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The influence of rainfall and soil-type distribution on uptake of small grains in semi-arid regions of Zimbabwe: A case of Mberengwa and Zvishavane districts

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ABSTRACT

Climate change resulted in farmers shifting from drought intolerant to drought tolerant crops in dry regions of the world. The study assessed the influence of precipitation and soil-type distribution on uptake of small grains in Mberengwa and Zvishavane districts in Zimbabwe. A mixed methods research design was adopted in this study and both qualitative and quantitative research approaches were employed to probe data. Questionnaires, interviews, focus group discussions and observations were used to collect data in this study. Microsoft excel 2013 and Geographic Information System (GIS) were adopted for data analysis in this study. Findings showed that soil type and precipitation distribution have significant influence on uptake of small grains in Mberengwa and Zvishavane Districts. Research findings indicated that perceptions of farmers towards small grain production are determined by precipitation received in the area and the type of soil available. Areas with high precipitation and soils of higher water retention capacity had low uptake of small grains compared to areas with lower precipitation and soils of poor water retention capacity. The study concludes that declining precipitation in arid and semi-arid regions requires adoption of small grains which thrives under dry conditions despite some areas receiving enough precipitation for maize production. The study recommends that organizations or projects that wish to support small grain production in areas of heterogeneous soil type and precipitation distribution focus more on areas of little precipitation and soils of poor moisture retention capacity which do not support large grains to guard against compromising small grain uptake.

1. Introduction

Climate change is posing unfavourable consequences in the agricultural sector as frequency of seasonal and inter-seasonal droughts increased (Bang and Sitango, 2003). High temperatures that are being experienced in most parts of the globe will eventually reduce yields of desirable crops while encouraging weed and pest proliferation (Juana and Ignowski, 2012). The changes in precipitation patterns will significantly lead to crop failure and production decline (Juana and Ignowski, 2012). Despite scientific evidence proving that there will be an improvement in crop production in some regions of the globe where the climate has shifted towards favourable conditions, some regions are experiencing dry conditions. However, the general impacts of climate change on agriculture are anticipated to be negative, leading to food security challenges in the world (Mallet and Plessis, 2001).

In countries where agriculture is the chief source of livelihood, proffering solutions to climate change impacts on agricultural production should be of precedence (FAO, 2010). Myriads of solutions have been suggested by scientists and development experts but with insignificant success. Small grain production has been devised and encouraged in dry areas where maize production is being threatened by erratic precipitation (FAO, 2010). Sorghum and millet are believed to be the breakthrough to Africa in context of climate change. In area where soils are poor in nutrients and precipitation is below average, it seldom become a choice to grow small grains but rather a sole alternative for livelihood. Sorghum and millet have been noted by experts to be better performers in drought-prone areas and are considered to have better nutritional value than maize (Barret and Maxwell, 2005). This has led to their adoption as staple food grains in many semi-arid and tropic areas of the world, particularly in Sub-Saharan Africa because of their good capability to provide good yields under arid conditions (Wilhite, 2005; Maqbool et al., 2001; Sharma and Ortiz, 2000). Sorghum and millet production require little input during growth and with increasing world populations and decreasing water supplies, they became important crops for future human use (Muchuru and Nhamo, 2019; FAO and ICRISAT, 2008; Mallet and Plessis, 2001)

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However, uptake of small grains in semi-arid areas is still low as some areas are still receiving significant precipitation to support maize production. A study by Sharrat et al. (2003) on climatic impact on small grain production in the Subarctic region of the United States indicated that small grain production was bolstered in seasons with greater precipitation, more frequent precipitation, or lower evaporative demand. Their study also noted that, despite the cool growing seasons in interior Alaska, the primary climatic limitation to crop production was water stress, associated with low precipitation or high evaporative demand. According to Salomeyesudas and Satheesh (2009), in the Medak District of Andhra Pradesh in India, very low precipitation and poor soils forced farmers to adopt sorghum and millet due to their capacity to adapt to less moisture and poor nutrient soils especially poor soils of the Deccan Plateau.

Monyo et al. (2002) accentuated that in Tanzania, the adoption of small grains like millet and sorghum has been hampered by adequate precipitation to support maize production as the majority of smallholder farmers prefer maize due to myriads of reasons. In Kenya, only areas with inadequate precipitation like eastern Kenya have high uptake of small grains whereas those that are receiving enough precipitation to support maize have low uptake of small grains (Chambers and Conway, 1992). A study by Tirivangasi (2018) in Matabeleland North province revealed that very little rainfall in the Mangwe District (less than 500 mm per year) has forced most of small holder farmers to adopt drought tolerant small grains like millet and sorghum (Shumba, 2001; Gukurume, 2013). According to Dube et al. (2018) in their study on uptake of small grains in Gwanda and Tsolotsho in Zimbabwe, small holder farmers in these areas resist growing small grains despite their positive attributes within the context of climate change especially areas that are receiving better precipitation.

Arid and semi-arid Zvishavane and Mberengwa districts experience frequent severe agricultural and meteorological droughts which limit growing of large grains in the majority of areas within these districts. The Enhancing Community resilience and Inclusive Market systems (ECRIMS) project by CARE International and its supporting partners (ICRISAT, AGRITEX among others) initiated sensitization of small grain growing to farmers in Mberengwa and Zvishavane districts as an alternative to large grains which are gradually being phased out as a result of unconducive arid conditions. The goal of ECRIMS is to facilitate a transition from growing large grains like maize to adoption of small grains like sorghum, millet and rapoko which are drought tolerant. In 2017, ECRIMS started giving short season varieties (Okashana sorghum and finger millet) of small grains to farmers in 33 wards of Mberengwa and 17 wards in Zvishavane districts irrespective of variability in precipitation and soil type distribution among these wards. However, uptake of these small grains has potential of being affected by precipitation distribution since some wards might receive adequate precipitation to support maize which lead to resistance to adoption of small grains. This is likely to make some farmers deem it unnecessary to shift from maize crop to small grains. Variability in soil types from ward to ward has also potential of determining whether farmers find it necessary to adopt small grains over large grains as moisture retention capacity of soils can determine thriving of large grains which aggravates resistance to change from maize to small grains. This research will contribute information on spatial distribution of precipitation and soil type at ward level and how they shape uptake of small grains. This information is lacking in most studies yet it is important for making decisions related to climate change resilience building in rural communities. This will guide climate change resilience building stakeholders to strategically implement their climate change resilience initiatives in areas with heterogeneous precipitation and soil type. This will amplify the achievement of Sustainable Development Goals (SDGs) 1 and 2 of hunger and poverty eradication. This research therefore seeks to assess ward to ward soil type and precipitation distribution and how they affect uptake of small grains Zvishavane and Mberengwa districts.

2. Description of study area

The study was conducted in Zvishavane and Mberengwa districts which are adjacent to each other, located in Midlands province at 1,039 m above sea level. Zvishavane is located 97 kilometres west of Masvingo, on the main Bulawayo - Masvingo road (20° 20’S; 30° 02’E) and Mberengwa district is located at approximately 24 km south east of Zvishavane (20° 29′ 0" S, 29° 55′ 0" E).

