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Managing Dry Spell Risks to Improve Rainfed Maize Productivity in the Semi-Arid Central Rift Valley of Ethiopia

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አህፅርኦት

ዓለም አቀፋዊ መረጃዎች እንደሚያስረዱት 80 በመቶ የሚሆነው የግብርና ልማት የሚካሄደው ከተፈጥሮ ዝናብ በሚገኝ ውሃ ነው፡፡ ይህም 60 በመቶ ያህል ለዓለም የምግብ ዋስትና ማረጋገጫ አስተዋፅዖ ይኖረዋል ተብሎ ይታመናል፡፡ ለጥናታችን መነሻ የሆነውም የኢትዮጵያ ግብርና ልማት በአብዛኛው የዝናብ ጥገኛ መሆኑ ሲሆን በኢትዮጵያ የግብርናን ምርት እና ምርታማነት ከሚቀንሱት የዝናብ ባህሪያት መካከልም የተራዘሙ የደረቅ ሰሞኖች አንዱ እና ዋነኛው ነው ከሚል መላምት በመነሳት ነው፡፡ ሆኖም ይህን ተፅዕኖ መቋቋም የሚችሉ የማሳ ላይ ሰብል አያያዝ ዘዴዎችን በማፍለቅ የበቆሎን ምርት እና ምርታማነት በዝናብ አጠር ወይም ሀሩራማ አካባቢዎች መጨመር እንደሚቻል አመላካች የጥናት ውጤት መረጃ ቀርቧል፡ ሙከራው የተካሄደው በመልካሳ ምርምር ማዕከል የሙከራ ማሳ ላይ ሲሆን የተሞከረውም .እ.ኤ.አ በ2000 እና በ2001 የክረምት ዝናብ ወቅቶች ነበር፡፡ ጥናቱ ሲጀመር ከዘልማድ ሞፈር ጋር ተጣምሮ የአፈር ውሃ ዕቀባ እንዲያግዝ በመልካሳ ምርምር ማዕከል የግብርና ሜካናይዜሽን የምርምር ክፍል የተፈበረከውን ሞልድ ቦርድ የተባለ ማረሻ መጠቀም አንዱ አካሄድ ሲሆን በተመሳሳይም በዚሁ የምርምር ክፍል የተፈበረከውን እና የዝናብ ጠብታን በቦታው ላይ የማቆየት አቅም ያለውን የቦይ መከተሪያ መሣሪያ መጠቀምም ሌላኛው የሙከራው አካል ሆኖ ቀጥሎም ሁለቱን የእርጥበት ዕቀባ መሣሪየዎችን መልካሳ 1 ከተባለው የበቆሎ ዝርያ አና የዝርያውን የተለያዩ የተክሎች ብዛት በሄክታር አሰባጥሮ በመዝራት አስፈላጊውን መረጃ መሰብሰብ ተችሏል፡፡ ከዚህም በተጨማሪ የዝርያውን የውሃ ፍላጎት በተለያዩ የተክሎች ዕድገት ደረጃ እና ከ5-15 ሳ.ሜ የአፈር ጥልቀት የነበረውን የውሃ መረጃዎችም ለጥናት ውጤቱ ተገቢ ግብዓቶች ነበሩ፡፡ ጥናቱ እንደሚያስረዳው አጫጭር የደረቅ ሰሞኖች (ለምሳሌ የ5፣ የ7 እና የ10 ቀናት ርዝማኔዎች) በተከታታይ የመከሰት ዕድላቸው ረዘም ካሉ የደረቅ ሰሞኖች (የ15፣ የ20 እና ከዚያ በላይ) ጋር ሲነፃፀር ከፍተኛ ሲሆን ነገር ግን ሁለቱም የደረቅ ሰሞኖች (አጭርም ሆነ ረዥም) በክረምት ወቅት የመከሰት ዕድላቸው እየወረደ ይመጣል፡፡ የመከሰት ዕድላቸው ያነሰ ይሁን እንጂ ረዘም ያሉ የደረቅ ሰሞኖች በተለያዩ የተክሎች የዕድገት ደረጃዎች ከተከሰቱ ግን የሚያስከትሉት ጉዳት ከፍተኛ ይሆናል፡፡ የደረቅ ሰሞኖችን ስጋት በመቋቋም ምርታማነትን ማሳደግ ይቻላል ሲባልም የትኛው የደረቅ ሰሞን ርዝማኔ ምን ያህል ጉዳት ማስከተል እንደሚችል በጥናት ከተረጋገጠ በኋላ እጅግ አስጊ ለሆነው የደረቅ ሰሞን ተስማሚ እና ፍቱን የአያያዝ ዘዴ በምርምር በማፈላለግ ረገድ እንዲህ ዓይነት