Soil and Water Relationships of Some Crops in Sahel-Dori, Burkina Faso

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Abstract: This study was conducted in Sahel-Dori region, located in Sahelian region of Burkina Faso, for studying the soil and water relationships of some crops, cowpea, groundnut, millet and sorghum. This study aims at assessing crop water requirements, soil water balance, irrigation needs on the basis of previous climate data (rainfall, temperature, sunshine, wind speed, evapo-transpiration, relative humidity of the air) and of soil type. This study shows that soil water reserves naturally increase according to rainfall, they generally fall at the onset of the season (May to mid-July), sharply increases during the period of "heavy rains" to reach a maximum value in early September and then decreases as rains become infrequent, to reach its minimum level at the end of the dry season. In the regions of the Sudan-Sahelian and in the Sahelian regions, water deficits are experienced towards the end of the rainy season. In the Sahel irrigation needs for crops at the end of the season are substantial.

Key words: Water requirements · Water balance · Crops · Burkina Faso

INTRODUCTION

Soil productivity in semi-arid zones is often limited by water availability. Moreover, in these regions, runoff is among the main causes of soil degradation and inefficient water utilization by plants. Burkina Faso is located in the Sudan-Sahelian zone of West Africa and is subject to a high degree of both climate variability and population growth (2.3 % / year). The main climatic features of the country are a low level of rainfall, spatial and temporal variability, high level of evapo-transpiration (ET) and high temperatures particularly during the dry season.

Beyond the Sahelian zone, the dry land savannah of the Sudanian zone, which registers an average annual rainfall greater than 600 mm/year, has also experienced serious climate shocks, particularly droughts, since the 1980s. In addition to growing demands for natural resources by an expanding population, these climate shocks compromise the sustainability of the current systems of land use and seriously threaten food security among rural populations. Since rainfall constitutes the main source of water for growing crops, rainfall is essential element of the water balance. But when soils are highly degraded, actual rainfall limits growth and production of vegetation less than the amount of water that infiltrates the soils. Because of this inter-annual variability of rainfall and to soil degradation, the measures taken consisted of the implementation of isohypses works for absorbing runoff. These water and soil conservation measures appear to be very effective for collecting and redistributing water in soil. However, data on crops water requirements, on needs for irrigation and on variations in soil water balance according to variations in climatic and rainfall data for different agro-climatic regions of Burkina Faso are almost non-existent. To mitigate that, this study aims at assessing crop water requirements, soil water balance, irrigation needs on the basis of previous climate data (rainfall, temperature, sunshine, wind speed, evapo-transpiration, relative humidity of the air) and of soil type [1-5].

MATERIALS AND METHODS

Climatic data were provided by the National Meteorological Service. They are monthly averages for the minimum and maximum temperature, relative humidity of the air (minimum and maximum), sunshine, wind speed, rainfall and geographic coordinates (altitude, latitude, longitude) from 1963 to 2008. At least one site sahel-Dori region was chosen per agro-ecologic zone, as shown in Map 1.
Map 1: Burkina Faso showing the province selected for the study

The Cropwat software Smith [6, 7] was used in calculating crop water requirements (maximum evapotranspiration MET), effective rainfall, reference evapo-transpiration (ET0), irrigation needs, soil water balance (useful reserve and easily usable reserve) and soil water deficit. It uses monthly averages of the climatic parameters mentioned above. ET0 is calculated using the Penman-Monteith’s method Allen et al. [8] and effective period, the highest amounts of rain were recorded in 2003 rainfall is estimated to be 80 % of rainfall amount. Irrigation is applied when 80 % of easily usable reserve is exhausted and has 70 % efficiency. The maximum depth of crop roots is 80 cm. An average soil depth was considered for simulation in the different regions. Data on crop coefficients are provided by the software as well as crop culture (cowpea, groundnut, millet and sorghum).

**Sahelian Region: Dori**

**Geographic Situation:** The Séno province belongs to the Sahelian region of Burkina Faso and has Dori as its administrative center. This province covers a surface of 7,020 km². It is bordered by Oudalan province to the north, Niger to the east and by the provinces of Soum and Namentenga to the west, the provinces of Gnagna and Yagha to the south. Dori is situated at a latitude of 14°02 north and longitude of 2°88 west, at an altitude of 288 m high Orstom [9].