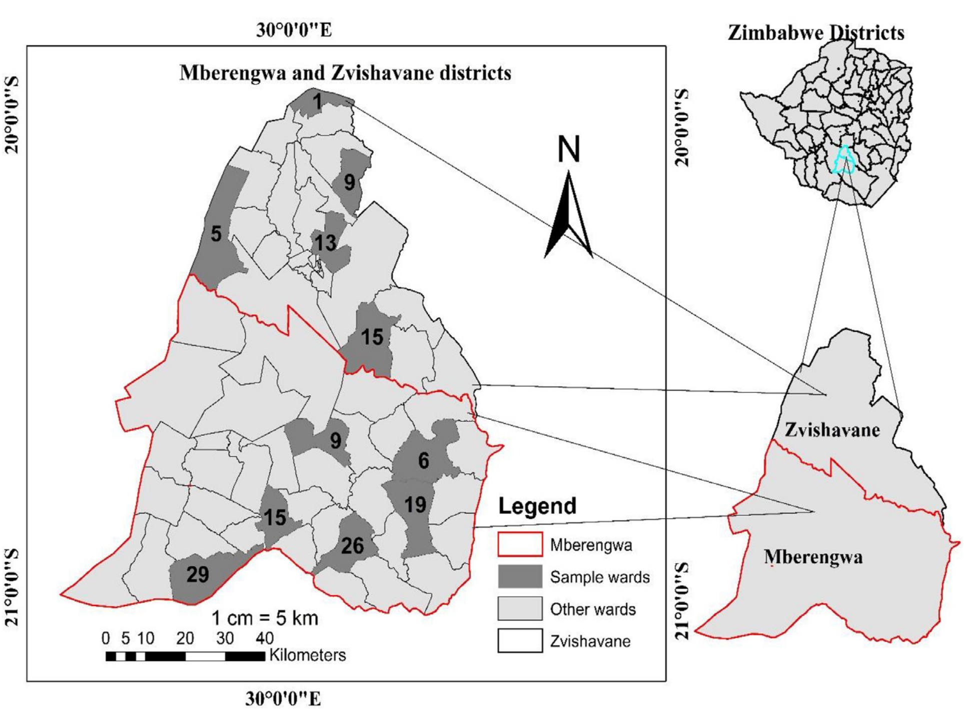

Fig. 1. Zvishavane and Mberengwa districts map.

Based on precipitation and temperature records since 1990s, both Zvishavane and Mberengwa districts receive an average annual rainfall of about 500 mm and experience average temperature of around 28 °C (Chigumbu, 2015).The geology is related to the Great Dyke which consist of layered mafic intrusions that are related to economically essential metals like platinum, chromium, nickel, vanadium, copper, titanium, iron, and tin (Badlock et al., 1991). Combretum and Acacia trees together with some Brachystegia species characterises the vegetation of the area (Burgess et al., 2004; Zimudzi et al., 2013). The total area of Mberengwa and Zvishavane is 5066 km^2 and 2476 m^2, respectively (Zimbabwe national population statistics, 2012). According to Moyo et al. (2012), Zvishavane has a population of 52 734 of which 27 815 are women and 24 919 are men whereas the population of Mberengwa is 185,757 with males constituting 86,764 of the population while females constitute 98,993. According to the Zimbabwe Poverty Assessment Study Survey Summary, 2003 report, mining and farming are the main sources of livelihoods in Zvishavane and Mberengwa. Minerals such as platinum, gold and asbestos are mined in Zvishavane whereas gold, tantalite and emeralds are mined in Mberengwa. However, small-scale farming of crops such as cotton, sunflowers, maize, sorghum and vegetables as well as livestock rearing for subsistence is practiced in rural communities of both districts despite challenges of changing climatological conditions.

3. Methodology

The research adopted a mixed methods research design to allow for data triangulation. Both quantitative and qualitative research methods were considered for data collection in this research. The qualitative approach employed questionnaires and interviews to collect data on whether farmers' uptake of small grains is being influenced by soil type and precipitation distribution and probing perspectives of AGRITEX, International Crop Research Institute for Southern African Tropics (ICRISAT) and other relevant stakeholders on the influence of soil type and precipitation distribution on uptake of small grains by farmers respectively. The quantitative approach used Geographic information system (GIS) based quantification of precipitation amount for wards in Mberengwa and Zvishavane districts. Closed ended questions were also used to quantify responses of selected respondents.

The research targeted 4537 households in Mberengwa and 2695 in Zvishavane. AGRITEX, ICRISAT and Ward representatives were considered in this research. AGRITEX was targeted to provide information on performance of small grains on different soils and in different wards and on the influence of precipitation distribution on uptake of small grains in different wards. ICRISAT was targeted as provider of precipitation distribution data as they collect ward to ward precipitation records from AGRITEX officers whom they have provided with rain gauges for this purpose. ICRISAT was also targeted to provide information on uptake of small grains in different wards under Zvishavane and Mberengwa districts because it is responsible for monitoring small grain production under the Enhancing Community Resilience and Inclusive Market Systems (ECRIMS) project in these areas. Creswell and Poth (2016) stipulated that 10–20% of the target population is a justifiable sample size to represent the target population with minimum error margin hence this research used 10% of Zvishavane and Mberengwa districts households who are under ECRIMS project and have been supplied with small grain seeds and received training on how to grow them. This translates to 454 households in Mberengwa and 270 in Zvishavane (Table 1). A total of 6 randomly selected wards in Mberengwa (6,9,15,19,26,29) (Table 1) formed the sampling frame from which these beneficiaries of the project (ECRIMS) were randomly selected. For Zvishavane district a total of 5 randomly selected wards (1,5,9,13,15) (Table 1) were selected for the purpose of sampling.

The research adopted an assessment questionnaire as the main tool for data collection in this study. The questionnaire comprised of both open-ended and closed-ended questions. Open-ended questions were employed to allow for free expression of perspectives of farmers on the influence of precipitation and soil distribution on their uptake of small grains and closed-ended questions were considered to ensure probing of relevant information instrumental in answering the objectives of the study. The questionnaire was administered randomly to 454 and 270 households in Mberengwa and Zvishavane districts respectively.

Table 1
Sample size determination criteria.

District	Ward	Total Beneficiaries	Sample Size (10%)
Mberengwa	6	793	79
Mberengwa	9	572	57
Mberengwa	15	804	80
Mberengwa	19	948	95
Mberengwa	26	1028	103
Mberengwa	29	392	39
Zvishavane	1	442	44
Zvishavane	5	521	52
Zvishavane	9	871	87
Zvishavane	13	383	38
Zvishavane	15	748	75
Total	11	7232	724

Interviews were conducted with purposively selected key informants from AGRITEX (extension officers), ICRISAT (manager) and Wards (councilors). These key informants provided key information on precipitation and soil distribution, performance of small grains and uptake rates of small grains in target wards. Interviews were conducted with AGRITEX extension officers to get data on precipitation amounts in their respective areas.

To complement data gathered through the household survey questionnaire, focus group discussions were conducted within study areas. Eight Focus group discussions (FGDs) were conducted in randomly selected wards in Mberengwa and Zvishavane districts, 4 in each district. This was meant to give maximum freedom of expression to each farmer in the group since different farmers have different perceptions on adoption of small grains and influence of precipitation and soil distribution on relevancy of adopting them.

