Rainfall Characterization and Trend Analysis of Wet Spell Length across Varied Landscapes of the Upper Awash River Basin, Ethiopia

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Received: 6 October 2020; Accepted: 3 November 2020; Published: 5 November 2020

Abstract: Understanding the timing and variability of rainfall is crucial for the effective management of water resources in river basins dominated by rainfed agricultural practices. Our study aimed to characterize rainfall and analyze the trends in the length of wet spells (LWS) in the Upper Awash River Basin—one of the most water-stressed river basins in Ethiopia. We applied statistical descriptors and a Mann–Kendall (MK) test to determine the onset, end, and LWS for the small (Belg) and main (Kiremt) rainy seasons across different landscapes of the basin. We observed highly stable rainfall onsets in all stations during both seasons. However, unlike the Kiremt season, the LWS in the Belg season was too short and unreliable for rainfed agriculture. Based on the MK test, an increasing monotonic trend in LWS during the Kiremt season was detected only in the mountainous landscape of the basin. In contrast, we observed no trends in the remaining stations in the Upper Valley region of the basin, despite the linear regressions inferring an upward or downward pattern. Our findings provide accurate climatological information for the effective development of rainwater management strategies in the Upper Awash River Basin.

Keywords: rainfall onset; rainfall end; wet spell length; Mann–Kendall trend; Upper Awash

1. Introduction

The seasonal and interannual variability of rainfall in certain regions influences the management of rainwater for various anthropogenic uses [1,2]. Rainfed agricultural practices significantly impact the economy of developing countries; however, these practices are highly vulnerable to the effects of weather and climate [3,4]. Therefore, understanding the spatial and temporal patterns of rainfall is crucial for effective agricultural water management. In addition, the understanding of regional meteorology is necessary for improving stochastic assessments and predictions in order to develop effective rainwater management strategies for different landscapes and agricultural practices [5].

In countries like Ethiopia with tropical monsoon and diversified topography, rainfall variations occur mainly as a result of the difference in elevation and seasonal changes in atmospheric pressure systems, which control the prevailing winds [6]. These differences contribute to the occurrence of three seasons in Ethiopia: (1) the main rainy season (Kiremt), (2) the small rainy season (Belg), and (3) the dry season (Bega). The Kiremt season typically lasts from June to September and covers all of Ethiopia, except the southern and southeastern regions. The Belg season occurs from March to May and is the main source of rainfall to the water-deficient southeastern regions of Ethiopia. The Bega season usually
lasts from October to February, during which the entire country is dry, except for the occasional rainfall in central regions of Ethiopia [6,7].

The Awash River Basin is the most intensively cultivated river basin in Ethiopia. The basin is frequently affected by flood and drought events [8,9] either due to extended wet spells during the rainy season or the sudden delay in the commencement or termination of rain. These conditions have caused significant difficulties to farmers, pastoralists, and urban citizens [10–12]. The onset and end of the rainy season largely determine the success of rainfed agriculture and other water management practices [4,13]. Moreover, characterizing the rainy season can help to improve the design of drought preparedness, mitigate soil erosion, and improve flash flood control systems as well as sustainable agricultural and environmental management operations [14].

