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Onion water productivity Assessment in five lowlands in the Niayes area of Senegal

Alphousséný SANE[1], Lamine DIOP[1]*, Yaye Deffa WANE[1], Aminata SARR [1,2], Ibrahima DIATTA[3], Mariama Dalanda DIALLO[1], Ansoumana BODIAN[4], Sidy Mohamed SECK[3]

[1]Faculty of Agronomic Sciences, Aquaculture and Food Technology (S2ATA) , Gaston Berger University, Saint-Louis, Senegal.

[2]Irrigated agriculture, Mediterranean Agronomic Institute of Bari (CIHEAM-BARI), Bari, Italy.

[3]Interdisciplinary Research Group in Support of Regional Planning and Local Development, Gaston Berger University, Saint-Louis, Senegal.

[4]Faculty of Arts and Humanities UFR, Gaston Berger University, Saint-Louis, Senegal.

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Abstract: Water productivity monitoring is a key tool for irrigation management in the context of climate change and of areas where water source is very vulnerable. This study is carried out in five (05) lowlands in the North of Niayes: Deur Diabi, Boul Ayni, Lac Kalassane, Nguétiouro, and Ferset Ndoye. The objective of this study is to assess onion irrigation water productivity in the areas mentioned above. Surveys were carried out with 123 farmers. Water productivity was determined based on applied irrigation volume and onion yields. The results showed that water quantities applied varied between 4,245 m3/ha and 7,485 m3/ha with an average of 7,000 m3/ha. Yields oscillate between 17 and 35 t/ha, with an average of 27.5 t/ha. This gives a water productivity ranging from 3.15 kg/ to 4.27 kg/m3. These results show that onion water productivity in this area is very low and has to be improved. These results can be of great contribution to irrigation optimization.

Key words: Irrigation, lowlands, Niayes, Onion, Water productivity

INTRODUCTION

Agricultural sector is a key element for the world's economic activities, especially in this context of increasing food needs from year to year due to the high population growth recorded[1]. The world's population, which today fluctuates between 7.6 and 7.7 billion people, is expected to reach 9.8 billion by 2050[2]. As a result, agricultural production will have to be multiplied by 1.85 to reach the objectives set by the international community in terms of the fight against hunger[3].

Increased food production must be achieved through efficient and sustainable agriculture. An analysis of 93 developing countries predicts that global agricultural production will increase over the period 1998-2030 by 49% in rain-fed systems and 81% in irrigated systems[4-5]. However, rain-fed agriculture, which accounts for the largest part of global food production, is threatened by climate variability and change[6]. Thus, much of the additional food production is expected to come from irrigated land with three-quarters of which is located in developing countries[5]. Thus, it is necessary to turn to irrigated agriculture, which will help to meet the water needs of crops for the whole season. However, irrigated agriculture is by far the largest user of freshwater, accounting for about 70 percent of global withdrawals[7].

In Senegal, the agricultural sector accounts for 60% of the GDP and is based on cash crops (groundnuts, cotton), food and subsistence crops (millet, sorghum, maize), and mainly on rice cultivation and market gardening[8-9]. Market gardening in Senegal is monopolized by onion (Alium cepa) production, which extends particularly to the north, in two of the country's agro-ecological zones. The Niayes zone, which produces 80% of the country's vegetables, and the River Valley provide this essential commodity to a highly consuming population[10].

Onion is a vegetable very sensitive to water stress because it has a superficial root system. Thus, a lack of water during the vegetative phase can result in a delay in bulb development[11]. In the northern zone of the Niayes, onion is irrigated from groundwater. Manual dewatering and watering remain largely dominant on predominantly sandy soils, thus intensifying the risks of water wastage. Therefore, water productivity monitoring could be a key tool for irrigation management in this area.

Several studies have been carried out to assess water productivity, especially in irrigated agricultural systems in order to improve irrigation water management. Rashidi and Gholami[5] proposed to assess the water productivity of several vegetable crops to determine which crop consumes less water with higher or lower yield. Already, Sanon[12] was working on the optimization of irrigation in the onion plot in the Sahelian climate (northwest of Burkina Faso).