Field observations were also done to confirm the existence of small grains in sample wards as well as comparing their performance on different soil types. During field observation, coordinates were collected to confirm data provided on the soil map. Photos were captured to provide evidence of small grain performance in sample wards.

GIS was adopted to map precipitation and soil type distribution in Mberengwa and Zvishavane districts. Soil type, ward boundary and district shapefiles were downloaded from Diva-GIS website and imported to ArcMap 10.5 for analysis and creation of a thematic map showing distribution of soil types in Mberengwa and Zvishavane districts. Each soil type was assigned a distinct colour to differentiate it from other soil types. Values of precipitation amount for each ward were imported to ArcMap 10.5 and each ward was assigned a colour representing precipitation amount category in which it belongs to produce a map showing precipitation distribution in both Mberengwa and Zvishavane wards. Precipitation amount for each ward was determined by averaging precipitation amount received in each ward in the past three years (2017, 2018 and 2019). These three wards were considered because they fall within the timeframe of ECRIMS project which has been supplying small grains to farmers in Zvishavane and Mberengwa districts.

Data collected using closed-ended questions of the questionnaire was checked for relevancy and cleaned. This data was coded and analysed using Microsoft excel package before being imported into ArcMap 10.5 software for presentation using maps. Qualitative data collected using interviews and open-ended questions of the questionnaire were sub-

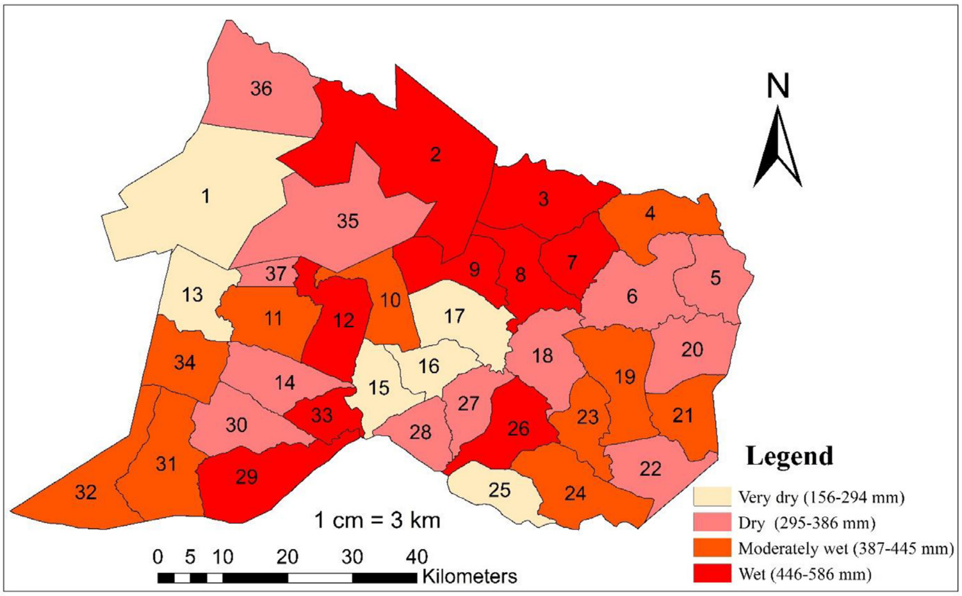

Fig. 2. Precipitation distribution in Mberengwa District.

jected to content analysis and was used to support data that was collected using closed-ended questions of the questionnaire and GIS data sets. Data on precipitation and soil distribution was presented in the form of maps generated using ArcMap 10.5.

4. Results

4.1. Precipitation distribution in Mberengwa District from 2016 to 2020

The findings from this research highlighted that average precipitation distribution in Mberengwa District is heterogeneous. Of the 36 wards in Mberengwa district, about six have experienced very dry conditions between 2017–2018 and 2019–2020 seasons, experiencing precipitation averaging 155–294 mm (Fig. 1). These wards include wards 1 and 13 to the west, wards 17 and 16 at the centre and wards 15 and 25 to the south of the district. Findings also indicated that about 12 wards in this district are better than the aforementioned wards but still under dry conditions and have experienced precipitation averaging 295–386 mm between 2017–2018 and 2019–2020 seasons. These wards include ward 36 to the northern part of the district, ward 37 to the west, ward 35 stretching from the west towards the centre of the district, wards 14 and 30 to the south-western part of the district, wards 28 and 27 located to the southern part of the district, ward 18 at the centre, ward 22 to the south-east and wards 6, 20 and 5 to the far east of the district. Precipitation records from AGRITEX extension officers confirmed that other 10 wards of Mberengwa district have received moderate precipitation averaging 387–445 mm between 2017–2018 and 2019–2020 seasons. These encompassed wards 11 and 34 to the west, wards 31 and 32 to the south-western part of the district, ward 10 at the centre, ward 4 to the north west and wards 19, 21, 23 and 24 to the south eastern part of the district. Despite Mberengwa District being semi-arid, 9 of its wards experienced relatively wet conditions (446–586 mm) between 2017–2018 and 2019–2020 seasons (Fig. 1). Among these wards are wards 29 and 33 to the south-western part of the district, ward 12 to the west but close to the center of the district, ward 8 and 9 close to the centre of the district but to the northern side from the centre, wards 2, 3, and 7 to the north and 26 to the south eastern part of the district. These results shows that, despite Mberengwa District being semi-arid, some wards are exyremely dry whilst others are extremely wet and some are experiencing moderately dry conditions yet others experiencing moderately wet conditions.

4.2. Precipitation distribution in Zvishavane between 2016 and 2020

The research showed that precipitation in Zvishavane is also heterogeneously distributed with some wards being very dry over the past three seasons yet some have experienced moderately wet and wet conditions over the same period. Ward 16 which is located to the South eastern part of the district experienced very dry conditions with precipitation averaging 278 mm from 2016/2017 season to 2019/2020 season. Five wards of Zvishavane District encompassing wards 2 and 9 to the North, ward 10 at the center, ward 11 to the west and ward 15 to the south eastern part of the district experienced dry conditions (279–372 mm) over the same period though comparatively wetter than driest ward 16. The majority (10 wards) of Zvishavane wards experienced moderately high precipitation (373–500 mm) on average from 2017/2018 to 2019/2020 season (Fig. 1). These include wards 1, 3, 6, 4, and 8 to the North of the district, ward 13 at the center of the district, ward 14 which stretches from the east to the southern part of the district, wards 19 and 12 to the south and ward 17 to the south eastern part of the district. Despite Zvishavane being semi-arid district, wards 5, 18 and 7 of Zvishavane experienced very wet conditions with average precipitation exceeding 600 mm from season 2017/2018 to season 2019/2020.

