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The Influence of Rainfall Variability on Arable Land Use at Local Level: Realities from Nzhelele Valley, South Africa

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Abstract. Climate change poses a threat to rain-fed arable land use and crop production in the semi-arid agro-ecological zones of South Africa. Rainfall variability in such areas makes them more susceptible to climatic shocks and uncertainties. Rainfall variability has resulted in droughts or floods which have significantly impacted on the rural poor who rely on natural rainfall for crop production. The aim of this paper is to assess the influence of rainfall variability on arable land tillage for crop production along the Nzhelele River valley in Limpopo Province of South Africa. Rainfall statistics from 2000 to 2009 for three weather stations servicing six subsistence farming communities along the Nzhelele River valley were obtained from the South African Weather Services. Arable land use data was drawn from the Department of Agriculture and the local farmers' representative committees. Using rainfall variability as a predictor we evaluated the relationship between rainfall variability and arable land cultivation using *regression analysis*. Results show that many farming communities received above normal average rainfall during the period under review. Arable land use trends depict that tillage fluctuated significantly in response to rainfall changes. A significant negative correlation was discerned between rainfall and arable land use. Such data suggest that arable land use has been severely affected by rainfall variability. As a result most farmers are finding it difficult to predict and plan ahead. Therefore there is need for creation of an enabling environment for, and the promotion of arable land use practices that rely less on natural rainfall.

Key words: climate change, rain fed, land use, rainfall variability.

1. Introduction

Rainfall, among other factors, has always dictated how land is used in one way or another. This is especially true for semi-arid areas which rely on natural rainfall for agricultural production. Climate change impact assessments done by the Intergovernmental Panel on Climate Change (IPCC) (2007) and Buddenhagen *et al.* (1992) conclude that rain fed agriculture in Africa risks negative impacts due to climate change. Rain fed agricultural production in Africa in general is projected to be reduced by up to 50% by 2020 (IPCC, 2007) and in southern Africa in particular by 2080. Projected impacts relative to current production levels range from −100% to +168% in econometric, from −84% to +62 % in process-based, and from −57% to +30% in statistical assessments (Muller, *et. al.*, 2011). Such impacts spell serious food security challenges for the continent.

Climate change and rainfall variation pose serious risks to rain-fed agricultural land use in the semi-dry agro-ecological zones of Africa. Rainfall variability has significantly impacted on the rural poor (Allamano *et. al.*, 2010) who rely most on natural rainfall for land tillage and crop production. The impacts vary from droughts, floods, storms, coastal inundation, ecosystem degradation, heat waves, wild fires, epidemics, and even conflicts over land. The frequency of the climatic extremes has increased in the past century, significantly reducing land put under crops, and hence crop yields (Australian Academy of Science, 2010; Hewitson, *et. al.*, 2006; Tadross *et. al.*, 2005) and forcing farmers to adopt new agricultural techniques fitting the altered conditions. Their effects are compounded by the fact that rain-fed agriculture is commonly practiced in developing countries where farmers are finding it difficult to adapt (Muller, *et. al.*, 2011; Agrawal & Perrin, 2008; Ziervogel, *et. al.* 2006; Downing*et. al.*, 2005).

Rain-fed crop production is a dominant mode of food production in the majority of rural Sub-Saharan Africa (Cooper, *et. al.*, 2008). For this reason it is important to study rainfall patterns and variability in line with the agricultural land-use and production. The reliance of the agricultural sector on natural rainfall places it at a serious risk of shrinkage due to the inter-annual rainfall variations. With the declining rainfall trends in Southern Africa and most of the Sub-Saharan Africa region (Droogers, Seckler, & Makin, 2001; Nnyaladzi, 2009), agricultural production is most likely to decline, raising concerns about issues of food security.