Recently, Gebremedhin et *al*.[13] did the same study on onion in Ethiopia, showing that water productivity is higher when irrigation is reasoned according to crop needs. As far as we know, no study in this sense has been done in northern Niayes. This research aims to assess onion water productivity in five lowlands in the Niayes area of Senegal.

MATERIALS AND METHODS

Study area: The study is located in the northern Niayes, and concerns five (05) market gardening lowland: Deur Diabi, Boul Ayni, Lac Kalassane, Ferset Ndoye and Nguethiouro **(Figure 1)**.

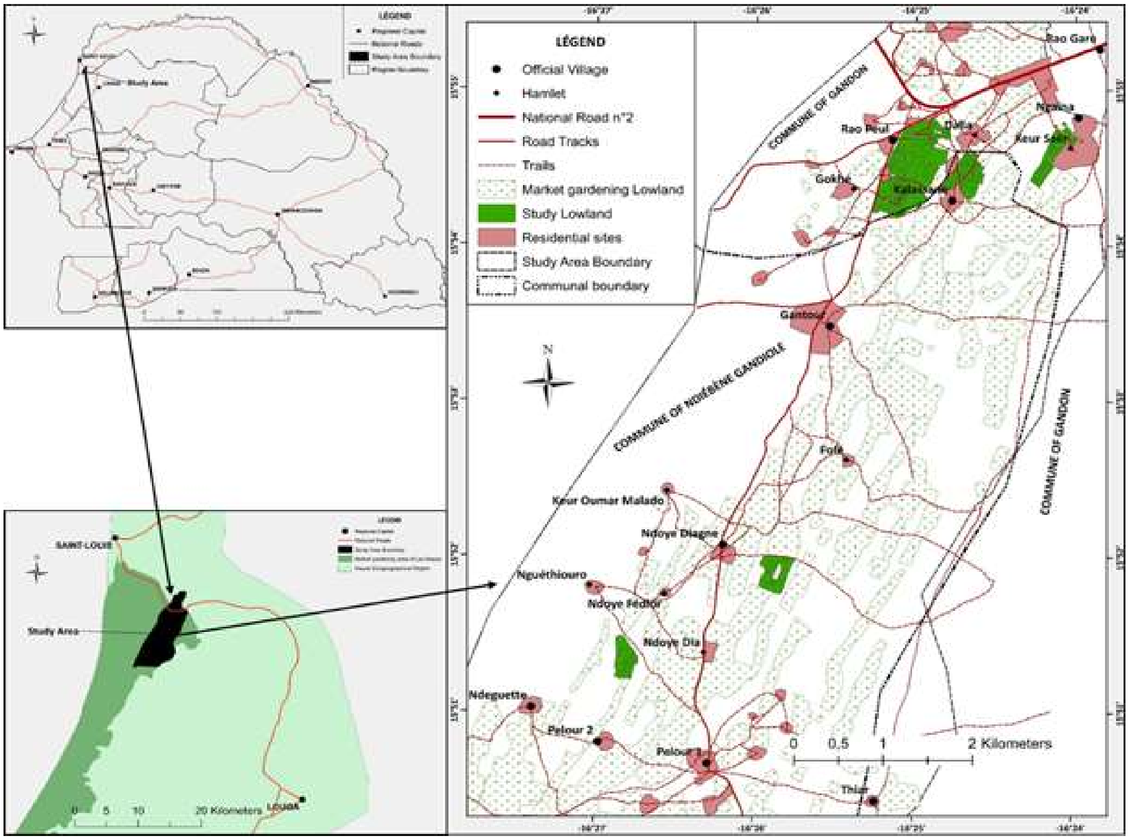

Figure 1: Location of the study area

Climate and ecology of the study area: Climate in the study area is Sahelian with a long dry season from October to June and a short rainy season of three months. Average annual temperatures are between 23.7°C and 25°C. The highest average monthly temperatures are between 35 °C and 37 °C and occur during rainy season. From November to February, minimum and maximum temperatures are below 18°C and 28°C respectively. Relative air humidity remains high and reaches 90% near the coast, with minima above 15% in the inland parts of the Niayes. Average annual precipitation is low and rarely exceeds 300 mm/year. In this area, the overall geomorphology is a mosaic of dunes and inter-dune basins with flat bottoms, more or less incised, where soils are formed with little evolution of input, poor and very susceptible to erosion[13].

Data and methods: Data collected in this study come from surveys carried out on plots level in the five lowlands from August 26 to September 19, 2019, with a semi-structured questionnaire administered to producers owning plots. Also, measurements of water volume and yields collected were done.

Sampling frame: The sampling frame consists of a list of 216 plots from the five lowlands. The Sample size was calculated using the formula of Giezendanner (2012). For this study, margin of error of ε = 5% and 95% confidence interval was chosen; this resulted in a sample size of 123 plots. To determine sample size at each lowland, a sampling rate was calculated (56.9%) based on the overall sample size and the total number of plots **(Table 1)**.

Table 1: Sample size by lowland.

Lowland	Nomber of plots	Sample size
Deur Diabi	110	63
Lac Kalassane	36	20
Boul Ayni	32	19
Ferset Ndoye	23	13
Nguethiouro	15	9
Total	216	123