4.3. Influence of precipitation distribution on uptake of small grains in Mberengwa District

Based on the findings of this research, precipitation distribution proved to be significantly influential on the rate of uptake of small grain production in Mberengwa District. The questionnaire survey indicated that farmers' perceptions towards adoption of small grains is determined by precipitation amount in different wards of Mberengwa. The heterogeneity of precipitation distribution in the district as in the district led to differences in rates of small grain uptake in the district. Ward 15 which experienced driest conditions over the last three rain seasons (222 mm of rainfall) compared to other sampled wards had the highest uptake rate of small grains (81%). In contrast, ward 29 and ward 9 which have experienced wettest conditions (586 mm and 548 mm of rainfall respectively) in Mberengwa over the last three rain seasons had the lowest uptake rate of small grains (29 and 18% uptake rate) compared to other sampled wards. This clearly shows that the amount of precipitation received in each ward determines whether farmers opt for maize or small grains. High precipitation supports

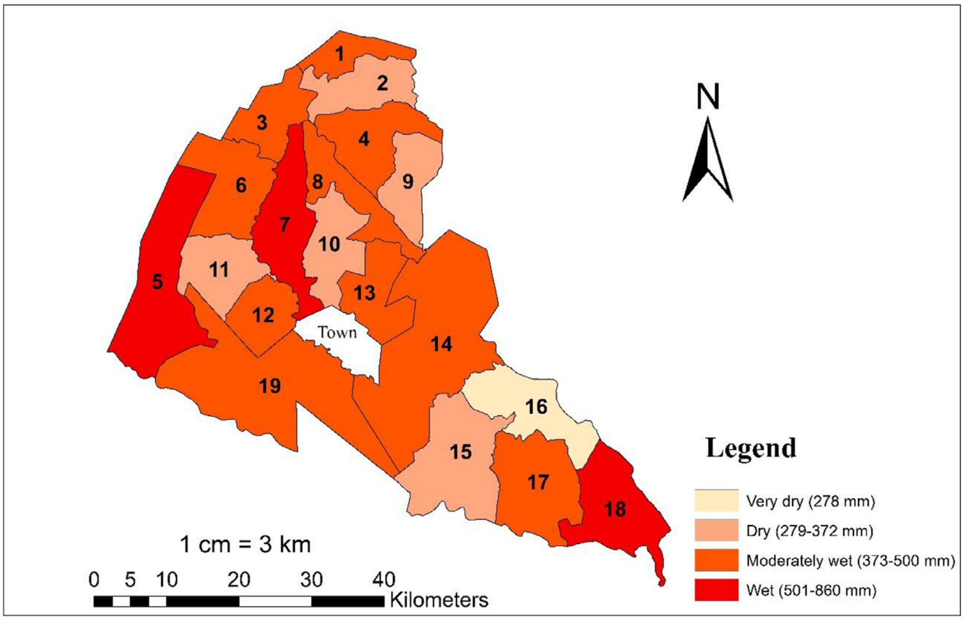

Fig. 3. Precipitation distribution in Zvishavane district.

growth of maize whilst low precipitation does not, hence most farmers in dry wards grow drought tolerant small grains. However, ward 26 which was among the wettest areas (511 mm) of Mberengwa over the study period, had moderate uptake of small grains (62% uptake rate) most probably due to generally positive attitudes people in this ward have towards growing small grains as revealed during the focus group discussion.

The research confirmed that Ward 6 which experienced relatively dry conditions (363 mm) during the study period had moderate (53%) uptake of small grains. During field observations the researchers observed that this area is not dry to an extent of failing to support growth of early maturity varieties of maize, hence some farmers are still growing maize thus moderating the rate of small grain uptake in this ward. Ward 19 of Mberengwa district has been moderately wet (429 mm) from 2016–2017 season to 2019–2020 season which led to most farmers finding it appropriate to grow maize than growing small grains. As a result, the uptake rate in this ward was moderate (54%) and lower than that of ward 15 (81%) which was very dry and ward 6 which was relatively dry. Focus group discussion at Rengwe in ward 9, revealed that adequate precipitation to support maize production is received hence households tend to grow small grains at a small scale to feed their Boschveld chicken. An observation in Gaha area in ward 29 of Mberengwa district also confirmed that the area has a micro-climate as it receives more precipitation compared to other wards and people are growing and harvesting tons of maize and very few have grown sorghum and millet.

4.4. Influence of precipitation distribution on uptake of small grains in Zvishavane District

Precipitation distribution proved to be influential on small grain uptake as indicated by statistics from sample wards. Ward 5 which experienced wet conditions (641 mm) between 2017/2018 and 2019/2020 season had the lowest uptake of small grains (11%) (Fig. 4). In this ward the majority of farmers grow maize since the amount of precipitation support growth of large grains thus ignoring small grains. In contrast, ward 15 which experienced dry (356 mm of rainfall) conditions over the

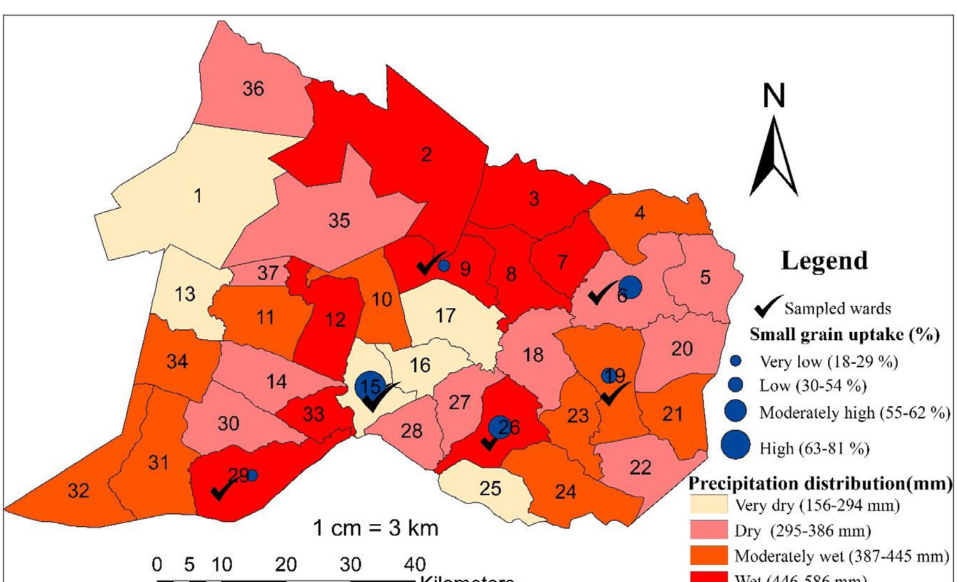

Fig. 4. Precipitation distribution and Small grain uptake rate in Mberengwa District.