ጥናቶች ጠቀሜታቸው የጎላ ነው፡፡ የተክሎችን የውሃ ፍላጎት በተመለከተም መልካሳ 1 የተባለው ዝርያ በመልካሳ እና ተመሳሳይ የአየር ፀባይ ባላቸው አካባቢዎች በክረምት ውቅት (ከሰኔ እሰከ መስከረም) የሚመረት ከሆነ 315 ሚሜ ውሃ እንደሚያስፈልገው እና ይህም በተለያዩ የተክሎች የዕድገት ደረጃዎች ሲከፋፋል 39.1 ሚሜ በቡቃያ 85.7 ሚሜ በፈጣን የዕደገት ደረጃ 150.8 ሚሜ በአበባ ማውጫ እና 29.4 ሚሜ ደግሞ በፍሬ መሙያ ወቅት እና ከመጎምራቱ በፊት በሚኖሩት የዕድገት ወቅቶች እንደሚያስፈለግው መረዳት ተችሏል፡፡ ሞልድ ቦርድ የተባለው ማረሻን በመሬት ዝግጅት ወቅት በመጠቀም እና በ53,333 የተክሎች ብዛት ጋር ማቀናጀት ከፍተኛ ምርት (11849 ኪግ በሄክታር) አስገኝቷል፡፡ በሌላ በኩልም የቦይ መከተሪያ መሳሪያምን ከ53,333 የተክሎች ብዛት ጋር ማቀናጀት ተመሳሳይ ምርት ሊያሰገኝ ችሏል፡፡ አካባቢው የዝናብ እጥረት ያየለበት ከመሆኑ ጋር በተያያዘም 53,333 ተክሎችን በሄክታር መጠቀም የአካባቢው ዝናብ ማስተናገድ ከሚችለው ብዛት በላይ ነው ብሎ መውሰድ ቢቻልም ነገር ግን ከዚህ የተክሎች ብዛት የተገኘው ምርት ከፍተኛ ሊሆን የቻለበት ምክንያት ከነበረው የአፈር ውሃ ዕቀባ ተግባር ጋር በማያያዝ የተክሎች የውሃ ፍላጎት በተለያየ የዕድገት ደረጃ ላይ በመሟላቱ መሆኑን የጥናቱ ውጤት ያመለክታል፡፡ በዕድገት ደረጃ ሲታይም በሁለቱ የሙከራ ዓመታት በፍሬ መሙያ ወቅት የውሃ ፍላጎታቸው ሲሟላ በአበባ ማውጫ ወቅት ግን በ2000 ብቻ የውሃ ፍላጎታቸው ተሟልቶ እንደነበር እና በ2001 ደግሞ በፈጣን የዕድገት ደረጃ ውቅት ተሟልቶ ነበር፡፡ በሌላ በኩል ደግሞ 70 ከመቶ የሚሆነው የመልካሳ 1 የበቆሎ ዝርያ ምርት የተገለፀው በመዝሪያ ወቅት ከሞልድ ቦርድ ማረሻ እና ቦይ መከተሪያ መሳሪያ ጋር በተያያዘ አፈር ውስጥ በነበረው የርጥበት መጠን ነበር፡፡ ለምሳሌ የአፈር ርጥበት መጠን 119 ሚሜ በነበረበት ወቅት የተገኘው ምርት በሄክታር 1480 ኪግ ሲሆን የአፈር ርጥበት መጠኑ 136.5 ሚሜ በነበረበት ወቅት ግን 1845 ኪ.ግ ነበር፡፡ በአጠቃላይ ምንም እንኳን የጥናቱ ውጤት በርካታ ለምርምር የሚሆኑ ጥያቄዎችን ያስነሳ ቢሆንም ብዙ ክፍተቶች እንዳሉ መረዳት ይገባል፡፡ ዋናው ቁም ነገር የጥናት ውጤቱ የዝናብ ስርጭት መዘባትን ለምርት መቀነስ እንደ ዓይነተኛ ምክንያት ለሚያቀርቡት የህብረተሰብ ክፍሎች የአፈር ውሃ ዕቀባን ከተስማሚ ዝርያ እና ከተክሎች ብዛት ምጣኔ ጋር በማቀናጀት ቴክኖለጂዎችን በተለያዩ የምርምር ዘዴዎች በማፈላለግ በደረቅ ሰሞኖች ሳቢያ ሊደርስ የሚችለውን ጉዳት በመቀነስ የበቆሎን ምርት እና ምርታማነትን በዝናብ አጠር አካባቢዎች ማሳደግ ይቻላል የሚለውን ጭብጥ መያዝ ተገቢ ይሆናል፡፡ በተለይም በመካከለኛው ስምጥ ሸለቆ እና በተመሳሳይ ዝናብ አጠር አካባቢዎች የተሻሻሉ የበቆሎ ዝርያዎችን የሚያወጡ ተመራማሪዎችም ሆኑ አርሶ አደሮች እንደ የአካባቢው ተጨባጭ ሁኔታ የአፈር ውሃ ዕቀባን ከተገቢው ዝርያ እና ከተክሎች ብዛት ጋር አቀናጅቶ የማልማት አቅጣጫ ላይ አንዲያተኩሩ ይመከራል፡፡