Determination of total volume of water applied: The total volume of water used was estimated from the number of buckets used per irrigation unit and per irrigation day, the volume of buckets and the number of irrigation days per crop throughout a season. The number of irrigation days **(Equation 1)** was obtained from the frequency of irrigation and the crop cycle of speculation. These two parameters were obtained from field surveys. The number of days of irrigation was obtained from crop cycle and number of rested days (without irrigation).

$$\text{Number of day of irrigation} = \text{Crop cycle} - \text{Number of rest day} \quad (\text{Eq. }1)$$

The number of irrigation days was multiplied by the volume of water applied per irrigation day per unit to determine the total volume of irrigation water applied to a unit (TVU) **(Equation 2)** throughout the season for a given crop.

$$\text{TVU} = \text{Number of buckets} * \text{Volume of bucket} * \text{Number of irrigation day} \quad (\text{Eq. }2)$$

Number of buckets per unit was obtained from field surveys and area harvested was obtained by measurement from the Field Area Measure (FAM) application. Unitary area (Sp) was calculated from dimensions such as length (L) and width (l) of each unit obtained using a decameter. Length (L) was multiplied by width (l) to obtain the unit area (Sp), as shown in **Equation 3**:

$$\text{Sp} = \text{L} * \text{I} \quad (\text{Eq. }3)$$

Where Sp is surface area of units (m2), L is length of units (m), and l is width of units (m).

Total volume is divided by the area of the unit and then multiplied by the area cultivated **(Equation 4)** to obtain the volume brought in throughout the season.

$$Ve = \frac{Se}{Sp} * VTP \quad (\text{Eq. }4)$$

Where Ve is Volume of water (m3/ha), Se is Cultivated area (ha), Sp is Surface area of units (ha), and VTP: Total volume of water per unit (m3/ha).

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Yield determination: Yield was determined based on production and area cultivated. Production was obtained from interviews and calculations based on the number of bags obtained per area cultivated and the weight of the bags. Number of bags was multiplied by weight of each bag to determine production. This production corresponds to the quantity of products expressed in kg per area cultivated. Production was divided by cultivated area expressed in ha and then converted into tons (t) in order to estimate the average yield of each speculation in Gandiolais area.

Water productivity calculation: the formula proposed by IWMI[14] and Dembélé et *al.*[15] **(Equation 5)** was used:

$$PE = \frac{P}{Ve} \quad (Eq. 5)$$

Where PE is Irrigation Water Productivity or Physical Water Productivity (kg.m-3), Ve is Volume pumped or Volume of water abstracted at source for irrigation m3/ha, and P: Yield (kg/ha).