Various studies have attempted to characterize seasonal rainfall to determine the onset and end of wet spells across the world, including in Central America [15], Brazil [16–18], India and Nigeria [19], India [20], equatorial East Africa [21], Tanzania [22], West Africa [23,24], and Ethiopia [25–27]. These studies show the importance of understanding the rainfall characteristics in terms of onset, end, and LWS for effective agricultural water management to avert the risk of crop failure and recurrent drought. Kebede et al. [26] studied the length of dry spells, onsets, and cessation of the wet season rainfall in the Upper Baro-Akobo Basin, Ethiopia—part of the Nile River Basin. The authors defined the onset/end of rainfall as when the dekadal rainfall amount is greater/less than half of the reference evapotranspiration, and the significance of trend fluctuation in onset, cessation, and duration was tested using Mann–Kendall’s test statistics. The mean onsets of the rainy season in different sub-basins of this western part of the Ethiopian region range between the first dekad of April and the third dekad of May. The wet spells end between the first dekad of September and the first dekad of December. This region has a wide diversity of climatic conditions resulting in a variation in onset and end spell dekads in different sub-basins. Similarly, Gebremichael et al. [25] assessed the seasonal rainfall variability in the southern region of Ethiopia through characterization of the onset, end, and length of growing period of the crops. They assumed an accumulated rainfall of 20 mm over three consecutive days to determine the onset of rainfall over the regions and identified that during the Belg, onset seasons (February and March) may lag two to six weeks. This delayed onset of wet spells could lead to soil moisture stress in agricultural fields and may ultimately lead to total crop failure. Therefore, understanding the exact period when the onset/end of rainfall commenced/terminated in certain basins requires in-depth monitoring and time-series analysis.

The interannual and spatial variability of different rainfall variables of Equatorial East Africa (Kenya and Northeastern Tanzania) was studied by Camberline et al. [21]. The total rainfall amount, the number of rain days, and the daily rainfall intensity were the major variables considered for the study. They found that the seasonal rainfall total of the long rains depends on a combination of virtually unrelated factors, which may account for the difficulty in its prediction. However, the onset, which exhibits large interannual variability and strong spatial coherence, has a prime role. Conversely, in the short rains, though the onset is again more decisive than the cessation, the different intra-seasonal descriptors of the rains are more strongly interrelated [21]. Marengo et al. [16] determined the onset and end of the rainy season in the Brazilian Amazon Basin by averaging daily rainfall data from many stations and then constructing 5-day averages (pentads) for use as a threshold to characterize the rainy seasons. Kowal and Knabe [28] defined the onset as the first 10-day period (dekad) with more than 25 mm, provided that rainfall in the next dekad exceeded half the potential evapotranspiration.

Defining the onset and end of rainfall is not easy due to the intermittent and patchy nature of rainfall [29]. Therefore, the onset date may be defined in different ways for a different purpose [30]. The assumption of onset/end of rainfall when the dekadal rainfall amount is greater/less than half of the reference evapotranspiration by different authors [25–27] as stated above is too general to characterize the rainfall at a river basin level where diversified types of crops are cultivated. Therefore, we used the water requirements of the dominant crops cultivated in the mountainous and Upper Valley region of the Awash River Basin to characterize the rainfall. Similarly, understanding the
frequency and stability of the onset of wet spells in a specific dekad assists crop and water resource management tactics [30]. These kinds of studies have a crucial role in forecasting the seasonal rainfall category to guide agricultural practices, implementation of soil and water conservation practices, and weather-responsive water resource management with the variation in onset, end, and length of wet spells (LWS) particularly in the Upper Awash River Basin, an area that frequently suffers from various severity levels of floods and droughts [9].

The local water user communities around the river basin lack adequate information on the timing, variability, and quantity of seasonal and annual rainfall to conduct effective water management practices in response to different climatic conditions—particularly for rainfed agricultural activities. Accurate rainfall information can help to mitigate drought events and effectively plan agricultural operations. It can also help to set an appropriate index for agricultural insurance to reduce damage affecting rainfed dependent farmers in the event of delayed onset or early termination of rainfall. For this reason, we characterized the rainfall and trends of wet spells by computing the long-term patterns of the onset, end, and length of wet spells for the Kiremt and Belg seasons in the Upper Awash River Basin.

2. Materials and Methods

2.1. Study Area

The Awash River is one of the largest rivers in Ethiopia, and the basin is divided into three distinct zones based on various interrelated factors: (1) the Upper Awash, (2) the Middle, and (3) the Lower Basins [9]. The Upper Awash River Basin comprises the Upland sub-basin, which is dominated by a mountainous landscape (Debrezeit station) and the Upper Valley sub-basins (Wonji, Melkassa, and Metehara stations), which form part of the great rift valley area (Figure 1). The altitude of the region ranges from 794 to 4187 m above sea level.