Abstract

The existing evidences support that some eighty percent of the world's agricultural land is rainfed, contributing to the tune of sixty percent to food production worldwide. This empirical research was conducted on-station during June to September main growing season over two years (2000 and 2001) to substantiate that, managing dry spell risks through development of compatible technologies can improve rainfed maize productivity in the semi-arid zones of Ethiopia. Firstly, two soil water conserving tillage practices i.e a metal handled-Erf and Mofer attached MB plough and Tie Ridger (TR) both of which are simple tillage tools were used. Secondly, varying plant population level was linked to the in-season dry spell length for 5, 7, 10, 15, 20 and more, as well as to the crop water requirement and plot soil water content at land preparation stage. The result revealed that the shorter dry spells have higher probability of occurrence, compared to the longer dry spells in general. On the other hand, the probability of dry spells is higher during the early parts of the growing season, with a declining trend until the peak of the rainy season and slopping up towards the end of the rainy season. The result on water requirement information under Melkassa climate shows that a total of 315 mm of soil water is required for maize throughout June/July to September growing period. MB plowing realized significantly highest grain yield at 5% alpha level (1849 Kg.ha^{-1}) at the recommended plant population (53,333 plants ha^{-1}), whereas, TR resulting in nearly similar yield for the same population. Although the study area is known for water scarcity and hence lower plant population is preferred, it was possible to achieve high yield at this population level. This could be because, the crop water requirement was met at physiological maturity stage in both seasons and at flowering in one (2000) of the two seasons. The water requirement for vegetation was met in both seasons; however, it was followed by lower WRSI at least in one of the seasons, which could have caused a reduction in yield at this plant population level. Further, 70% of the variability in maize grain yield was explained by the root zone available soil water at planting. For instance, grain yield was 1480 kg ha^{-1} at 119 mm of available soil water at planting; while the same was 1845 kg ha^{-1} at 136.5 mm of soil water. Overall, the paper provided empirical evidence that management of dry spell risks is possible, but it demands for the innovative management practices that outsmart the business as usual (BAU) approach i.e. the miraculous drought tolerant or drought escape crop cultivar development strategy.

Key words: *Dry spell, Plant population, Risk, Soil water, Tillage, WRSI*

Introduction

The existing evidences lend a support that some eighty percent of the world's agricultural land is rainfed, contributing to the tune of sixty percent to food production worldwide (Cooper *et al*., 2009, Corbeels *et al*; 2014). Ethiopian agriculture has hitherto been evolving over years, but in the process, it has developed its own risk profile, much of which is climate related. Ever since, weather and climate have been sometimes very good servants, while turning ruthless masters, and exerting anger in extremes, the other times. The widespread drought and extended dry spells in the semi-arid regions are among the key climate variables that define the well known '*one ton farming system*' in Ethiopia (Girma et al; 2012, Girma et al; 2013). The other accompanying challenge is the mental model construct of the Ethiopian dry land farmers and crops researchers alike, who state that dry land farming system in Ethiopia, suffer not only from the deficit seasonal amount, but also from the uneven distribution of rainfall through a growing season, in which little can be helped.