**Climate:** The climate is sub-Sahelian climate, with a rainfall lower than 600 mm/year. The average rainfall during the last forty five years is 500mm/year. During this period, the highest amounts of rain were recorded in 2003 (753 mm), in 1963 (748 mm) and in 1966 (736 mm). There is however, a considerable inter-annual variability in rainfall (Fig. 1). The tendency is for a general decline in precipitation over the years. Therefore, rainfall decreased from 748 mm in 1963 to 259 mm in 1987. The driest period is situated between 1977 (279 mm) and 1987 with 259 mm (Fig. 1).

Figure 2 shows the trends in maximum, average and minimum temperatures, under cover of Dori. Also, it shows slight increase in maximum and minimum temperatures during the last 45 years. During the last 45 years, there has been a significant inter-annual variability in temperature, with a rising trend along the years. So, the average annual minimum temperature varied from 20.0 to 23.5°C, by a margin of 3.5°C and an average
Fig. 1: Rainfall and effective rainfall trends from 1963 to 2008 in Sahel Dori, Burkina Faso

Fig. 2: Temperature trends from 1963 to 2008 in Sahel Dori, Burkina Faso

of 21.9°C. The average annual maximum temperature grew from 36.3 to 38.4°C, by a margin of 2.1°C and an average of 37.3°C. The average temperature from 1963 to 2008 is 29.6°C. The highest temperatures recorded are 38.4°C in 1987, 2007 and 2008 and 43.7°C in April, 2000 and 44.2°C in May, 1993. The minimum temperatures are 22.0°C in 1965 and 1972 and can fall to 11°C in January or December. The relative humidity is low, particularly during the dry season. The annual average minimum humidity over the last 45 years ranges from 25 to 62 %,
Fig. 3: Relative humidity trends from 1963 to 2008 in Sahel Dori, Burkina Faso

with an average of 43%, while the maximum humidity varies from 50 to 72% (Fig. 3). The minimum relative humidity of the air varies from 21 to 31%. Two types of winds are dominant in the region, the Harmattan, which is a hot and dry wind, dominates between January and April and the Monsoon, which is wet and cool, dominates between May and October. Over the last 45 years, the average wind speed was 2.9 m/s.

Soils: Several soil studies have been undertaken in the Sahelian region Orstom [9], Boulet [10] Leprun [11] and Bunasols [12,13]. In a study for the Burkina Sahelian region, based on three transects (Oursi-Tin Akoff, Gorom-Markoy and Dori-Falagountou), Pallo [14] and Robina and Giovanni [15] highlights the importance of isohumic soils and the presence of iron and manganese sesquioxides soils and of sodic soils. The sub-arid red brown soils slightly differentiated or haphic arenosols and the sub-arid red brown modal soils or luvic arenosols are constituted of Aeolian sands. They have a solid structure, a low to average cohesion and low organic matter contents (< 3%). The sub-arid brown alkaline soils are associated to sesquioxides and are located on uplands with negligible slope. They are made of clayey-sandy materials resulting from water erosion. The structure, which is cubic on the surface, becomes heavy at greater depth. They have a very hard cohesion. The brown sub-arid vertic soils are found on sloping uplands and on clayey materials of poorly drained plains. They have a high rate of saturation (90% on average) of the surface profile and a pH from slightly acid to neutral at the surface and alkaline at greater depth. The iron and manganese sesquioxides soils are composed of slightly leached tropical ferruginous soils and leached tropical ferruginous soils. The latter cover a large part of the Sahelian region of Burkina, certainly due to their Aeolian origin (sandy deposits) and to the low rainfall, which does not allow for considerable leaching of clay material. The sodic soils are solonetz with a column structure of the B horizon, having developed on materials resulting from granite formations. They are characterized by limestone accumulation, in the form of nodules, formation of black concretions and presence of hydromorphism spots, sign of a poor drainage.

RESULTS AND DISCUSSION

Water Requirements for the Main Crops in Dori:

Water Requirements for Cowpea: Figure 4 illustrates cowpea water requirements in the Dori region, by comparing rainfall supply, ET and irrigation needs for the crop. These trends indicate that water requirements for cowpea are met by effective rainfall only during a short period of the crop’s cycle (from 8/07 to 7/08). Rainfall amounts fall sharply while water requirements continue to grow, to reach 4.9 mm/decade (10 days) for a value lower
than 3.9 mm / decade for the maximum climatic supply. This implies that irrigation is sorely needed for two months before the end of the development cycle. Irrigation needs rise and reach a maximum value (4.0 mm / decade) around the 26th of September, before falling as illustrated by the irrigation curve (mm / p).