![Figure 1. Location of the Upper Awash River Basin, Ethiopia.](image-url)
The mean annual rainfall in the Upper Awash River Basin is greater than 600 mm (Table 1). The highest temperatures in the basin are typically observed between May and July, which coincides with the rainy season. This combination minimizes the effectiveness of moisture storage in soil [8]. A description of the study area and a summary of the climatic data are shown in Table 1.

Table 1. Description of the study area and a summary of the climatic data used.

| Stations   | Latitude | Longitude | Altitude (m a.s.l.) | ARF<sub>mean</sub> 1 (mm) | T<sub>mean</sub> 2 (°C) | RH<sub>mean</sub> 3 (%) | Data Used   |
|------------|----------|-----------|---------------------|---------------------------|-------------------------|------------------------|-------------|
| Debrezeit  | 08°44’   | 38°57’    | 1900                | 889                       | 25.3                    | 48.0                   | 1977–2008   |
| Wonji      | 08°31’   | 39°12’    | 1550                | 830                       | 21                      | 60.0                   | 1977–2008   |
| Melkassa   | 08°24’   | 39°21’    | 1550                | 872                       | 21.2                    | 54.1                   | 1977–2008   |
| Metehara   | 08°53’   | 39°52’    | 975                 | 610                       | 24.9                    | 58.3                   | 1977–2008   |

1 Mean annual rainfall; 2 mean temperature; 3 relative humidity.

The station metadata information for the study basin explaining any anthropogenic impacts on the measured data is shown in Table 2.

Table 2. Station metadata information for the Upper Awash River Basin.

| Stations  | Class | Status | Location                                      | Features                                      | Highways | Data Collection Convenience |
|-----------|-------|--------|----------------------------------------------|----------------------------------------------|----------|-----------------------------|
| Debrezeit | 1     | active | Inside the Ethiopian Agricultural Research Center compound, Bishoftu district Inside Wonji sugar factory; Near the sugar state research office, Wonji-Shoa area (State farm) | flat surface; some grasses and weeds; open field; no nearby buildings; no nearby irrigated flat surface; some grasses and weeds; open field; no nearby buildings; away from irrigated land | no       | yes                         |
| Wonji     | 1     | active | Inside the Ethiopian Agricultural Research Center compound, Melkassa district Inside Metehara sugar factory; Near the sugar state research office, Metehara (State farm) | flat surface; some grasses and weeds; open field; no nearby buildings; no nearby irrigated area flat surface; some grasses and weeds; open field; no nearby buildings; away from irrigated land | no       | yes                         |

The dominant soil types in the basin are eutric cambisols, pellic vertisols, eutric nitosols, haplic xerosols, and lithosols. The major crop grown in the Debrezeit area is teff—a crop native to Ethiopia—while maize is predominantly grown in Wonji and Metehara, especially during the main rainy season. Moreover, sorghum is commonly cultivated in Melkassa, as the crop is tolerant to moisture stress. We calculated the water requirements of the dominant crops to be used as threshold values for determining the onset and end of the rainy periods.
2.2. Data Acquisition and Use

The meteorological data were obtained from various sources (National Meteorological Agency of Ethiopia (NMA), Wonji-Shoa Sugar Factory, Metehara Sugar Factory, and Melkassa Agricultural Research Center). The data used in the analysis include dekadal (10-day) data of mean maximum and minimum temperatures (°C), relative humidity (%), sunshine hours (h), wind speed at 2 m height (km/day), and rainfall (mm). A total data duration of 31 years was used for selected stations in the Upper Awash Basin, including Debrezeit, Wonji, Melkassa, and Metehara. Dekadal mean climatic data were generated from the daily dataset for each station. Moreover, we estimated the reference evapotranspiration ($ET_o$) for each dekad of the study period using the CropWat-8 program for the standard meteorological dekad order, as shown in Appendix A, Table A1. The standard meteorological dekads represent periods of 10 days for the first two dekads (between the 1st and 10th and the 11th and 20th days) in each month and 8, 9, 10, or 11 days for the last dekad of the month ([31] as cited in [32]).