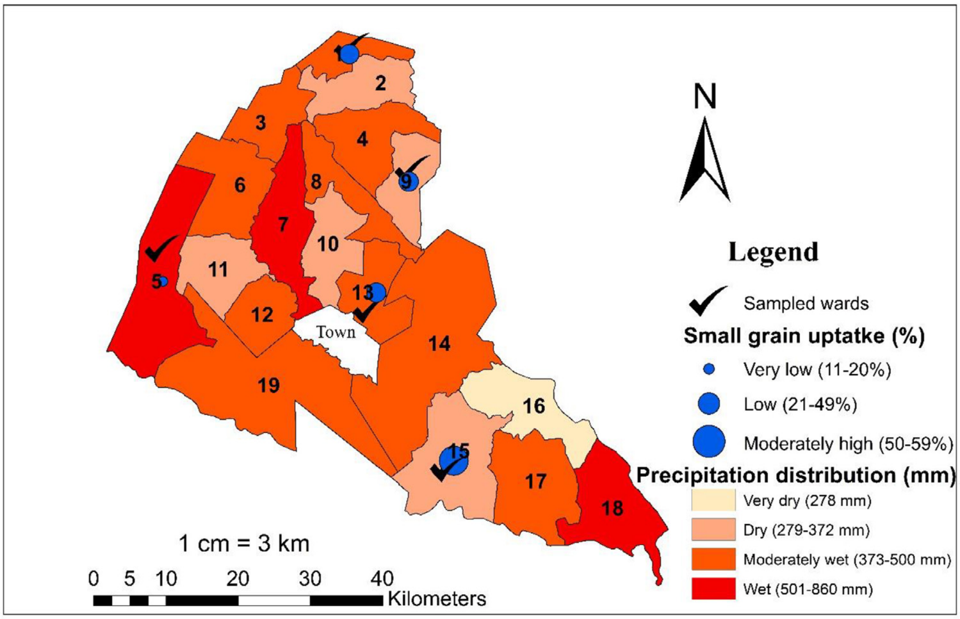

Fig. 5. Precipitation distribution and small grain uptake in Zvishavane District.

same time period had the highest uptake of small grains(59%) among all sampled wards though moderately high. In an interview, ward 15 AGRITEX extension officer highlighted that dry conditions in this area do not support large grains like maize hence most of the farmers are forced to opt for small grains like sorghum and millet and they are doing well in this ward. Wards 1, 13, and 9 which have experienced moderately wet (373–500 mm) conditions from 2017/2018 to 2019/2020 season had low uptake of small grains (11–20%) though relatively higher than ward 5 (11%). This indicated that moderately wet conditions in these wards are supportive of large grains hence most farmers are opting for maize over small grains. In ward 5 village 2a under Mhondongori area, an observation confirmed thriving of some maize varieties in most fields and very few have grown small grains. Most of farmers who had grown small grains in this area were *model farmers* and those *follow on farmers* who had only small portions of sorghum compared to maize. However, those farmers who have adopted small grains in other wards like ward 9, and 15 are having good harvests with some harvesting tons of sorghum in these areas.

4.5. Soil type distribution in Mberengwa District

When classifying Zimbabwe soils according to orders (Nyamapfene, 1985; Balasubramanian, 2017), Mberengwa District is dominated by Ustalf soils, a suborder of Ulfisol soil type (Balasubramanian, 2017). These soils are usually dominant in arid and semi-arid areas. These are light colored sandy soils with low water retention capacity hence are characterized by moisture deficit (have lower clay content) (Asumadu and Weil, 1988). The greater portion of Mberengwa is dominated by this type of soil. Only parts of wards 36, 1, 13, 34 and 11 to the east of the district have Tropepts type of soil which are usually found in tropical regions (Fig. 6). Tropepts are a suborder of Inceptisols (Nyamapfene1985;

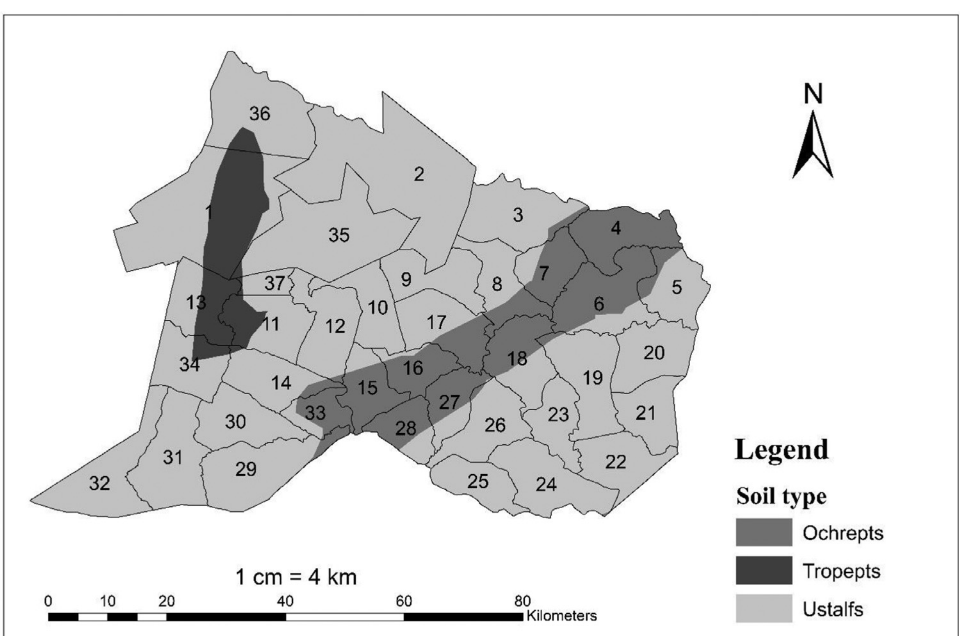

Fig. 6. Soil type distribution in Mberengwa District.

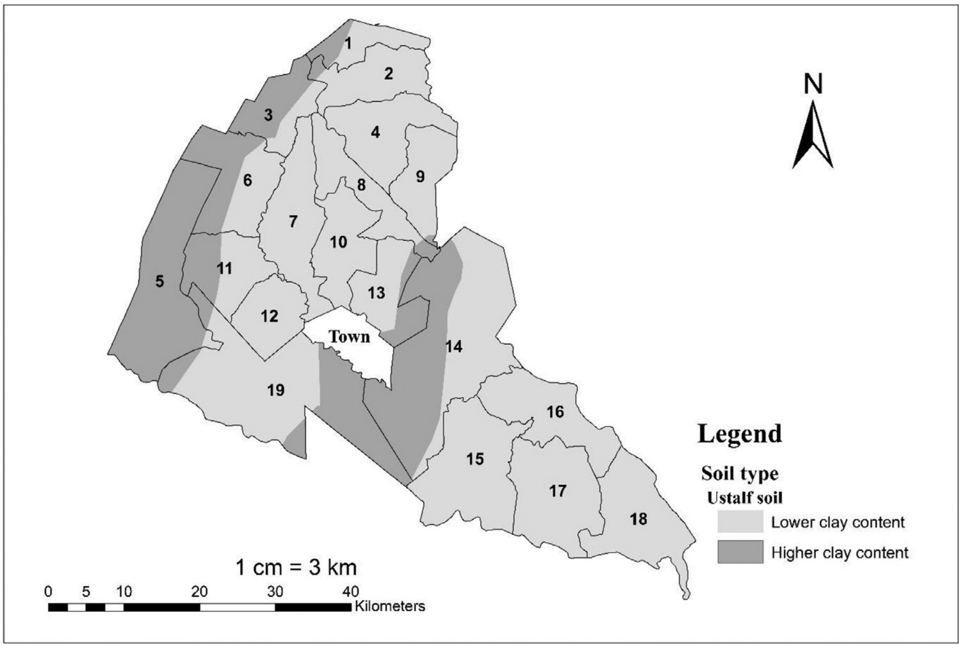

Fig. 7. Soil type distribution in Zvishavane district.