Marginal rain-fed agricultural areas with low and erratic precipitation are the most vulnerable and worst affected. Especially difficult to predict are changes in rainfall patterns. Droughts or floods result in low and unpredictable levels of crop production due to changed agricultural conditions (Allamano *et. al.*, 2010). Almost all of the increased hunger related effects are expected to wreak havoc in sub Saharan Africa (Parry, *et. al.*, 2009). The dominant factor to all the challenges is rainfall variability. In a study of Mangondi village in Limpopo of South Africa, Ziervogel, *et. al.* (2006) conclude that one of the constraints facing the community is high climate variability. The high climate variability is personified by numerous droughts and floods, especially in the last decade. They further observe that the rainy season is now starting and finishing later than the normal (September and March, respectively).

The fluctuating rainfall trend was also observed by Nnyaladzi (2009) in a study of rainfall patterns in southern Africa over a 30 year period beginning 1975 and ending 2005. The major finding of this study is that rain-fed agricultural production in southern Africa was steadily declining. It is projected that by the year 2020, southern Africa will suffer serious water deficiencies due a declining trend in rainfall totals. Thus amongst other influences on agricultural production rainfall variability is arguably the most significant (Meinke, *et. al.*, 2004).

Rainfall patterns significantly influence the amount of land cultivated and the type of crops planted by farmers (Veldkamp & Lambin, 2005). Understanding the magnitude and scope of such influence could go a long way in informing adaptation practices adopted by local farmers. Adaptation by farmers could significantly reduce the negative effects of rainfall variability brought by climate change (Parry, *et. al.*, 2009). This poses a vexing challenge to subsistence farmers who are unable to know what to expect – drought or floods. Such uncertainties often result in a climate maze in which farmers find themselves unwittingly caged.

It is important for us to understand the implications of climate change on arable land use and crop production as it has a bearing on food security as well as local adaptation practices. Rainfall fluctuations that often characterize Nzhelele River valley of Limpopo province in South Africa poses a potential threat to arable land use with obvious implications on food security issues. This paper looks at the relationship between rainfall variability and the dynamics of arable land-use. Following this introduction we outline materials and methods used in this research. We then present and discuss the major findings in the next section before drawing some concluding remarks.

2. Materials and methods

We consider rainfall trends shown by figures obtained from three weather stations serving six subsistence farming communities along the Nzhelelele River valley of Limpopo province in South Africa. This data is compared to the amount of land under cultivation to show the influence that rainfall variability has on rain fed arable land use. We consider this to be an appropriate approach as many studies that seek to discern a relationship between the two often use rainfall variability as the predictor (Woldeamlak, 2009, 2006; Agbola and Ojeleye, 2007; Rugumayo *et al*, 2003).

Rainfall data was obtained from the South African Weather Services at the regional office in Vuwani as well as the Head Office in Pretoria. Agricultural data was obtained from the Department of Agriculture (Makhado) and the Representative Committees of local farmers in the study area. Three weather stations service six communities of interest including Fondwe, Mandala, Rabali, Tshavhalovhedzi- Mphaila, Tshiswenda and Tshituni. The weather stations are Siloam, Mandala and, Vondo. The main reason behind using these stations was their spatial distribution along the Nzhelele valley. The Vondo station serves

Fondwe, the Mandala station serves Mandala and the Siloam station serves Rabali, Tshavhalovhedzi – Mphaila, Tshiswenda and Tshituni area.

Nzhelele valley farmers are represented by committees that are made up of individuals who practice agriculture in the area. Data on the quantity of land cultivated for crops each year in the period under review was supplied by representatives from these committees. Regression analysis was employed to evaluate the relationship between rainfall variation and arable land use. The *F-test* was employed to discern the significance of the association observed.

Analysis of rainfall data involved characterising long term mean values and calculation of a proxy measure of variability and trends at annual time scales. The study area receives on average 400 to 800 mm of precipitation in a normal agricultural season. This translates to a normal median precipitation value of 600 mm per annum. Most studies employ precipitation indices such as Precipitation Concentration Index (PCI), Standarzed Rainfall Anomaly (SRA) and Standardized Precipitation Index (SPI) among others as statistical descriptors of rainfall variability (Woldeamlak, 2009, 2007; Seiler *et al*, 2002; McKee *et al*, 1993). Our analysis employed absolute precipitation deviations from normal median value of 600m as a *proxy* measure for rainfall variability. Agricultural rainy seasons were defined according to the scale portrayed in figure 1. Variability of statistics was further complemented by computing *skewness* and *kurtosis*.