On the same scale, the existing policy practice is much in support of the fact that Ethiopian agriculture has to be freed from its present virtually absolute dependence on rainfall and should transform radically into full fledge irrigated farming. This is impossible at least for two obvious reasons. Firstly, the relationship between seasonal rainfall availability and river or stream flow is very direct, with no rain implying no water for abstraction into the farmland. Secondly, the country has not built the institutional and technical capacity to operationalize irrigated farming to its full-scale. Rather, the country experiences plenty of annual rainfall (900 mm) and 400 to 600 mm during good rainy seasons, compared to those countries globally known for dryness; e.g Australia (420 mm) and Israel (250 mm) (Hayman, 2004). The paradox however is, Australia and Israel realize bumper harvests, despite such a meager annual rainfall, while Ethiopia produces in the order of one ton per hectare, even during good rainy seasons. This shows how some other unexplained factors must be accountable (and not only drought alone) for the lowest crop productivity in Ethiopia. Should the risks related to rainfall variability need to be disaggregated into its components, then, rainfall timing i.e onset and end dates, its frequency of occurrence, seasonal amount, duration, distribution and extended dry spells are the key to be considered in rainfed crop production across the semi-arid zones.

Globally, it's only few analyses that have been done on agricultural dry spells, their potential impact on crop growth, and their relative importance for risk management. Based on extensive research in East Africa, Stewart (1988) demonstrated that severe yield reductions due to dry spells occur ones or twice every five years, while, Sivakumar (1992) reported the frequency of consecutive dry spells lasting 10-15 days is highly probable, regardless of the early or late onset date of the rainy season, Barron (2004) and Baron *et al.* (2009) also studied the frequency of consecutive dry spells in semi-arid locations in Kenya and Tanzania and found a minimum probability range of 0.2 to 0.3 for a dry spell lasting more than 10 days at any time of the growing season and a probability of 0.7 for such a dry spell to occur during the sensitive flowering stage, which indicates the associated deficit to meet crop water requirements and therefore implying yield reduction.

This paper argues that there isn't clear signal that, rainfed farming would turn obsolete with the current state of the national capacity for irrigated farming, while the extended dry spell event particularly if occurs during the crop sensitive growth stages would continue to be as damaging as drought; thus requiring compatible management practices. In context, the technological achievements on record through the long established dry land farming research in Ethiopia is rather skewed towards the drought tolerant and escape variants; both of which are implemented during the earliest parts of the growing season and within a narrow planting windows, On the other hand, the research experience in developing improved management practices for the dry spell risks i.e days with no rain, which can be extended by about 2 to 4 weeks after the onset of the season is very weak. This area of research in the semi-arid regions has not yielded desirable impacts, and still lacking explicit policies and strategies to be implemented towards minimizing the dry spell related risks, and improving the rainfed farming systems. In effect, those improved crop cultivars already known for drought tolerance or escaping, fail to overcome the risks associated with the extended dry spells, thus resulting in substantial yield reduction or zero yield at times (Baron, 2004).

In context, smallholder farmers in the semi-arid Central Rift Valley (CRV) of Ethiopia, more often than not, take risk and opt to plant long cycle cereals (maize and sorghum at large) right up on the early start of the rainy season, despite success probabilities are poorly predictable. However, early start of the rainy season does not necessarily guarantee a successful harvest by itself, owing to the fact that the intervening in-season dry spells of varying length either during the early or later parts of the growing season can adversely impact on crop performance, particularly, if it takes place during any of the crop sensitive growth stages (Girma, 2005).