Balasubramanian, 2017), which are sands rich in organic matter, thick and brownish colored (Balasubramanian, 2017). A belt of another sub-order of Inceptisols called Ochrepts (Balasubramanian, 2017) stretches from south through the centre of the district to the North eastern part of the district. This belt is characterized by dark brownish-colored sand soils with high clay and organic matter organic matter. These soils have a better water retention capacity compared to light greyish-coloured Ustalfs (Balasubramanian, 2017).This belt covers wards 33, 15, 28, 27, a section of ward 8 and 18, greater part of wards 6 and 7 and the whole of ward 4.

4.6. Soil type distribution in Zvishavane District

The whole of Zvishavane district is covered by Ustalf soil type. The only variability is that ward 5, small section of ward 11, half of ward 6, grater part of ward 3 and a small portion of ward 1 to the west of the district and larger part of ward 14 stretching from the south through the center of the ward to the north east, small section of ward 19 to the south and the eastern side of ward 13 have sandy Ustalfs with relatively higher clay content compared to the rest of the district with comparatively lower clay content (Fig. 7).

4.7. Influence of soil type distribution on small grain uptake in Mberengwa District

As indicated on Fig. 6, wards 9, 19 and ward 29 which are characterized by sandy Ustalfs had the lowest uptake of small grains. Ward 9 and ward 29 have 18% and 19% uptake rate of small grain hence they were classified in the very low uptake rate class in this research. Ward 19 had an uptake rate of 54% and was classified in the low uptake rate class. However, ward 26 which also is characterized by Ustalf soils had moderately high uptake of small grains. Ward 6 and ward 15 which fall within Ochrepts soils, had moderately high (58%) and highest (81%) uptake rates of small grains. Generally, areas with lighter sandy Ustalfs proved to have low to moderately high uptake rates of small grains yet areas with darker loamy sand Ochrepts have moderately high to high uptake of small grains. This indicates that lighter sandy soils might be poor in supporting small grain growth compared to dark loamy soils which registered higher uptake of small grains. During focus group discussions, farmers in Fana village in ward 15 of Mberengwa reported that soils in their area despite receiving less precipitation, they support Millet and sorghum growth than other surrounding villages which motivates them to grow small grains. However observation confirmed that soils in this ward have higher clay content compared to neighbouring wards which shows that perceptions of farmers towards uptake of small grains are influenced by whether the type of soil is supportive to growth of small grains. Ustalfs have less moisture retention capacity compared to Ochrepts (García-Gaines and Frankenstein, 2015) hence considering poor precipitation in these areas, Ochrepts are likely to give maximum support to growth of small grains due to their better moisture retention capacity. Field observation confirmed failure of sorghum and millet crops at Matedzi area in ward 19 where the soils are sandy and could not sustain these small grains after a long period of no precipitation. Despite receiving the same amount of precipitation, ward 6 which borders with this ward (ward 19) registered moderately high uptake of small grains due to the fact that it has darker soils which are loamy and can retain moisture better. Field observation confirmed that small grains like sorghum were doing well in ward 6 during the same time.

4.8. Influence of soil type distribution on small grain uptake in Zvishavane District

As shown on Fig. 8 above, ward 5 which has Ustalfs of higher clay content had the lowest uptake of small grains (11%). In contrast, ward 15 with Ustalfs of lower clay content has the highest uptake of small grains (59%) though the rate was moderate. Ward 13 and ward 1 are dominated by Ustalfs of lower clay content and have small portions with ustalfs of higher clay content. The uptake rate of small grains in these two wards was low (21–49%) though comparatively higher than that of ward 5 (11%). However, ward 9 with Ustalfs of lower clay content had also low uptake of small grains. These findings indicate that soil type can determine the uptake rate of small grains. Clay content determines the water retention capacity of soil. Soils with larger clay ratio holds water for longer periods compared to those of lower clay ratio (Oosterveld and Chang, 1980; Adamun and Aliyu, 2012). Therefore, the fact that higher clay content of soils in ward 5 are capable of sustaining crops for longer growing periods, most farmers are growing maize because it can be sustained under intra-seasonal drought conditions. However, ward 15 with lower clay content soil that cannot hold moisture for longer periods, maize production might be difficult under intra-seasonal

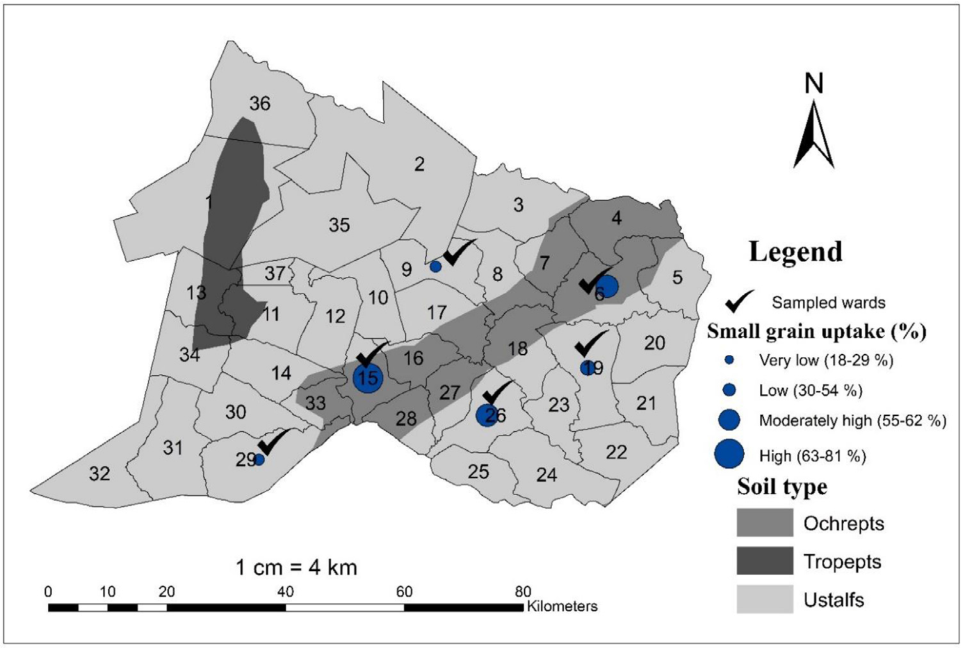

Fig. 8. Soil type and small grain uptake in Mberengwa District.