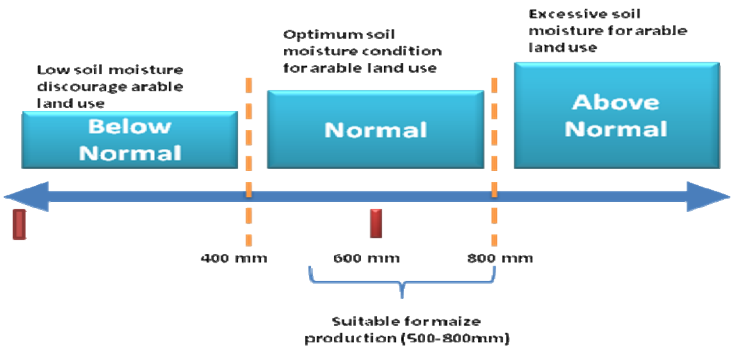


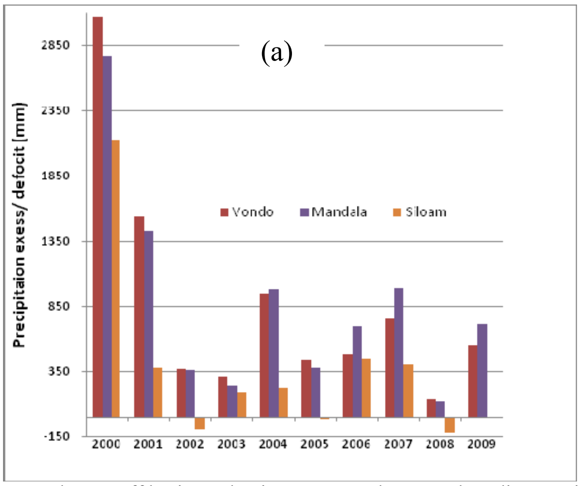
Fig. 1: Definition of agricultural seasons.

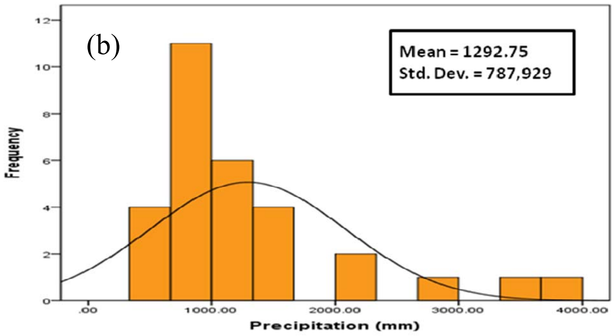
3. Results and discussion

3.1 Rainfall variability

Despite a projected decline in rainfall in Southern Africa (IPCC, 2007), existing statistics reveal that the valley received mean annual rainfall of 1292.75 mm (standard dev. = 787.929) during the period under review. Rainfall statistics during the period under review were largely skewed to the right (refer to figure 2). This is way above the mean annual rainfall of 600 mm. Rainfall statistics show that the year 2000 was characterised by relatively large amounts of rainfall throughout the valley. The 2000 figures fall way above the mean annual rainfall of the period because of Cyclone Eline that brought torrential rains. A normal rainy season in the valley receives between 400 and 800 mm of precipitation. Using a precipitation median value of 600 mm per annum, results reveal that two stations namely Vondo and Mandala received above median precipitation throughout the period under review (refer to figure 2).

Siloam station on the other hand recorded 4 years (i.e. 2002, 2005, 2008 and 2009) of below median precipitation. These statistics however are still within the bounds of a normal season. With the exception of 2008, Vondo and Mandala stations recorded above 800 mm of precipitation per annum. Siloam station on the other hand recorded a similar trend in the years, 2000, 2001, 2004, 2006, and 2007. These statistics signify excessive precipitation levels for a normal agricultural season. A normal agricultural season for maize production (the most commonly grown crop) would require precipitation levels of between 500 and 800 mm (FAO, 1986).