2.2.1. Tukey Fence Method

Almost all criteria for outliers are based on an assumed underlying normal (Gaussian) population or distribution [33]. When the data are not normally or approximately normally distributed, the probabilities associated with these tests are different. These outliers are the data point that differs significantly from observation [33,34]. The Tukey fence method was used to screen the outliers. This approach is recommended for abnormally distributed climatic data like rainfall [34]. The data range is expressed as:

$$[Q_1 - 1.5 \times IQR, Q_3 + 1.5 \times IQR]$$

where $Q_1$ and $Q_3$ are respectively the lower and upper quartile points (25% of the data is less or more than those points, respectively), 1.5 represents standard deviations from the mean, and $IQR$ is the interquartile range.

2.2.2. Homogeneity Test

The homogeneity of rainfall data for all stations in the Upper Awash River Basin was checked using double-mass curve techniques. The theory of the double-mass curve is based on the fact that a graph of the cumulation of one quantity against the cumulation of another quantity during the same period is plotted as a straight line so long as the data are proportional; the slope of the line represents the constant of proportionality between the quantities [35]. A break in the slope of the double-mass curve means that a change in the constant of proportionality between the two variables has occurred or perhaps that the proportionality is not a constant at all rates of cumulation [35,36]. The inconsistency of rainfall records may be observed due to the change of rainfall station, instrument malfunction, obstruction of gauging site, or data encoder skill limitations. Therefore, the deviation in time series observed data must be adjusted using the following equation:

$$P_a = \frac{b_a}{b_o} \times P_o$$

where $P_a$ is adjusted rainfall; $P_o$ is observed rainfall; $b_a$ is a slope of the graph to which records are adjusted; and $b_o$ is a slope of the graph at time $P_o$ was observed.

During the data pre-processing stage, inconsistencies in hydrometeorological data were checked and adjusted. The results revealed that the rainfall data records were found to be consistent in all stations (Figure 2). We then characterized the onset, end, and length of wet spells using the dekadal time step.
2.3. Characterization of Wet Spells

The dominant weather parameters controlling evapotranspiration are radiation, air temperature, humidity, and wind speed. Several procedures have been developed to assess the evaporation rate from these parameters. The evaporation power of the atmosphere is expressed by the reference evapotranspiration (ET$_{o}$), which represents the evapotranspiration from a standardized vegetated surface [37].

The Food and Agricultural Organization (FAO) [38] water balance concept states that the onset of the rainy season (beginning of the growing period) occurs when rainfall is equal to half of the ET$_{o}$. Moreover, the end of the rainfall period occurs when rainfall exceeds one half of the ET$_{o}$ during the recession of the rainy season [27,38,39].

The wet season characteristics—including the onset, end, and length of wet spells for commonly grown crops in the study area (teff, maize, and sorghum)—were evaluated using the crop evapotranspiration demand as a criterion.

2.3.1. Onset and End of Wet Spells

The onset of a wet spell marks the transition from the dry to the wet period, whereas the end of the wet spell marks the transition from the wet to the dry period. In this study, the crop water requirements of the selected crops during their initial growth stages were used to determine the onset of the wet spell for specific seasons. Moreover, the end of a wet spell dekad is defined as a dekad with a cumulative rainfall less than or equal to the dekadal water requirements of each crop during the late growing stage. Consequently, the onset and end of a wet spell were computed based on the following crop water requirement formulae [37]:

$$P_o \geq K_{c,\text{initial}} \cdot ET_o$$  \hspace{1cm} (3)

$$P_e \leq K_{c,\text{end}} \cdot ET_o$$  \hspace{1cm} (4)
where $P_o$ is the onset of wet spells (initial crop water requirement), $P_e$ is the end of wet spells, and $K_{c\text{ initial/end}}$ is the crop coefficient at the initial/end of the crop growth stage.