RESULTS AND DISCUSSION

Applied irrigation water: The volume of applied water varied across and within lowlands **(Figure 2)**. For Lac Kalassane lowland, the minimum value is equal to 5475 m3/ha and the maximum is estimated 9170 m3/ha with an average of 7485 m3/ha. At Nguethiouro lowland, the lowest volume of water applied is estimated at 5500 m3/ha and the highest at 9428 m3/ha. For this lowland, 67% of the farmers are using motorized dewatering. For the Boul Ayni basin, the volumes applied vary between 4245 and 7330 m3/ha, with an average applied volume of 6267 m3/ha. Half of the quantities of applied water are below the average value. For the Ferset Ndoye basin, the average volume of water is 6779 m3/ha with minimum and maximum values of 5500 and 8250 m3/ha, respectively.

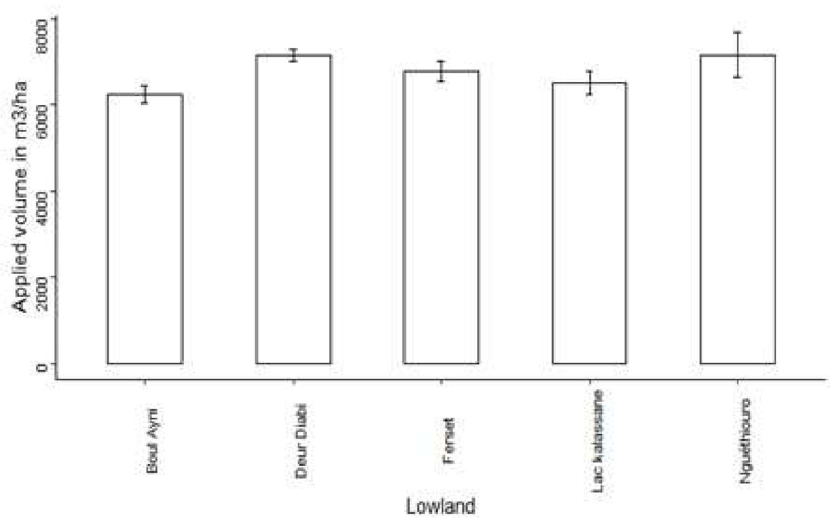

Figure 2: Average volume of water applied per lowland

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In the Deur Diabi lowland, the maximum applied volume reaches the value of 9500 m3/ha. This value corresponds to the farmers using pipe irrigation system. In this lowland, 16% of farmers apply water volumes below 6000 m3/ha with a minimum value of 5230 m3/ha and 84% of the growers apply volumes very close to or above 7000 m3/ha.

The average applied volume is greater than 6000 m3/ha for all five (05) lowlands **(Figure 2)**. It is highest in Lac Kalassane lowland (7485 m3/ha) followed by Deur Diabi (7154 m3/ha) and Nguethiouro (7050 m3/ha) lowlands.

The volumes of water applied are higher in Lac Kalassane and Nguethiouro lowlands. This could be explained by the fact that motorized dewatering is the most used method in these two lowlands by the farmers, which facilitates access to water. It should also be noted that in these lowlands irrigation frequencies are very close together, so the number of irrigation days is much higher.

For the Ferset Ndoye lowland, most farmers have manual dewatering. Access to water is difficult in these conditions, which could justify the moderate use of water in this basin compared to the others. Boul Ayni lowland is the lowland where the volumes brought for crop production are lower. In this lowland, more than 90% of the farmers are still using manual dewatering with sometimes very deep wells. This could explain the moderate use of water compared to the others lowlands. Irrigation frequencies are very far apart and the number of irrigation days is less important.