In managing agricultural dry spell risks under rainfed farming in semi-arid zones, there exist many avenues. In this study, two soil water conservation tillage practices i.e a metal handled-Erf and Mofer attached Mold Board (MB) Plow and Tie Ridger (TR) both of which are simple tillage tools developed by the Agricultural Mechanization Unit of EIAR were used. The MB Plow is advantageous because, it requires only sixty percent of the draft power and cutting deeper, relative to the traditional Maresha (AIRIC, 2000). The MB plough also reduces the surface area of the soil that is exposed and help minimize losses through evaporation and leaving dead furrow that can be laid along the contour to reduce runoff (AIRIC, 2000). Similarly, TR is a simple and effective practice for improving in-situ soil water availability in semiarid areas through reducing runoff or creating a series of miniature basins in the field (Reddy and Kidane; 1994). In comparison, the traditional Plow is the age old tool in use next to hoe culture and which is known in inverting and exposing the soil to erosion and runoff, particularly during the consecutive cross ploughing (Melese *et al*., 2007). Secondly, linking plant population density to the in-season dry spell risks related and crop water requirement information with the soil water content of the same growing period also helps dry land agronomists to establish the balance between plant available soil water in the crop root zone and number of plants per unit area, aiming at reducing the stiff competition for scarce water among standing plant population.

In this study, we argue that managing dry spell risks in the rainfed based semi-arid Central Rift Valley of Ethiopia is possible through understanding the characteristics of localized dry spells and integrating the same with drought tolerant/escape maize cultivars, and improved tillage practices to enable in-situ water harvesting and an adjusted plant population density.

Materials and Methods

Description of the study area

The experiment was conducted at Melkassa Agricultural Research Center (MARC) representing the semi- arid Central Rift Valley of Ethiopia (Fig 1). The average annual rainfall of the study area is 795 mm with high inter-annual variability in onset date, end date, amount, distribution and dry spells. The soil is characterized as sandy loam, which is medium in water holding capacity and therefore, plant available water (PAW) is also medium.

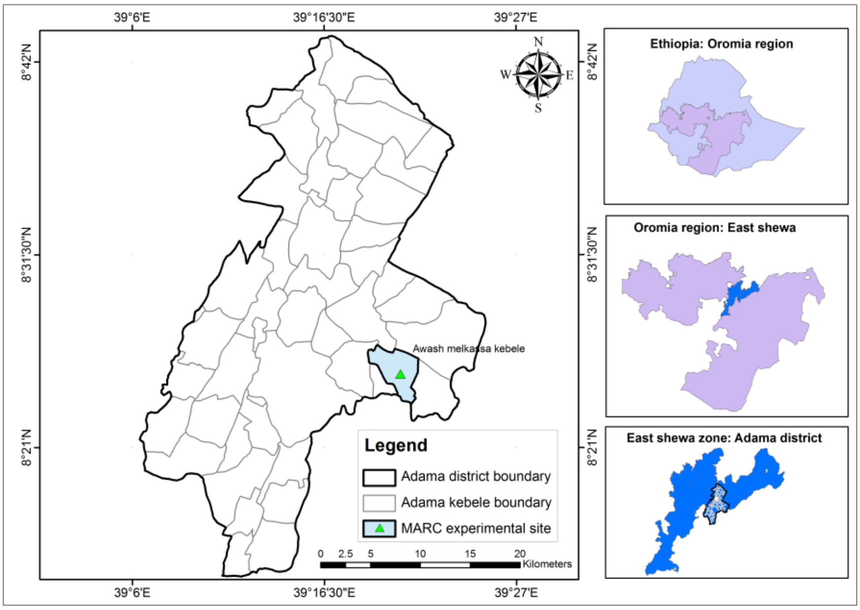


Figure 1. Location map of the study sites

Methodology

A maize cultivar, known as *Melkassa-1* that exhibits a 90 days growth cycle and characterized as drought escape variant was planted under three tillage practices and four planting densities in early June. The experiment was conducted during June to September rainy seasons in two consecutive years i.e. (2000 and 2001) that are assumed to represent fairly contrasting growing seasons in terms of soil water availability. The design of the experiment was a split plot in a randomized complete block with three replications in which tillage practice was assigned to the main plot; while planting density was assigned to the subplot.

The tillage treatments were: MB Plow, and Tied Ridger (TR). Planting densities were: 33,333 (P1), the 44,444 (P2), the recommended 53,333 (P3) and 66,666 (P4) plants ha^{-1}. Each plot had 10 rows of 10m length. The two outer rows from each side of a plot were used to reduce boarder effects. The next two innermost rows from each side were used to collect samples for measuring the intermediate/ phenological data; including biomass at different crop growth stages (initial, vegetative, flowering and physiological maturity). Finally, the central four rows were used for the measurement of the grain yield. The analyses of variance for maize yields were conducted using IRRISTAT software of the International Rice Research Institute (IRRISTAT, 2005). The probability of dry spells of a varying length in the study area was analyzed using 38 years (1977-2014) of MARC rainfall, using objective criteria for the start and end of the rainy season (Girma et al. 2013). The Markov coefficients that are correlated to the readily available point based (non-spatial) climate information and maize crop water requirements were also employed.