### 2.3.2. Length of Wet Spells (LWS)

The LWS is the period between the onset and end of the wet spell. It is determined by counting the number of dekads between the onset and end of wet spells in each year. Subsequently, the mean, standard deviation, and coefficient of variation of the LWS were computed to evaluate the effectiveness of the period in supporting crop growth. LWS variability was analyzed using the coefficient of variation for time series of 31 years [27].

$$\text{CV} = \frac{\text{SD}}{\bar{X}}, \quad (5)$$

where CV is the coefficient of variation of LWS, SD is the standard deviation of LWS, and $\bar{X}$ is the mean wet spell length.

### 2.3.3. Relative Frequency of Wet Spell Onsets in Specific Dekads

Frequency analysis predicts how often certain values of a particular variable occur and assesses the reliability of the wet spell. The relative frequency of wet spell onsets was computed using the following formula [40]:

$$f = \frac{n}{N} \times 100, \quad (6)$$

where $f$ is the relative frequency of wet spell onsets in a particular dekad, $n$ is the number of wet spell onsets occurring in a particular dekad, and $N$ is the total number of wet spell onsets during the study period.

### 2.3.4. Stability of Wet Spell Onsets

Assessing the stability of wet spell onsets is crucial for making informed water management decisions. Reddy [41] developed a method to assess the stability of wet seasons based on the standard deviation of the average onset dekads, as shown in Table 3.

| Standard Deviation (Dekads) | Stability   |
|-----------------------------|-------------|
| <1                          | Very high   |
| 1–2                         | High        |
| 2–4                         | Moderate    |
| 4 and above                 | Low         |

### 2.3.5. Mann–Kendall (MK) Trend Test

For this study, the Mann–Kendall (MK) trend test was used to test the LWS trends for the main rainy season over different time series. This method is the most widely used test for assessing time-series trends in hydrometeorological studies [42–45].

A positive (negative) value of $Z$ indicates that the data tend to increase (decrease) with time. The null hypothesis of no trend is rejected if the absolute value of $Z$ is higher than 1.96 at 5% significance level.

### 3. Results and Discussion

#### 3.1. Identification and Evaluation of Wet Spells in the Belg Season

The analysis results in Table 4 reveal that the onset of rainfall in the Belg season is rarely abrupt in the mountainous (Debrezeit) and valley (Wonji, Melkassa, and Metehara) regions of the basin. This season is usually preceded by a series of isolated rainfall of uncertain intensity. Moreover,
intermittent dry periods of varying duration were also noted. These may be false starts and could be followed by prolonged dry spells with durations of one, two, or more dekads. These periods decrease the moisture availability in the topsoil, and yields can reduce or fail due to late planting. These calamities are typically a result of short growing seasons [14,46–49].

Table 4. Characterization of wet spells in the Belg season for selected crops.

| Stations  | Dominant Crops | MOD ¹ | CV (%) | SMO ² | FMO ³ (%) | End of Rainy Season (Dekad) | LWS (Days) |
|-----------|----------------|-------|--------|-------|-----------|-----------------------------|------------|
| Debrezeit | Teff           | 9     | 16.6   | High  | 31.25     | 12                          | 41         |
| Wonji     | Maize          | 8     | 18.8   | High  | 33.33     | 10                          | 30         |
| Melkassa  | Sorghum        | 8     | 18.8   | High  | 28.13     | 9                           | 21         |
| Metehara  | Maize          | 9     | 20     | High  | 29.16     | 10                          | 21         |

¹ Mean onset dekad (MOD); ² stability of mean onset dekad (SMO); ³ frequency of mean onset dekad (FMO).