Onion yield: Yields obtained vary between 17 and 35 t/ha, with an average of 27.5 t/ha. Results **(Figure 3)** show yield value range from 17 to 32 t/ha in Boul Ayni lowland, 22 to 30 t/ha in Ferset Ndoye lowland, 27 to 30 t/ha in Nguethiouro lowland, 20 to 35 t/ha in Deur Diabi lowland and between 21 and 35 t/ha in Lac Kalassane lowland. The lowest yield was observed in Boul Ayni lowland (17 t/ha) and the highest in those of Lac Kalassane and Deur Diabi lowlands (35 t/ha).

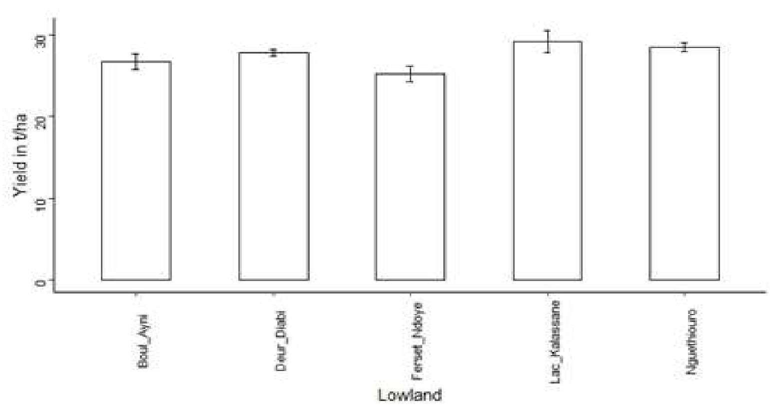

Figure 3: Onion yield per lowland

In Senegal, onion crop yields obtained in the literature vary widely. They vary on average between 19 t/ha and 21 t/ha in the groundnut basin. In the Senegal River Valley, yields vary from 10.7 t/ha[16] to 32 t/ha[17]. According to SAED, production reached 107,646 tons during 2012/2013 for a yield level of 24 t/ha. The year 2011/2012 was better in terms of yield obtained by farmers, settling at 32 t/ha. De Bon et *al*.[18] indicate a yield of between 25.4 and 25.7 t/ha between 2013 and 2014 in Senegal. Thus, onion yield in the five (5) lowlands studied is more or less acceptable on national scale in comparison to the results presented above.

Onion Water Productivity: Water productivity values are variable within farmers in the same lowland. Results of **Figure 4** shows that the highest values are recorded in the Nguethiouro and Lac Kalassane lowlands. For this purpose, onion crop water productivity varied between 3.15 and 4.85 kg/m3 in Nguethiouro lowland, 3.41 and 4.83 kg/m3 in Lac Kalassane lowland, 3.94 and 4.74 kg/m3 in Boul Ayni lowland, 3.2 and 4.33 kg/m3 in Deur Diabi lowland, and 3.6 and 4.31 kg/m3 in Ferset Ndoye Lowland.