In the process of dry spell risk analyses, the identification of the outlier values specific for each time series was conducted in order to ensure data homogeneity (Gonzalez-Rouca et al. 2001; Göktürk et al., 2008). In many studies, days with rainfall less than 0.1 mm per day are considered to make up the meteorological dry spell analyses, but in this study, 1mm was used as a threshold for the consecutive dry spells analyses. These criteria help to set a particular focus on how best to manage own field or farm, in case the dry spell actualizes itself during maize critical growth stages.

Soil water content and crop water requirement satisfaction index

The soil water content at planting was determined from the top soil (5-15 cm) using a gravimetric method for each factor and treatment (Singh, 1997), while Crop Water Requirement (CWR) was computed using the Penman-Monteih method in REF-ET program (Allen et al. 1998). Eventually, the FAO Water Requirement Satisfaction Index (WRSI) was computed for the experimental years and for various maize growth stages using the following generic formula (FAO, 1996).

$$WRSI = \frac{ET_A}{CRW} * 100$$

Where, *ETa* is the amount of water actually extracted (mm) from a soil by crop plants during each growth stage. *CWR* is the maximum amount of water required by the crop (mm) –both cumulatively and by crop individual growth stage. Understanding WRSI in connection with the dry spells in rainfed maize cropping is the most important indicator of the magnitude of water deficit or excess, therefore; it is useful for crop performance monitoring in the field and employing appropriate management practices. WRSI of less than 50 percent indicates total crop failure (worst case); between 51 to 74 percent indicates moderately adequate soil water (middling case); and greater than 75-100 percent indicating sufficient soil water (best case). Conversely, WRSI is also assumed to decreases by 3 percent for every 100 mm of excess water above the CWR because of the associated water logging (FAO, 1996) and suffocation of crop roots.

Result and Discussion

Dry spell risk analyses

Figure 2 depicts the probability of dry spells of 5, 7, 10, 15 and 20 days or more. The shorter dry spell events have higher probability of occurrence, compared to the longer ones in general. The probability of dry spell is higher during the early parts of the growing season, which continues to decrease up to the peak of the rainy season and increases further towards the end of the season. The longer dry spells pose greater adverse impacts for crops whereas the intensity of the impact depending on the sensitivity of crop types and varieties to water deficit, at any of their critical growth stages', whereas, the shorter dry spells may not exert significant adverse impact for most. Such distribution of dry spells across days of a season help farmers and researchers to identify the most damaging dry spell length for its management interventions through integrative approach i.e information on CWR and WRSI. The same figure also depicts that the probability of all ranges of dry spells drops sharply towards the start of June through the August. Therefore, in situ water conservation at the start of the season for better crop establishment could help increase yield.

Depending on individual farmer's attitude towards risk, such information on the in-season dry spell characterization at localized scale conveys a differential message to different group of farmers' i.e risk averse, or risk taker (Anderson et.al., 1977; Hayman, 2004). Risk averse is one that avoids risks and who worries about the downside production risk i.e. interested in realizing minimum crop yield that ensures family food security and not committed to explore opportunities in achieving maximum yield even from a good rainy season. Accordingly, risk averse, or the' poor farmer has to wait until the soil water accumulates fully in June or July, in order to make a planting related decision. Risk taker on the other hand worries about the upside production risk, aiming at the maximum target yield that can be achieved under the prevailing climate and other locally available resources. A risk taker may dare planting long duration cereal crops cultivars in April or May, despite any higher likelihood of the extended dry spells during the early or later parts through the critical growth stages of maize. Such a risk taker would most likely be the one endowed with better resources, like on-farm pond that provides additional water for protective irrigation during the early or terminal dry spells periods.

Practically, risk taker and risk averse would not adopt improved technologies to equal extent Such a detail specification of information on dry spells is useful to cluster the broader farming communities according to their attitude towards risk management, so that independent adaptation responses could be searched for localized field testing and scaling up activities. Finally, it can be noted from Figure 2 that the rightmost flank of each dry spell curve consistently steeped up in September, signaling an end of the rainy season and therefore implying the decisions related to physiological maturity, harvesting, storage and marketing to be made.