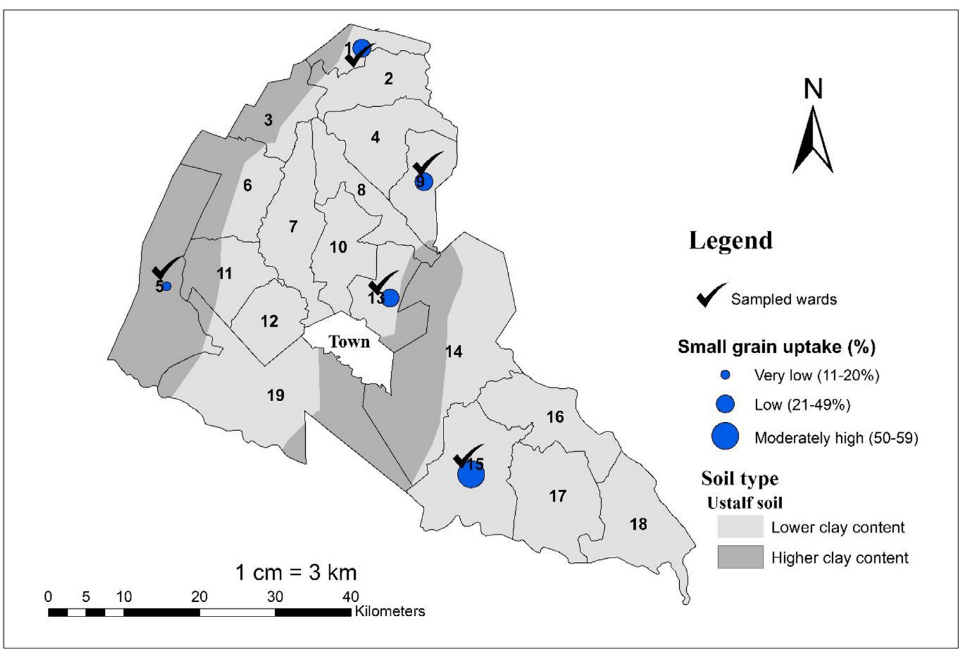

Fig. 9. Soil type distribution and uptake rate of small grains in Zvishavane.

drought conditions which might be the reason why uptake of drought tolerant small grains is high. Observations confirmed more maize fields in ward 5 where sandy Ustalfs with higher clay content are dominant compared to lower clay content Usatalfs of ward 15 where the majority of farmers had grown sorghum and millet (Fig. 9).

5. Discussion

The findings of this research indicated that precipitation distribution affect uptake of small grains in arid and semi-arid regions. Semi-arid regions experience micro-climates with some receiving high rainfall despite the aridity index. However other areas within semi-arid areas receive very little rainfall. This influences farmers' decisions on what types of crops to grow based on the amount of precipitation received. High precipitation in some wards of semi- arid and arid districts (Zvishavane and Mberengwa) supports growth of some early maturity varieties of maize which do not thrive under drier conditions of other wards. On the other hand, very low precipitation in some arid/ semi-arid areas leave farmers with no option except to grow drought tolerant crop varieties such as sorghum and millet to boost their livelihood options.

5.1. The inverse relationship between precipitation amount and small grain uptake in Mberengwa and Zvishavane districts

The adoption of small grains by farmers in arid/semi-arid areas like Mberengwa and Zvishavane is shaped by their perceptions which are also influenced by the extent of aridity in various wards of these districts. Those in wards that receive high precipitation like ward 9 of Mberengwa and ward 5 of Zvishavane consider small grains less yielding and labour intensive only because they have options to grow maize which thrive under wet conditions that are experienced in these wards. However, those who are under critical arid conditions have no choice but to grow what thrives under prevailing climatic conditions. This explains why ward 15 of Mberengwa District and ward 15 of Zvishavane District which receives little precipitation (average annual)have high

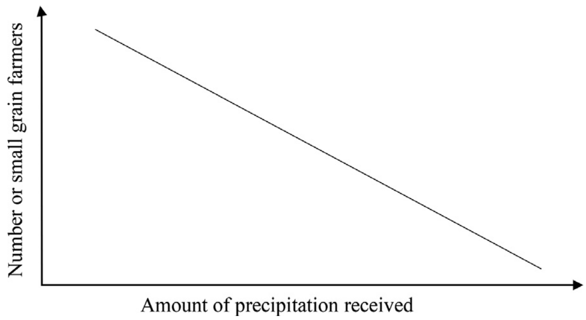

Fig. 10. The relationship between precipitation and small grain uptake in Mberengwa District.

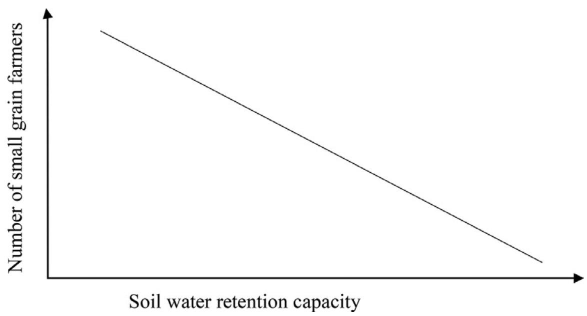

Fig. 11. The relationship between water retention capacity of soil and small grain uptake in Mberengwa and Zvishavane districts.

uptake of small grains yet ward 9 of Mberengwa and ward 5 of Zvishavane which receive high precipitation have very low uptake of small grains (Fig. 10).

5.2. The inverse relationship between water retention capacity of soils and small grain uptake in Mberengwa and Zvishavane districts

Besides precipitation amount, soil capacity to retain moisture also determine what types of crops thrives in a specific area (Mugabe, 1998). Soils with higher clay content can retain moisture for longer periods than sandy soils with less clay content (Oosterveld and Chang, 1980; Adamu and Aliyu, 2012). Therefore, the higher the precipitation the lower the small grain uptake rate as indicated on Fig. 11. Considering intra-seasonal drought conditions that are frequently experienced in Mberengwa and Zvishavane districts, moisture retention capacity of soil is a critical factor. This might be the reason why ward 15 of Zvishavane with sandy soils of less clay content has high uptake of small grains than ward 5 with sands of higher clay content.

5.3. The influential combination of precipitation amount and soil water retention capacity on uptake rate of small grains in Mberengwa and Zvishavane Districts

However, a combination of soil type and precipitation amount may influence small gain uptake differently than what each of these factors do independently. Some areas can have sandy soils of less clay content but when precipitation is sufficient to support large grains, uptake of small grains can be low (Fig. 12). This might be the case with ward 9 of Mberengwa district with light sandy Ustalfs which have less clay content but precipitation is high. This ward has the lowest uptake of small grains because precipitation is adequate for maize production though the water retention capacity of soil is poor. More so, wards with high precipitation and sands with high clay content have lowest uptake of small grains (Fig. 12) due to adequacy of precipitation to support large grains and high-water retention capacity of the soil to sustain maize over longer growing period. This is the case with ward 5 of Zvishavane District which has very low uptake of small grains because of high precipitation and sands of higher clay content (higher water retention capacity). Furthermore, a combination of low precipitation and sands of less clay content (low moisture retention capacity) lead to high uptake of small grains (Fig. 12) because they thrive better under such conditions than larger grains like maize. This can be exemplified by ward 15 of Zvishavane District which has low precipitation and lighter sands with less clay content (with less water retention capacity) but have highest uptake of small grains.