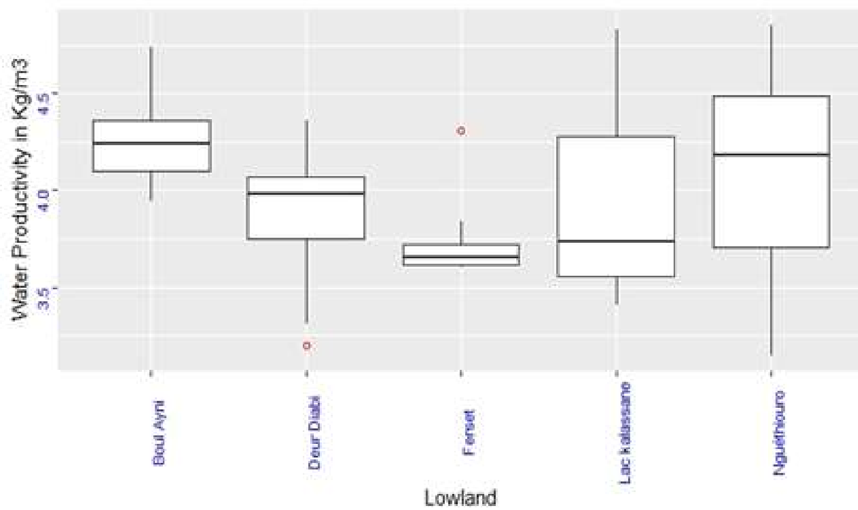

Figure 4: Variation in water productivity of Onion by lowland

However, the highest average values of onion crop water productivity are observed in Boul Ayni lowland, followed by Nguethiouro and Lak Kalassane lowlands **(Figure 5)**.

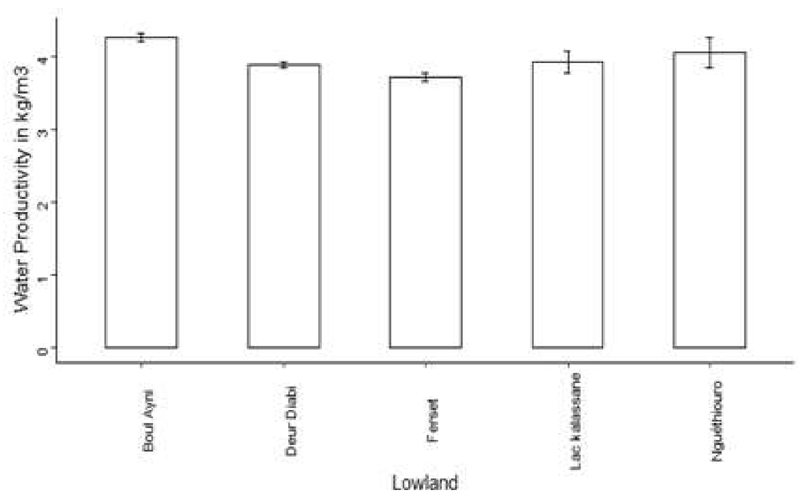

Figure 5: Average onion water productivity per lowland

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Results show that the mean water productivity values of onion are estimated at 4.27 kg/m3, 4.06 kg/m3, 3.93 kg/m3, 3.9 kg/m3 and 3.72 kg/m3 in Boul Ayni, Nguéthiour, Lac Kalassane, Deur Diabi and Ferset Ndoye lowlands, respectively.

Differences in water productivity between lowlands are related to differences in applied water volumes and yields. Water productivities in onion crops are generally low corresponding to the lower value of the water productivity ranges proposed by Molden et *al*.[19]. These reference values range from 3 to 10 kg/m3. However, onion Water productivity calculated by Kouanda[20] varied between 0.63 and 4.77 kg/m3 in Niger, 3.13 kg/m3 in Burkina Faso and 2.88 and 4.95 kg/m3 in Senegal (Mbawane and Keur Mbir Ndao). These results are reasonable at national scale and even in some areas, namely Niger, as indicated above. However, these values are relatively low in comparison to the values given by Molden et al. In these areas, farmers provide a large amount of water to harvest at the end of the season low crop yield in relation to the amount of water applied to the crops.

CONCLUSION

The objective of this study was to assess onion irrigation water productivity in the northern Niayes area in Senegal. A survey was carried out on a sample of 123 plots in Deur Diabi, Boul Ayni, Lac Kalassane, Ferset Ndoye, and Nguethiouro lowland. Results show that onion water productivity varies across and within lowland varying from 3.2 to 4.74kg/m^3. These values are low compared to references values varying between 3-10 kg/m^3. Low values of onion water productivity in the area is mainly due to high irrigation applied water. This should lead to a deeper investigation of irrigation management in order to use the resources in an optimal way.

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Corresponding author:** ***Lamine Diop

Agronomic Sciences, Aquaculture and Food Technology (S2ATA) UFR, Gaston Berger University, Saint-Louis, Senegal, lamine.diop@ugb.edu.sn

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