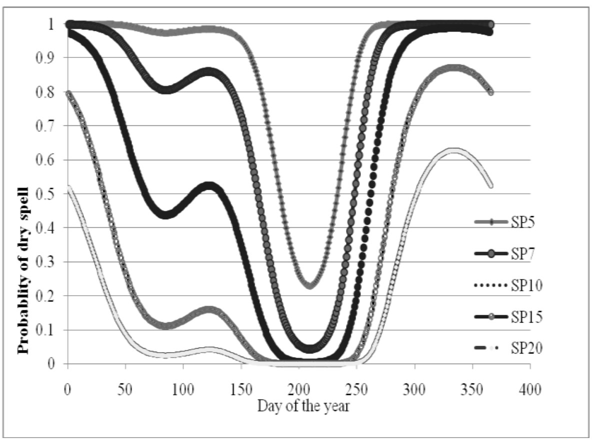
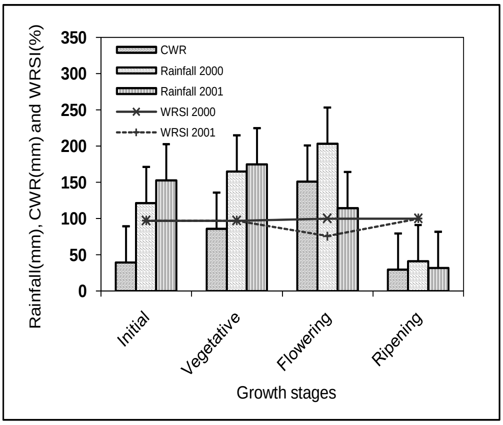


Figure: 2. Probability of dry spell events under MARC climate condition (dBase: 1977-2014).

Seasonal water requirement satisfaction (WRSI) for maize production

Figure 3 below defines that about 315 mm of soil water is required for maize throughout June-September growing period that can be partitioned into 39.1 mm at initial, 85.7 mm at vegetative, 150.8 mm during flowering and 29.4 mm during ripening stages. The water requirement satisfaction index (WRSI) information provides dual information viz., either deficiency or excess, during any growing season or growth stage. Water deficiency information points to the need for alternative dry spell risks management options; while water excess implies the need for safe disposal and harvesting of water to enable use of the excess water during risky moments.



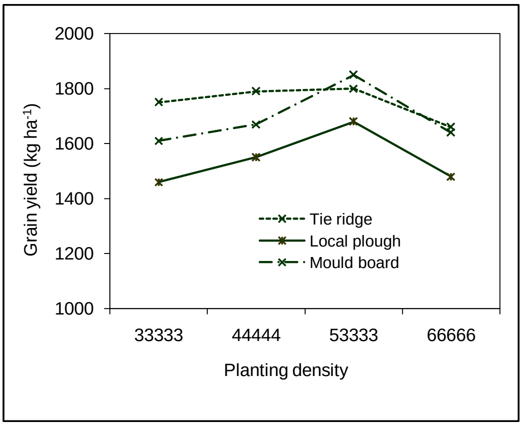


Figure 3. Rainfall, CWR and WRSI for Melkassa-1 maize cultivar grown during June-September at Melkassa,

Figure 4. Combined influence of tillage practices & planting density on grain yield of Melkassa-1 maize cultivar grown during June-September at

The interaction effect of tillage practices and plant population density

Figure 4 above illuminates that MB plowing realized significantly highest grain yield at 5% alpha level (1849 kg ha^{-1}) at the recommended plant population (53, 333 plants ha^{-1}), whereas, TR resulted in more or less the same, up to this plant population. Although the study area is known for water scarcity and hence lower plant population density is preferred for most, it was possible to succeed at this population level, which can be explained by the facts that the crop water requirement was met at ripening in both seasons and at flowering in one (2000) of the two seasons (Fig.3). Further increase in population could have a consequence in total water use because the high population means more vegetative growth per unit area. The water requirement for vegetative stage was met in both seasons; however, it was followed by lower WRSI at least in one of the seasons, which could have caused a reduction in yield at this plant population level.

