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Research Evidence for Policy

Water & Land Resource Centre
Addis Ababa University

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Clustering Climate Zones for Targeting Green Water Management Technologies in Ethiopia

Key Policy Messages

Identitication and mapping of houmogenous climate regions is important to guide decisions on greenwater management for rainfed agriculture. The case study presented in this brief has the following key messages.

- **Switch from the one-size-fits-all approach to local scale technology targeting**

  It is very important to switch greenwater and agronomic management technology targeting and selection from the usual one-size-fits-all approach to a local-scale problem-solving targeting practice. This is because local specific targeting is appropriate to address local scale climate related risks to the rain-fed agriculture.

- **Optimize agricultural productivity in short period monomodal rainfall areas**

  The agricultural productivity of some regions is constrained by short (2.5 – 3.5 months) LGP due to short monomodal rainfall pattern. Most of these areas have dense population; this means a large number of workforce is idle for a large part (6.5 – 7.5 months) of the year. Hence, it is important to optimize the agricultural productivity of these areas by introducing efficient technologies to harvest excessive amount of runoff that occurs during the short rainy season.

- **Target package-based technologies to address multiple climate-compounded risks to the rain-fed agriculture in some areas**

  The impact of multiple risks on the rain-fed agricultural activity and crop productivity can be better addressed by carefully understanding their co-occurrences and synergies and by accurately targeting package based management technologies.

Climate Varaibiity and Greenwater Management

Climate variability is a major constraint to the rain-fed agriculture and crop productivity in Ethiopia (Conway and Schipper, 2011). The annual rainfall cycle, amount, rainfall onset and cessation times, length of growing period (LGP), and occurrence and impact of climate-related risks, such as drought, flood, erosion, pest, and diseases, vary across space and over time. Similarly, the patterns of temperature and evapotranspiration, which have significant effects on soil moisture availability and crop growth, are different in different areas and seasons. On top of this, climate change is expected to worsen the impact of climate variability on the rain-fed agriculture (Conway and Schiper, 2011). Moreover, poor water utilization and management practices are the other driver of limitation for the low level of rain-fed agricultural productivity in the county (Tamene et al., 2022). Many of the previous soil and water conservationand agronomic interventions have not produced the intended outcomes as they followed a top-down and one-size-fits-all approach without considering regional and local scale climate variations (Tibebe et al., 2022). On the other hand, the customary large-scale agroecological zones (AEZ) based recommendations of green water and agronomic management practices cannot effectively support accurate targeting, mainly due to the prevalence of local scale climate variations. All this evidence suggests the urgent need for policy reconsideration and the introduction of appropriate site-specific greenwater management technologies and practices.

In other words, it is important to cluster areas into homogeneous hydro-climate regions for targeting site-specific agricultural water managementpractices and technologies. The objective of this brief is to illustrate the significant spatiotemporal variation in climate-induced water insecurity for rain-fed agriculture in Ethiopia using a case study conducted in the Abbay River Basin. (Rahmani et al., 2014; Popović-Bugarin, 2015).

Climate Clustering Methods

The k-means clustering approach was used to generate homogeneous climate clusters. The k-means is the most commonly used non-hierarchical classification algorism to classify regions into homogeneous units (Rahmani et al., 2014; Popović-Bugarin, 2015). The K-means is an unsupervised clustering algorism, which is simple to apply and can be used with relatively large data (Rahmani et al., 2014). The data inputs used for classification purposes were rainfall amount, length of growing season, precipitation concentration index (PCI), onset and cessation dates, evapotranspiration, soil moisture, and elevation that have the potential in determining the availability of greenwater for the rain-fed agricultural practices (Figure 1). The elbow method is applied to identify an optimal number of clusters. Moreover, Principal Components Analysis (PCA) was used to manage and remove the effect of multi-collinearity between hydro-climate variables that were used for the classification. The climate classification result was validated by expert consultation.

The climate classification was done for the kiremt season. The length of the growing period (LGP) was defined as the number of days when the precipitation amount exceeded half the potential evapotranspiration. The rainfall onset and cessation dates were also determined by considering this water balance approach.