We observed a maximum mean LWS of 41 days (Debrezeit) and a minimum mean LWS of 21 days (at Melkassa and Metehara) in the Belg season (Table 4). The length of the wet period was predominantly short at all stations. This suggests that rainfall is unreliable for rainfed agriculture and cannot support long-duration crops, despite the stable rainfall onsets observed in this season. In general, yields may suffer significantly due to the shorter LWS in the basin in response to the early cessation of wet spells. Likewise, rainfall distribution is unreliable due to the high frequency of damaging dry spells within the season. This finding is in agreement with previous results in the central highlands of Ethiopia [39]. However, the moisture retained during this season can facilitate some agricultural operations, such as early land preparation for the main rainy season [39]. Moreover, short-duration vegetables can be grown with supplemental irrigation to sustain food security. This study can be used as a basis for understanding the drought conditions of the regions, including frequency, intensity, magnitude, and severity of the drought. Likewise, the results serve as an input to establish different index levels for agricultural insurance purposes.

3.2. Identification and Evaluation of Wet Spells in the Kiremt Season

Table 5 shows the statistical results of the Kiremt season onset and its stability. The mean onset dekad of the Kiremt season in Debrezeit, Wonji, and Melkassa was dekad 17; the mean onset in Metehara occurred later in dekad 19.

Table 5. Onset of the Kiremt season and its stability.

| Stations  | MOD | SD (Dekads) | CV (%) | FMO (%) | SMO       |
|-----------|-----|-------------|--------|---------|-----------|
| Debrezeit | 17  | 0.9         | 5.4    | 53.13   | Very high |
| Wonji     | 17  | 1.31        | 7.5    | 27.27   | High      |
| Melkassa  | 17  | 1.12        | 6.4    | 29.03   | High      |
| Metehara  | 19  | 1.5         | 7.9    | 41.67   | High      |

Early and delayed onsets of rainfall period occurred in dekad 16 and dekad 18, respectively, in all stations except Metehara; in this station, the early and delayed onsets occurred in dekads 18 and 20, respectively (Table 6). The Kiremt season ended in dekad 27 in all areas except Metehara, which had a shorter season that ended in dekad 24. These results are in agreement with the findings of Segele and Lamb [50] concerning the characterization and variability of the Kiremt season across Ethiopia. Figure 3 presents plots of the average dekadal rainfall and the corresponding water requirements for selected crops during the Kiremt season at each station. A dekad above the blue line is considered as wet spell and below as dry spell period in which the rainfall cannot satisfy the evapotranspiration demand of the crop.
Table 6. Onset, end, and LWS of the Kiremt season.

| Stations | Early | Mean | Delayed | Early | Mean | Delayed | SD (Days) | CV (%) | Mean LWS (Days) |
|----------|-------|------|---------|-------|------|---------|-----------|--------|-----------------|
|          |       |      |         |       |      |         |           |        |                 |
| Debrezeit| 16    | 17   | 18       | 26    | 27   | 28       | 12        | 10.8   | 112             |
| Wonji    | 16    | 17   | 18       | 26    | 27   | 28       | 22        | 22.1   | 100.3           |
| Melkassa | 16    | 17   | 18       | 26    | 27   | 28       | 17.3      | 17.2   | 100.6           |
| Metehara | 18    | 20   | 23       | 23    | 24   | 25       | 19.1      | 31.9   | 60              |

According to the criteria proposed by Reddy [41], the onset of wet spells during the Kiremt season was highly stable in all stations (Table 5). The mean LWS in Debrezeit, Wonji, Melkassa, and Metehara was 112, 100, 101, and 60 days, respectively (Table 6). Similarly, the relative frequency of the Kiremt season onsets in specific dekads across the study area is presented in Table 7. The onsets of wet spells are highly frequent and stable in dekad 17 (in Debrezeit, Wonji and Melkassa) and dekad 19 (in Metehara areas).