**Water Requirements for Groundnut:** Figure 5 shows that, until August 18th, effective rainfall exceeds water requirements for groundnuts. After this time, effective rainfall declines, while water requirements grow to a maximum value of 0.7 mm / decade between September 7th and September 27th. This situation may result in water stress unless rainfall is complementary with irrigation.
Irrigation needs are the highest (around 0.85 mm/day) between October 7th and October 17th. Similar results were obtained by Some and Sivakumar [1], Gouyahali and El-Hassan [2], Some et al. [3], Abdel-Rahman et al. [4] and Robina et al. [15].

**Water Requirements for Millet:** Figure (6) shows the trends in potential evapo-transpiration (PET), MET, effective rainfall (Efr) and irrigation needs of the crop during the development cycle of millet. It indicates that, between the beginning and the end of the cycle, the PET (that is, the maximum amount water a vegetative cover may lose by transpiration and evaporation) falls, ranging between 33 mm and 48 mm. The MET represents the amount of water effectively lost by millet and varies between 7.0 mm and 21 mm. From the beginning of the cycle to August 17th, the MET is less than the effective rainfall. Between August 27th and September 26th effective rainfall become insufficient to meet the needs for water of the crop, which grow to a maximum of about 18 mm / decade. Figure 6 suggests that irrigation may be needed to deal with a water deficit resulting from decline in rainfall or premature end of the rains. The crop’s irrigation needs are highest around October 6th (18 mm / decade).

**Water Requirements for Sorghum:** Figure (7) illustrates the trends in PEO, MET, effective rainfall (Efr) and irrigation needs during the development cycle of sorghum. It shows that, until August 4th, water requirements for sorghum can be met by rainfall, since the Efr values are higher than the MET. During the following month (14/08 to 23/09) the supply of rainwater falls under the water requirements, which grow and stay higher than 14 mm, decreasing afterward. The curve for irrigation needs starts rising on August 4th to reach its highest values between September 23rd and October 13th.

**Soil Water Balance in Dori:**

**Soil Water Balance in a Cowpea Plot:**

**Rainfall Increase During Two Stages:** at first, they gradually increase from the onset of the season to late August (this period is known as the time of heavy rains). Then Rainfall stabilizes around 62 mm and 138 mm every 5 days respectively (Fig. 8). Rainfall remains low until late August, gradually increasing thereafter to equal the Rainfall around September 20th. This happens because rains become irregular, while water requirements for the crop remain significant, so that the Rainfall is gradually consumed by the crops. After this time, the sedimentations decreases to reach 15 mm/5 days on September 30th, before rising again to equal the Rainfall at the end of the season (Fig. 8). The sedimentations reach 50 % of the RAM more than one month before the end of the crop cycle, as rains becomes again erratic and infrequent. This period coincides with the critical stages of grain formation and maturation, when water deficit can severely affect yields and therefore complementary irrigation may be necessary.
Fig. 7: Water requirements for sorghum in Sahel Dori, Burkina Faso

Soil Water Balance in a Groundnut Plot: Figure 9 shows the soil water balance of a groundnut plot in the Dori region. It indicates that soil water reserves (TAM and RAM) are replenished until early September, with values of respectively 48 mm/decade and 112 mm every 5 days. These values remain constant until the end of the groundnut cycle. The SMD remains low until early September. Then, from mid September on, it sharply rises to reach the RAM value. In the Sahel, this period is marked by declining and more erratic rainfall.
Soil Water Balance in a Millet Plot: As shown in Figure 10, the soil water balance remains positive over most of the millet cycle. Indeed, the sedimentations curve describes very low values until the end of August. From early September to early October it increases from 8.0 mm to 104 mm/5 days. This substantial increase in sedimentations coincides with the stages of heading, flowering and grain formation, therefore complementary irrigation may be needed to optimize yields. The rainfall rise between early in the season and late September, with respective values of 101 mm/5 days and 168 mm/5 days, these values remain constant until the end of the cycle.
Soil Water Balance in a Sorghum Plot: The sedimentations for sorghum remain negligible until the end of August. Between early September and mid-October it rises from 8.0 mm to 122 mm/5 days. Since this period coincides with grain formation, the deficit can severely affect sorghum yields.

CONCLUSION

This study shows that soil water reserves naturally increase according to rainfall: they generally fall at the onset of the season (May to mid-July), sharply increases during the period of "heavy rains" to reach a maximum value in early September and then decreases as rains become infrequent, to reach its minimum level at the end of the dry season. In the Sahelian regions water deficits are experienced towards the end of the rainy season for cereal crops and groundnut and irrigation needs at the end of the season are substantial.

REFERENCES