	N	Minim	Maxim	Mean	Std. Dev.	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Precip. (mm)	30	478.20	3675.80	1292.747	787.9289	1.805	.427	3.028	.833

NB: The cut-off horizontal axis represents the normal median precipitation value of 600mm / annum. Each bar represents precipitation excess / deficit from this norm.

Fig. 2: (a) Nzhelele valley precipitation (b) Rainfall variability

3.2 Rainfall variability and arable land use

Areas on the eastern portion of the Nzhelele valley (Mandala and Fondwe) often cultivate a larger proportion of land per year relative to the other areas. They have an average of 69, 34 ha and 61, 12 ha per year, respectively (Table 1). This can be attributed to generally more precipitation received in the areas as compared to the western villages. Such a relationship should not be surprising as empirical evidence from elsewhere has revealed that high (normal) precipitation levels are often associated with a high acreage of area under cultivation (FAO, 2010).

However, in the period under review an increase in the amount of rainfall translated into decrease in arable land usage. Results revealed a significant negative relationship between annual rainfall and arable land tillage ($\beta = -0.022$, $r^2=0.537$, $F=18.585$, p-value < 0.005). Summary results are shown on Figure 3.

4. Concluding remarks

It is important to note that farmers in Nzhelele valley rely on rainfall for subsistence crop production. The above analysis revealed a significant negative relationship between rainfall and arable land use.

Table 1: Nzhelele valley rainfall and arable land use.

Station	Vondo		Mandala		Siloam				
Area served	Fondwe		Mandala		Rabali		Tshavhalovhedzi-Mphaila	Tshiswenda	Tshituni
Year	Precip (mm)	Area (ha)	Precip (mm)	Area (ha)	Precip (mm)	Area (ha)	Area (ha)	Area (ha)	Area (ha)
2000	3675.8	19.9	3373	15.9	2730	15.2	34.3	8.08	12.1
2001	2137.7	82.3	2032	67.8	973.7	45.6	85	26.1	
2002	970.9	39.3	960.2	27.3	499.8	30.8	66.7	10.8	28.1
2003	913.4	47.3	845.7	36.4	782.5	28.1	63.9	7.75	24.4
2004	1547.5	88.6	1576	81.5	820.7	54	95	41.5	51.1
2005	1034.9	94.1	980.8	84.3	585.8	58.9	98	42.9	51.4
2006	1075.6	92.8	1291	97.5	1045	74.8	102	58.2	70.9
2007	1351.6	81.8	1588	74.8	999.2	73.1	98.2	60	69.7
2008	734.3	58.3	718	44.8	478.2	32.4	61.4	17.7	28.9
2009	1153.7	89.2	1307	81	599.9	56.8	97.4	42.3	53.1
Av.	1459.54	69.34	1467.2	61.1	951.5	47	80.2	31.5	43.6

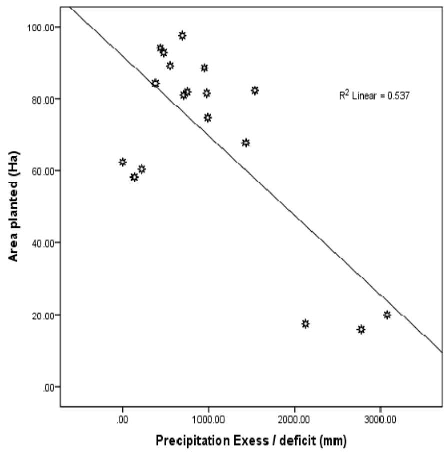


Fig. 3: Nzhelele valley precipitation and arable landuse relationship

Such analysis suggest that rain fed agriculture has been significantly affected by rainfall variability. This reinforces the observations by Buddenhagen, *et. al.* (1992), IPCC (2007) and Allamano (2010) that climate change in southern Africa will result in negative impacts on agriculture. This by extension poses serious food insecurity issues to farmers who rely on rain fed agriculture. Therefore there is need for creation of an enabling environment for, and the promotion of arable land uses that rely less on natural rainfall but guarantee food security to local farmers.

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