Table 7. Relative frequency of Kiremt season onset dekads.

| Station | Characteristics | Standard Dekad No. |
|---------|-----------------|--------------------|
|         |                 | 16 | 17 | 18 | 19 | 20 | 21 |
| Debrezeit| NOs 1 | 15 | 11 | 5  | 1  | 0  | 0  |
|         | FO (%) 2 | 46.88 | 34.38 | 15.63 | 3.13 | 0.00 | 0  |
| Wonji   | NOs | 9  | 9  | 8  | 4  | 3  | 0  |
|         | FOs (%) | 27.27 | 27.27 | 24.24 | 12.12 | 9.09 | 0  |
| Melkassa| NOs | 6  | 9  | 9  | 6  | 1  | 0  |
|         | FOs (%) | 19.35 | 29.03 | 29.03 | 19.35 | 3.23 | 0  |
| Metehara| NOs | 2  | 1  | 4  | 10 | 5  | 0  |
|         | FOs (%) | 8.33 | 4.17 | 16.67 | 41.67 | 20.83 | 0  |

1 Number of occurrences; 2 Frequency of occurrences.
Our results indicate that the LWS in the Kiremt season is adequate for supporting the growth of cereal crops, such as teff, maize, and sorghum, in Debrezeit, Wonji, and Melkassa, respectively. However, the LWS in Metehara is unlikely to support even drought-resistant crops during most of the year. The production of short-duration crops in the area also requires high irrigation. Further, the temporal variability of LWS is also very high in Metehara, with a CV of 31.9% (Table 6). This area usually experiences delayed onsets coupled with early terminations of wet spells during the main rainy season. Figure 4 shows the temporal variations and trends of LWS in the Kiremt season, and Table 8 shows the test statistics ($S$-statistics, $Z_{MK}$, and $p$) for each station in the basin.

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The LWS linear regression lines in Figure 4 infer upward trends in Debrezeit and Wonji and downward trends in Melkassa and Metehara; however, only Debrezeit showed an increasing monotonic trend at a significance level of 5% throughout the analysis period, while monotonic trends were not observed in the other three stations (Table 8). The LWS temporal trends via linear regression showed a maximum of 6- and 5-day increments over a 10-year period in Debrezeit and Wonji stations, respectively. In contrast, the trends decreased by 1 and 2 days in Melkassa and Metehara, respectively. Thus, the LWS over the Upper Awash River Basin showed no trend in the Upper Valley (Wonji, Melkassa, and Metehara) except in the Upland sub-basin (Debrezeit).

According to a previous study [51] that analyzed the relationship between agricultural production and the vegetation condition index (VCI) and standardized precipitation index (SPI), our study sites are located in an area that suffers from moderate to extreme drought conditions. The previous macro study emphasized the impact of El Niño in 2002/2003 and 2010/2011 and highlighted the similar spatial patterns between the two El Niño events and other meteorological conditions in Eastern Africa.

Figure 4. Temporal variations and trends of LWS in the Kiremt season at (a) Debrezeit, (b) Wonji, (c) Melkassa, and (d) Metehara.

Table 8. Mann–Kendall test result for LWS in the Kiremt season.

| Stations  | $S$-statistics | $Z_{MK}$ | $p$-Value |
|-----------|----------------|----------|-----------|
| Debrezeit | 157            | 2.5 *    | 0.013     |
| Wonji     | 51             | 0.81 **  | 0.42      |
| Melkassa  | −51            | −0.79 ** | 0.43      |
| Metehara  | −41            | −0.64 ** | 0.53      |

* shows trend; ** shows no trend.
Therefore, the absence of trends in the Upper Valley in our study may be explained by changes in El Niño as well as other climatological factors. However, our study focused on regional cases using in situ data; therefore, the detailed understanding of rainfall patterns through the characterization of the Kiremt and Belg seasons can contribute toward local agricultural water management practices.