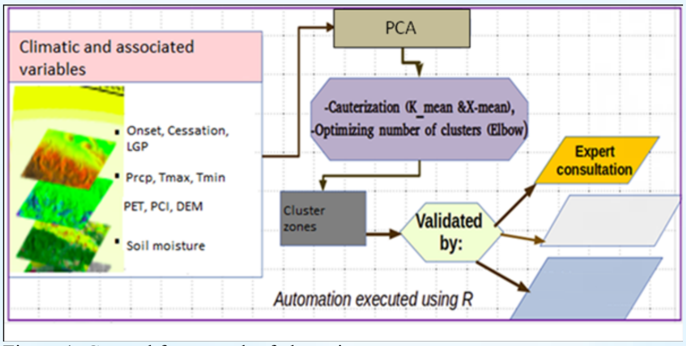

Figure 1. General framework of clustering

Hydroclimate Variables for Clustering

The climate variables considered for the clustering purpose were selected using PCA. The PCA offers two components, which have eigenvalues greater than one, and explained more than 75% of the variation. Of this, 52.3% of the variation was explained by the first component, and the remaining 25.2% of the variation was explained by the second component. The quality of variable representation was analyzed and demonstrated on the Cos2 factor map (Figure 2). Accordingly the length of the growing season, rainfall onset, maximum and minimum temperatures, elevation, soil moisture, and potential evapotranspiration contributed the most to dimension one, while precipitation concentration index, PET, and precipitation contributed to dimension two.

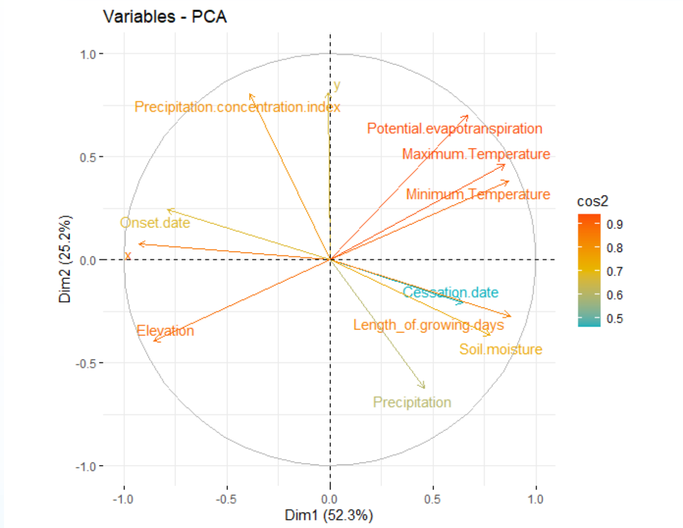

Figure 2. Cos2 factor map representing the quality of variables

Climate Clusters of the Abbay River Basin

The unsupervised k-means clustering generated 150 climate classes. These large numbers of clusters were reduced to an optimum and manageable number of classes by using the Elbow method, which is a quasi-objective method that is used to identify an optimum number of clusters. Based on this, 12 climate clusters were identified and mapped (Figure 3). These climate clusters provide important information for the identification and introduction of locally relevant greenwater management technologies and practices.

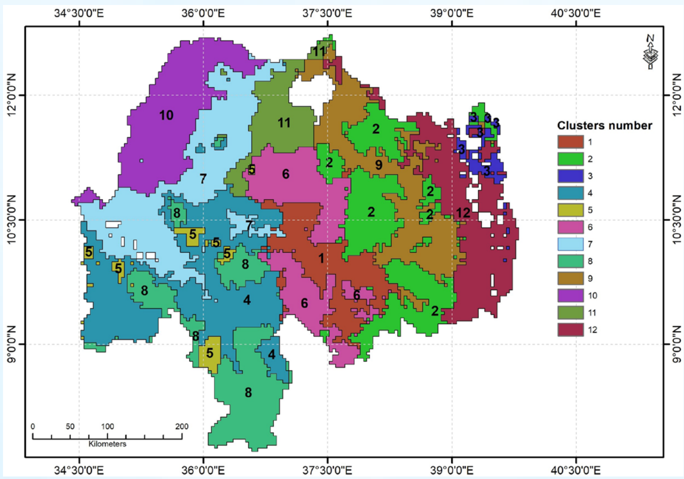

Figure 3. The distribution of climate clusters in the Abbay Basin

It was found that four of the climate clusters (2, 3, 9 and 12) experience a bimodal (Belg and Kiremt) rainfall pattern, and all of them are found in the eastern part of the basin. The remaining eight climate regions experience monomodal rainfall pattern that occurs in the Kiremt season. The length of growing period (LGP) for Kiremt rainfall season varies between 2.5 months in climate region 12 and 5.6 months in climate region five. The climate regions located in the western part of the basin have relatively long growing period (4.5–5.6 months). In contrast, the LGP was relatively short (3.3–3.9 months) for those climate regions located in the central and eastern parts of the basin, except for region three where the LGP is 5.1 months.

