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ESTIMATING RICE IRRIGATION WATER REQUIREMENT DURING THE OFF-SEASON IN THE OFFICE OF IRRIGATED LAND OF BAGUINEDA (OPIB), MALI

Research article

Abstract

Rice is one of the main crop growths in Mali and the water availability constitutes a limiting factor for rice productivity in Mali. A better monitoring for irrigation water productivity requires a significant improvement in the knowledge of management of crop water needs. The present study aims to determine the water requirement and develop a planning schedule for rice irrigation during the off-season in a zone of the “Office du Perimètre Irrigué de Baguinéda (OPIB)”. The reference evapotranspiration by Penman-Monteith is used to determine the crop water requirement and irrigation calendar is analyzed for different planting dates (2nd and 3rd dekade of January, 1st and 2nd dekade of February). Results reveals that the amount of water used for irrigation is much higher than the water required by rice during the off-season cropping. A reduction in irrigation water needs of about 200 mm could be achieved by delaying the transplanting to the end of January or early February. The fraction of useable water is slightly higher for the planting dates of 3rd dekade of January, 1st decade of February. These two dates of planting are best compromised reducing the net irrigation water with increase water usability. Unfortunately, the existing irrigation practice at OPIB does not consider a such irrigation schedule and the fields are continuously flooded. Effort needs to be deployed to have adequate irrigation infrastructure. Irrigation control and scheduling tools must be provided to technicians in charge of irrigation.

Keywords: evapotranspiration, irrigation water requirement, OPIB, Mali.

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ОЦЕНКА ПОТРЕБНОСТИ В ВОДЕ ДЛЯ ОРОШЕНИЯ РИСА В МЕЖСЕЗОНЬЕ В УПРАВЛЕНИИ ОРОШАЕМЫХ ЗЕМЕЛЬ БАГИНЕДЫ (OPIB), МАЛИ

Научная статья

Аннотация

Рис является одной из основных сельскохозяйственных культур в Мали, и доступность воды является ограничивающим фактором для урожайности риса в Мали. Улучшенный мониторинг продуктивности воды для орошения требует значительного улучшения знаний об управлении потребностями сельскохозяйственных культур в воде. Настоящее исследование направлено на определение потребности в воде и разработку графика планирования орошения риса в межсезонье в зоне «Office du Perimètre Irrigue de Baguinéda (OPIB)». Эталонная эвапотранспирация по Пенману-Монтейту используется для определения потребности сельскохозяйственных культур в воде, а календарь орошения анализируется для различных сроков посева (2-я и 3-я декада января, 1-я и 2-я декада февраля). Результаты показывают, что количество воды, используемой для орошения, намного выше, чем вода, необходимая рису во время внесезонного посева. Сокращение потребности в оросительной воде примерно на 200 мм может быть достигнуто за счет переноса пересадки на конец января или начало февраля. Доля полезной воды несколько выше для сроков посева 3-я декада января, 1-я декада февраля. Эти две даты посадки лучше всего скомпрометированы, сокращая чистую поливную воду с увеличением полезности воды. К сожалению, существующая практика орошения на ОПИБ не предусматривает такой график орошения, и поля постоянно затапливаются. Необходимо приложить усилия для создания надлежащей ирригационной инфраструктуры. Технические специалисты, отвечающие за ирригацию, должны иметь инструменты контроля и планирования орошения.

Ключевые слова: эвапотранспирация, потребность в оросительной воде, ОПИБ, Мали.

1. Introduction

In West African Sahel, the precariousness of rainwater impacts the profitability of the agro-pastoral sector which constitutes the employability of more than 80% of the rural world [1], [2]. This lack of rainwater is one of the main factors limiting their sustainable development. This deficit corresponds to the result of the alteration of the hydrological cycle, under the combined effect of climate change, poor knowledge of water management in irrigation agriculture due to farmers' lack of information [3], [4]. The agricultural sector, considered an engine of economic growth and an effective tool in the fight against rural poverty. This sector consumes between 80% and 90% of the water resources in the country [5] although it experienced a major crisis of poor rainfall. As result of the global warming, water availability in West Africa is projected to decrease towards the end of the twenty-first century by − 0.418 mm/day [6].

Rice is one of the main crop growths in Mali and the water availability constitutes a limiting factor for rice productivity in Mali. According to Global Water Initiative [7]. 75% of the active population in Mali is dependent on agriculture representing 40% of GDP and irrigated agriculture makes up 34% of the country's agricultural production. Approximately 2,200,000 hectares are deemed to be suitable for the development of irrigated agriculture in Mali but only 20% of this land is currently developed [7]. Rice is crop with high water demanding and the country water resources (i.e., rivers) are significantly impacted by seasonal rainfall. The vulnerability of the country to climatic phenomena is mainly due to the low level of adaptation of the agricultural sector to these rainfall disturbances and the difficulty of undertaking better development of agricultural water resources.

Since the rainfall is considerably irregular in Mali, it is more important than ever to have an irrigation system which reduce water use, and increase yields. The accurate determination of crop water needs and an irrigation schedule is a time-consuming and complicated process [8]. Water loosed by crop through evapotranspiration is an appropriate approach to determine crop water needs. Evapotranspiration can be evaluated with lysimeters as in a case study in the areas of the Office du Niger, Mali [9] or it can be estimated from atmospheric variables as using Penman-Monteith equation [10]. However, a better monitoring for irrigation water use efficiency requires a significant improvement in the knowledge of the management of crop water needs [11]. Thus, the present study aims to determine the water requirement and develop a planning schedule for rice irrigation during the off-season in a zone of the “Office du Perimètre Irrigué de Baguinéda (OPIB)”.