Areas with low precipitation and sandy soils with higher clay content contributes to moderately high uptake of small grains (Fig. 12). In such areas, moisture retention capacity of soil ceases to be a significant factor to growth of large grains like maize because of limited moisture recharge that does not last longer despite the soil's capacity to retain moisture. Therefore, people in these areas tend to maximise using that limited moisture to grow small grains which can thrive under such conditions. Ward 6 of Mberengwa District is a good example of this scenario whereby soils with higher clay content doesn't support maize growth without adequate precipitation thus leading to moderately high uptake of small grains.

Moreover, areas with soils of higher clay content and moderate precipitation can have low uptake of small grains (Fig. 12) because that moderate precipitation received in such wards can be retained for considerably longer time periods leading to maturing of early maturity va-

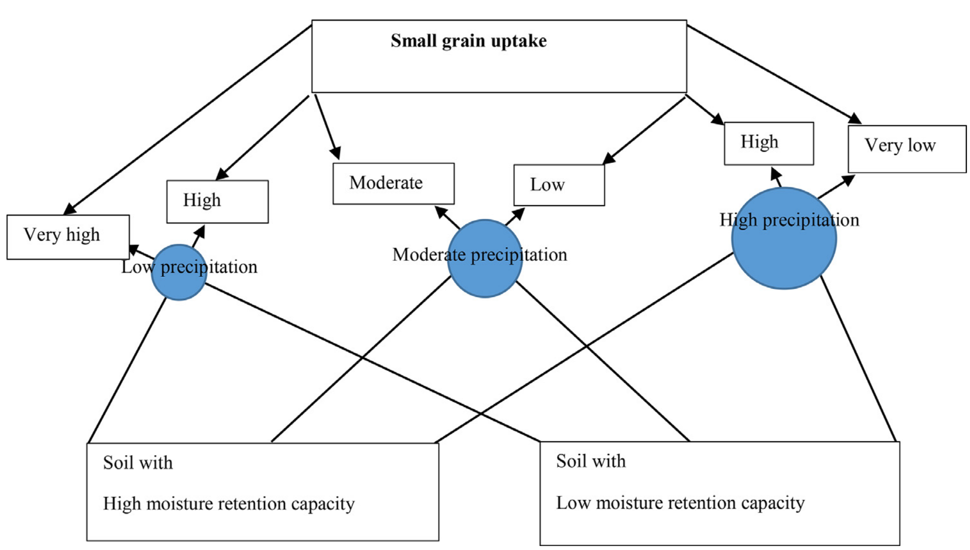

Fig. 12. The influence of precipitation amount and soil water retention capacity combination on uptake rate of small grains.

rieties of maize. However, areas with soils of less clay content and moderate precipitation can have moderate uptake of small grains mainly because options may be there to grow short season and less water demanding large grain varieties leading to some choosing not to grow small grains. Therefore a combination of both precipitation and soil type distribution influence uptake of small grains more than what each of these two factors do alone.

Generally, small grain uptake seems to be affected more by precipitation distribution compared to soil type. Zvishavane District receives more average annual precipitation than Mberengwa as confirmed by maximum precipitation received in wards of Zvishavane District (863mm) (Fig. 3) being more than maximum precipitation received in Mberengwa District (586mm) (Fig. 2). More so the lowest average anual precipitation received per ward in Zvishavane is 278 mm yet for Mberengwa it is 156 mm. This might be the reason behind overall small grain uptake in Zvishavane District being lower than small grain uptake in Mberengwa District. To support this, highest small grain uptake per ward in Zvishavane District (59% in ward 15) (Fig. 5) is lower than highest small grain uptake per ward in Mberengwa District (81% in ward 15) (Fig. 5).

6. Conclusion

The study assessed the influence of precipitation and soil-type distribution on uptake of small grains in Zvishavane and Mberengwa districts. Findings showed that precipitation amount and soil type vary across wards in Zvishavane and Mberengwa districts. It was confirmed that some wards in both districts experience very dry conditions whereas others experience wet and moderately wet conditions. Soil type and precipitation distribution indicated to have significant influence on uptake of small grains in both Mberengwa and Zvishavane districts. The study confirmed that wards which receive little precipitation have higher uptake of small grains than wards which receive high precipitation whereas wards with soils of better water retention capacity (higher clay content) have lower uptake of small grains compared to wards with soils of less moisture retention capacity (lower clay content). Results highlighted that precipitation amount and soil type influence attitudes and perceptions of farmers towards adoption of small grains. A close analysis of the influence of both soil type and precipitation amount on small grain uptake showed that combination of precipitation amount and soil type influence uptake of small grain significantly. The study showed that farmers opt to grow small grains when precipitation is very low and the soil water retention capacity is low. This was mainly because these conditions are not conducive for maize production which makes small grain production the only alternative under dry conditions.

Recommendations

In light of the findings of this study, it is recommended that:

- ➢ Organizations or projects which wish to support small grain production in areas of heterogeneous soil type and precipitation distribution focus more on areas of little precipitation and soils of poor moisture retention capacity which do not support large grains to guard against compromising small grain uptake.
- ➢ Instead of providing small grains to all farmers including those in wet areas, climate change resilience projects should provide early maturity varieties of maize in areas that support maize production because one size fits all criteria will not yield results in these areas.
- ➢ Drought resilience projects in semi-arid areas should consider a dilemma of crop choices that exists in wards that receive moderate precipitation. Perceptions of farmers in such wards towards small grain production significantly determine uptake of these grains hence awareness campaigns and education should be done to motivate these people to adopt small grains.
- ➢ Organizations that provide small grain seeds to farmers in arid and semi-arid areas (for example ICRISAT)should research more on resilient small grain varieties to ensure acquisition of improved varieties that thrive under areas of extreme precipitation shortage to reduce failure of small grains in some wards yet they are considered an alternative livelihood source in such conditions.
- ➢ The government of Zimbabwe should provide financial support to AGRITEX and the Meteorological Service Department to study ward level precipitation distribution to ensure availability of local precipitation records for informed implementation of climate change resilience projects.
- ➢ The government of Zimbabwe should also support enhanced soil studies in all areas of Zimbabwe to ensure ward-specific spatial knowledge of the conduciveness of soil types for specific agricultural activities.

Declaration of Competing Interest and Authorship Conformation Form

- ○ All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.
- ○ This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.
- ○ The authors have no affiliation with any organization with a direct.

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Appendix A

Table A2.

Table A2
Zvishavane wards.

Ward number	Ward name
1	Shavahuru
2	Guruguru
3	Runde
4	Chiwonekano
5	Chenhunguru
6	Shauke
7	Mapirimira
8	Ngomayebani
9	Vhukuso
10	Dayadaya
11	Ture
12	Hombe
13	Msipani
14	Murowa
15	Mototi
16	Indava
17	Mutambe
18	Small scale Commercial farming area
19	Large scale commercial farming area

Appendix B

Table A3.

Table A3
Mberengwa wards.

Ward number	Ward name
1	Chizungu
2	Cheshanga
3	Ruremekedzo
4	Baradzamwa
5	Magamba
6	Mataruse Bl
7	Muchembere
8	Mataruse B ll
9	Zvomukonde
10	Masvingo
11	Murerezi
12	Ngungumbane
13	Bhinya road
14	Mataga
15	Maziofa
16	Danga
17	Chegato
18	Chingechuru
19	Chebvute
20	Vukomba

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