The rainfall onset and cessation dates varied between climate clusters. Rainfall onset and cessation dates were earliest for climate region 3. It starts in early March and ends in early August. Region 12 has also the same rainfall cessation dates. The rainfall onset time in five climate regions (4, 5, 7, 8 and 10) is in the first two weeks of April. The rainfall onset for the other six climate regions is between early May (Regions 6 and 11) and third week of May (Regions 2, 9 and 12). On the other hand, the rainfall cessation time for four climate regions (1, 2, 6, and 9) is in the last week of August, while it is in early September in five climate regions (4, 7, 8, 10 and 11). Different from the others, the rainfall cessation time for region five is in October.

The mean annual rainfall is relatively small (less than 1200 mm) for climate regions 2, 3, 9 and 12, and all these regions are located in the eastern and central parts of the basin. The mean annual rainfall is relatively high (1514.2–1769.5 mm) in four (4, 5, 6, and 8) climate regions which are located in the southwestern part of the basin. On the other hand, the intensity of rainfall as represented by PCI is lowest (14.6 mm) in climate region 8 and highest (21.1 mm) in climate region 12. Similarly, the mean annual PET is lowest (1261.2 mm) in region 2 and highest (1846.8 mm) in region 10. On the other hand, the mean annual minimum and maximum temperatures are relatively low in the eastern part and high in the western part of the basin.

Implications for Targeting Greenwater Management Technologies

Climate variability is a leading environmental constraint to the rain-fed agriculture and crop productivity in Ethiopia. An empirical study conducted in the Abbay basin clearly illustrates the prevalence of very high spatiotemporal variation in the climate system (e.g., mean annual rainfall amount, LGP, onset and cessation dates, and rainfall intensity), and this has a significant effect on availability and use of greenwater in the rain-fed agriculture. The results generated by this study contribute to identifying climate-induced water security risks and to targeting greenwater management technologies and practicies. For example, some climate regions (such as 1, 6 and 11) experience short (3.5 – 3.9 months) monomodal rainfall patterns and have relatively short LGP, which means longer dry periods, hence it is very important to target water management technologies that enhance water availability for dry period agricultural production. It is also useful to adopt fast-growing (short-season) crop varieties in these regions. On the other hand, it is important to give priority to soil management practices in some of the climate regions (2, 3, 9, 11, and 12) that have relatively high PCI. This is because, high rainfall intensities result in low infiltration and high runoff rates, potentially causing severe soil erosion (Tibebe et al., 2022).

Soil acidity management should be a priority of the greenwater management strategies in the climate regions of 4, 5, 6, and 8 that experience high mean annual rainfall amount (>1500 mm). There is large area in region 12, particularly in Semien Shewa and Debub Wollo, where large areas of farmlands are affected by water logging and cannot grow crops in the Kiremt season. Therefore, managing this water logging problem should be a priority greenwater management issue in these areas. Also, it is worth exploring opportunities to produce crops more than once using the rain-fed system in those climate regions that have relatively long LGP (4.5 and 5.6 months) in climate regions 3, 4, 5, 7, 8, and 10 by introducing fast growing crop varieties. Some areas have experienced multiple climate compounded risks such as drought, soil erosion, water logging, and pests and diseases. Hence, the impact of such multiple risks on rain-fed agriculture and crop productivity can be efficiently addressed by carefully understanding their co-occurrences and synergies and by accurately targeting package-based management technologies.

Conclusion

Clustering a given geographic region into homogenous climate classes is very useful to accurately identity and target locally relevant green water management technologies to efficiently address local-scale climate induced risks.

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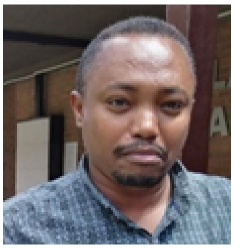

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