The highest yield in MB ploughing can be explained by the fact that MB has the capacity to cut the soil deeper and obstruct capillary water rise and therefore, reducing evaporative losses, which is a key window for improving green water productivity. Van Averbeke and Marais (1992) reported that maize planted under improved soil water management at seven population densities ranging from 4000 to 111000 plants ha^{-1} showed a positive interaction. For instance, plant population for optimum yields was decreased from 60,000 plants ha^{-1} with 650 mm rain water supply down to 10,000 plants ha^{-1} for the 238 mm of rainwater. Stewart (1988) found over 10 seasons with annual rainfall of 540 mm on a deep soil that the optimum row width and plant population for maize were 1.83 m and 17000 plants ha^{-1}, respectively and that, long fallow increased the average yield from 1665 to 2250 kg ha^{-1} Hensley et. al. (2000) in South Africa used PUTU model to compare expected maize yields in a marginal ecotope under conventional (CON) and in-field water harvesting (IWH) practices, when full to empty root zones were planted to maize. From the experiment, the superiority of the IWHB over CON as well as the significance of the root zone water content at planting was clearly demonstrated.

Further, 70 percent of the variability in maize grain yield was explained by the root zone available soil water at planting (Figure 5). For instance, maize grain yield was 1480 kg ha^{-1} at 119 mm of available soil water at planting; while the same was 1845 kg ha^{-1} at 136.5 mm. This experimental result could be likened to the fallowing that helps to fill the soil profile with water at planting in crops management in the dry Liverpool of Australia. Similarly, Fawcett (1967) made detailed studies of the effect of row spacing and stored soil water on maize yields in North Western Australia, but did not at that stage comment on using the depth of interaction of wet soil as a measure of stored soil water for management decisions.

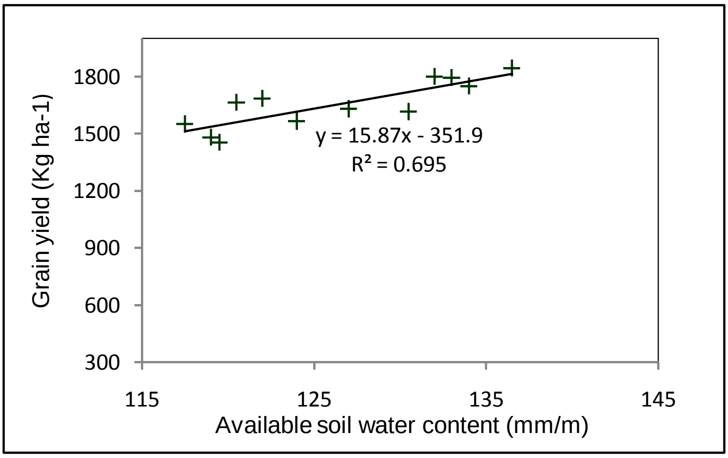


Figure 5. Relationship between available root zone soil water content at planting and grain yield of Melkassa-1 maize cultivar grown during June to September at Melkassa, CRV.

Overall, the paper presents an empirical evidences that the extended in-season dry spells (during both early or later parts of the growing season) in the semi-arid farming zones makes a critical challenge, compared to drought; thus opening a new era of opportunities for the development of smart practices either during the land preparation stage i.e early part of the growing season or later in the growing season.

We also emphasize the need for expanding such analyses to the other similar agroecologies through spatial mapping. This helps to detect areas with less likely dry spells on one hand, and those with highest probability of crop failure for differential dry spell risk management practices, based on locally available resources. This is possible by increasing the capacity of smallholder farmers and enabling them to use their agricultural land through enhanced access and use of improved material technologies (seeds, feeds and fertilizer), as well as, climate, extension services and market information.

Although, further investigation is required to address the likely uncertainties, the present study provided an empirical evidence that management of dry spell risks is possible and it can take the leverage, but it demands for innovative management practices that outsmart the business as usual (BAU) approach i.e 'the miraculous drought tolerant or drought escape crop cultivar development strategy' . Such an innovative dry spell risk management practices has to involve not only the engineering measures, but also a proper evaluation of the social factors surrounding a system and focus has to be set on the socio economic reality of the local farming communities in point. Equally, the way of thinking by professionals and policy-makers about agricultural water management should focus on improved water use efficiency and effective water use in rainfed cropping across semi-arid farming zones.

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