4. Conclusions

In this study, we characterized the bimodal rainfall types in the Upper Awash River Basin for the Belg and Kiremt seasons. The major findings, conclusions, and recommendations of this study are as follows:

- The onset of rainfall in the Belg and Kiremt seasons was rarely abrupt and highly stable in all stations. However, the LWS during the Belg season was too short and unreliable for rainfed agriculture in all stations.
- The LWS during the Kiremt season was adequate for supporting the growth of selected crops in the mountainous and valley landscapes of Debrezeit, Wonji, and Melkassa, but not Metehara.
- No monotonic trends in LWS were identified in the Upper Valley of the basin. However, we identified an increasing monotonic trend at a significance level of 5% in the mountainous landscape of the basin. Therefore, the focus should be placed on this region under extended LWS events to prevent damage to the sown crops, which may affect the quality of the product.

5. Recommendations

- Early/delayed onset of wet spells in rainy seasons must be aligned with responsive farming practice particularly in the Belg season. The extended length of wet spells in a mountainous area of the Upland sub-basin (Debrezeit area) or the shortest length of wet spells in the Upper Valley sub-basin (Metehara area) during the main rainy season indicates the need for policymakers, implementers, and water professionals to act on effective weather response water or crop management options for use in the dry season.
- A thorough understanding of the onset, end, and LWS of rainfall periods across different landscapes can contribute toward the development of new rainwater management strategies that are synchronized with the agricultural practices in the region. Such information is also useful for early drought mitigation, land preparation, mitigation of soil erosion, crop insurance, and flash flood control systems as well as for improving sustainable rainfed agricultural and environmental management operations.

Author Contributions: Conceptualization, G.B.A. and B.A.H.; methodology, G.B.A. and B.A.H.; software, G.B.A.; validation, G.B.A. and B.A.H.; formal analysis, G.B.A. and B.A.H.; investigation, G.B.A. and B.A.H.; resources, G.B.A. and W.-K.L.; data curation, G.B.A. and B.A.H.; writing—original draft preparation, G.B.A. and B.A.H.; writing—review and editing, G.B.A., C.S. and W.-K.L.; visualization, G.B.A., B.A.H., C.S. and W.-K.L.; supervision, G.B.A. and W.-K.L.; project administration, G.B.A.; funding acquisition, G.B.A. and W.-K.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The authors gratefully acknowledge the support by the OJEong Resilience Institute (OJERI) at Korea University, the National Meteorological Agency (NMA) of Ethiopia, Debrezeit Agricultural Research Center, Wonji Sugar Factory, Metehara Sugar Factory, and Melkassa Agricultural Research Center for providing data for this research. In addition, we thank Fistume Yemenu and Ayalew Mamo for their constructive discussions.

Conflicts of Interest: The authors declare no conflict of interest.
Appendix A

Table A1. Standard dekad numbers ([31] as cited in [32]).

| Month    | Dekad No | Date   | Month    | Dekad No | Date   |
|----------|----------|--------|----------|----------|--------|
| January  | 1        | 1–10   | July     | 19       | 1–10   |
|          | 2        | 11–20  |          | 20       | 11–20  |
|          | 3        | 21–31  |          | 21       | 21–31  |
| February | 4        | 1–10   | August   | 22       | 1–10   |
|          | 5        | 11–20  |          | 23       | 11–20  |
|          | 6        | 21–28  |          | 24       | 21–31  |
| March    | 7        | 1–10   | September| 25       | 1–10   |
|          | 8        | 11–20  |          | 26       | 11–20  |
|          | 9        | 21–31  |          | 27       | 21–30  |
| April    | 10       | 1–10   | October  | 28       | 1–10   |
|          | 11       | 11–20  |          | 29       | 11–20  |
|          | 12       | 21–30  |          | 30       | 21–31  |
| May      | 13       | 1–10   | November | 31       | 1–10   |
|          | 14       | 11–20  |          | 32       | 11–20  |
|          | 15       | 21–31  |          | 33       | 21–30  |
| June     | 16       | 1–10   | December | 34       | 1–10   |
|          | 17       | 11–20  |          | 35       | 11–20  |
|          | 18       | 21–30  |          | 36       | 21–31  |

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