from 69 to 75%.

At Asebe Teferi, the highest probability of occurrences of wet dekade was observed during dekade 8-11 and at dekade 13, ranged from 47 to 50% while all dekades had more than 50% probability of occurrences for dryness (Table 6). The probability of occurrences of dry dekade after dry is still very high for most of the dekades at this same area and planning important agricultural operations except plowing could be some how difficult.

The probability getting wet dekade during belg at Meiso is relatively low as compared to Hirna and *Aseb Teferi* (Table 7). There were only two dekades (8 and 10) that had 50% probability of having wet dekade, the rest experienced lower than 40% of occurrences. On the

Table 6. Dry-wet spell probability distribution of *Belg* based on the Markov Chain Model *Asebe Teferi* area (1985-2014).

Dekade no.	P-W	P-D	P-WW	P-DD	P-wD	P-DW
7	17.00	83.00	20.00	80.00	20.00	80.00
8	50.00	50.00	47.00	43.00	60.00	53.00
9	47.00	53.00	43.00	56.00	44.00	57.00
10	50.00	50.00	33.00	40.00	60.00	67.00
11	50.00	50.00	40.00	40.00	60.00	60.00
12	40.00	60.00	33.00	56.00	44.00	67.00
13	50.00	50.00	46.00	40.00	60.00	54.00
14	43.00	57.00	46.00	65.00	35.00	54.00
15	37.00	63.00	27.00	63.00	37.00	73.00

Table 7. Dry-wet spell probability distribution of *Belg* based on the Markov Chain model *Meiso* station.

Dekade no.	P-W	P-D	PWW	PDD	PWD	PDW
7	22	78	25	71	29	75
8	50	50	60	44	63	40
9	22	78	25	64	36	75
10	39	61	43	55	45	57
11	50	50	56	56	44	44
12	22	78	0	64	36	100
13	33	67	17	58	42	83
14	28	72	20	62	38	80
15	17	83	33	73	27	67

other hand, the occurrence of dryness is relatively higher than 50% during this same season, reaching as high as 13%. The implication is that there shall by no means planning for major agricultural operations in the study area for Belg.

Conclusions

Decision making in agricultural operation requires rigorous analysis of precipitation data. The results presented in this study exhibited that the chance of having wet dekades is relatively higher during last of June to the start of October for all the study locations. The probability of having wet after wet is also fairly enough that farmers can take significant agricultural operations, like planting. In order to take the full advantage of the main growing season, farmers should be ready to use the soil moisture from the small rainy season to plough their lands so that they can directly plant their crops right after the start of the main rainy season. On the other hand, the dates at the end of the growing season should be regularly monitored as the chance of having wet period is comparatively low. For long maturing crops, the dryness of October can have impact on the yield as demand for water would be higher and thus some soil and water (*in-situ water harvesting)* conservation practices can help to build the soil moisture reserve of their land so that crops would not suffer from low soil moisture.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Aneja D, Srivastava O (1986). A study technique for rainfall pattern. Aligarh J. Stat. 6:26-31.

Aneja D, Srivastava O (1999). Markov chain model for rainfall occurence." Journal of Indian society of Agricultural Statistics, 52(2).

Feyerherm A, Bark L (1967). Goodness of fit of a Markov Chain Model for Sequences of wet and dry days. J. Appl. Meteorol. 6:770-773.

Gonfa L (1996). Climatic Classification of Ethiopia NMSA, Addis Ababa, Ethiopia.

Jayawardene HK, Sonnadara WIDUJ, Jayewardene DR (2005). Trends in rainfall in Sri Lanka over the last century.Sri Lankan J. Phy. 6:7-17.

Kulandaivelu R (1984). Probability Analysis of Rainfall and Evolving Cropping System for Coimbatore." Geophys. Res. Lett. 5:3.

Manning H (1950). Confidence Limit of Monthly Rainfall. J. Agric. Sci. 40:169.

NMSA (National Meteorological Services Agency) (1996). Climate and agro climatic resources of Ethiopia, Meteorological Research Report

Series. Addis Ababa 1(1):137.

Phien H, Ajirajah T (1984). Application of log-pearson Type-3 distributions in hydrology. J. Hydrology 73:359-372.

Purohit R, Reddy G, Bhaskar S, Chittora A (2008). Markov Chain Model Probability of Dry, Wet weeks and Statistical Analysis of Weekly Rainfall for Agricultural Planning at Bangalore." Karnataka Journal of Agricultural Science, 2(1).

Reddy SJ (1990). Methodology: Agro-climatic Analogue Technique and Applications as relevant to dry land agriculture. Agro climatology Series Eth 86/21-WMO/UNDP, NMSA 60 p.

Reddy G, Purohit R, Bhaskar S, Chittora A (2008). Markov Chain Model Probability of Dry, Wet weeks and Statistical Analysis of Weekly Rainfall for Agricultural Planning at Bangalore." Karnataka J. Agric. Sci. 2(1).

Segale ZT, Lamb PJ (2005). Characterization and Variability of Kiremt Rainy season over Ethiopia. Meteorol. Atmos. Phys. 89:153-180.

Sharma TC (1996). Simulation of the Kenyan longest dry and wet spells and the largest rain sums using a Markov Model. J. Hydrol. 178:55-67.

Srinivasa GV, Bhaskar SR, Puro hit RC, Chiltora AK (2008). Markov chain Model Probability. Dry,Wet Weeks and Statistical Analysis of Weekly Rainfall for agricultural Planning atBangalure, Karnataka. J. Agric. Sci. 21(1):12-16.

Tadesse T (1994). The Influence of the Arabian Sea Storms/monsoon Variability and Prediction, WCRP-84 and WMOTech.Doc.619,Geneva, Switzerland. World Meteorological Organization pp. 228-236.

Tamire H (1981). Soil, water and forest conditions in Haraghe highlands, Alemaya Unpublished report, Alemaya University, Alemaya, Ethiopia.

Topalogu F (2002). Determining Suitable Probability Distribution model for flow and precipitation series of the Seyhan River Basin. J. Agric. 26:189-194.

Virman SM(1976). The agricultural climate of the Hyderabad Region in relation to crop planning. A simple analysis, in hone be publication of ICRISAT, Hyderabad, india. 54 p.

International Journal of Water Resources and Environmental Engineering