2. Methods

2.1. Study site

The study is done in the Office du Périmètre Irrigué de Baguinéda (OPIB) located near Bamako, aside of Niger river extending over an area of approximately 990 km² (Figure 1).

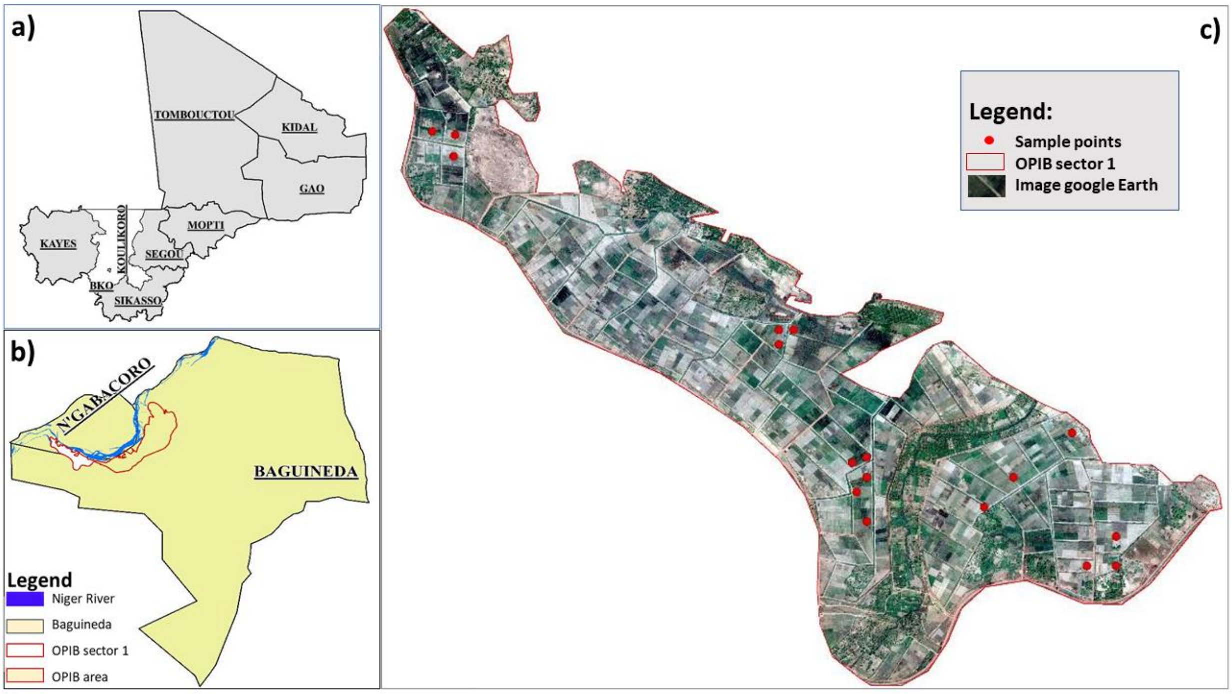

Fig. 1 − The Office of the Irrigated Perimeter of Baguinéda (OPIB)
a − study area showing by the map of Mali; *b* − the administrative district of Baguineda; *c* − the google Earth image of irrigated rice farm of OPIB and sampling points in red dot

The main climatic variables considered are: air temperature, relative humidity, wind speed, sunshine duration, precipitation and reference evapotranspiration (ETo). Analyses are performed with 10-day mean referred by dekade.

2.2. Characteristics of the crop

Rice is the crop understudy characterized by a crop coefficient (Kc) which is used to determine the real evapotranspiration of the crop (ETc). Kc varies depending to the type of plant and the vegetative stage. The Four phases during the rice cycle are initial phase (Kc = 1.1), development phase (Kc = 1.1), mid-season phase (Kc = 1.25) and end-season phase (Kc = 1.0).

2.3. Soil parameters

The hydrodynamic parameters of the soil are obtained from 34 soils samples processed at the Laboratory of Optics, Spectroscopy and Atmospheric Sciences (LOSSA) and using Pedo-transfer functions. The variables measured are the Field capacity, Wilting point, Maximum infiltration rate and Saturation. The deep percolation rate estimated in the study field varies 0.5 to 0.9 mm/s.

2.4. Reference evapotranspiration

The cropwat software is used to determine the reference evapotranspiration using the Penman-Monteith equation (1) and the water loss by crop referring to crop evapotranspiration is determined following equation (2). Further details on ET0 equation can be found in water balance study in Neguela [10].

$$ET_o = \frac{0.408\Delta(R_n + G)d + \gamma\left(\frac{900}{T+273}\right)u_2(e_a + e_d)}{\Delta + \gamma(1 + 0.34u_2)} \tag{1}$$

$$\text{ETc} = \text{Kc} \times \text{ETo} \tag{2}$$

Irrigation water requirement was estimated as the total of crop actual evapotranspiration augmented by irrigation water losses to deep percolation. The runoff is neglected since the rice paddy was bordered by dikes. The influence of ground water is insignificant in the fields since the water rising rate is less than 0.15 mm/s.

3. Results and discussion

The climatic conditions in the study site are represented at seasonal basis in Figure 2. The highest temperatures are recorded in the site from March to May and the lowest temperatures are from December to January. Based on rainfall distribution, two seasons exist: a rainy season from May to October with a maximum monthly precipitation of about 300 mm falling in August and a dry season between November and April. The off-season irrigation is done during the dry season. During the off-season period, the evapotranspiration is very high revealing an excessive loss of water by crop. Also, the contribution of rainfall during the offseason is negligible.

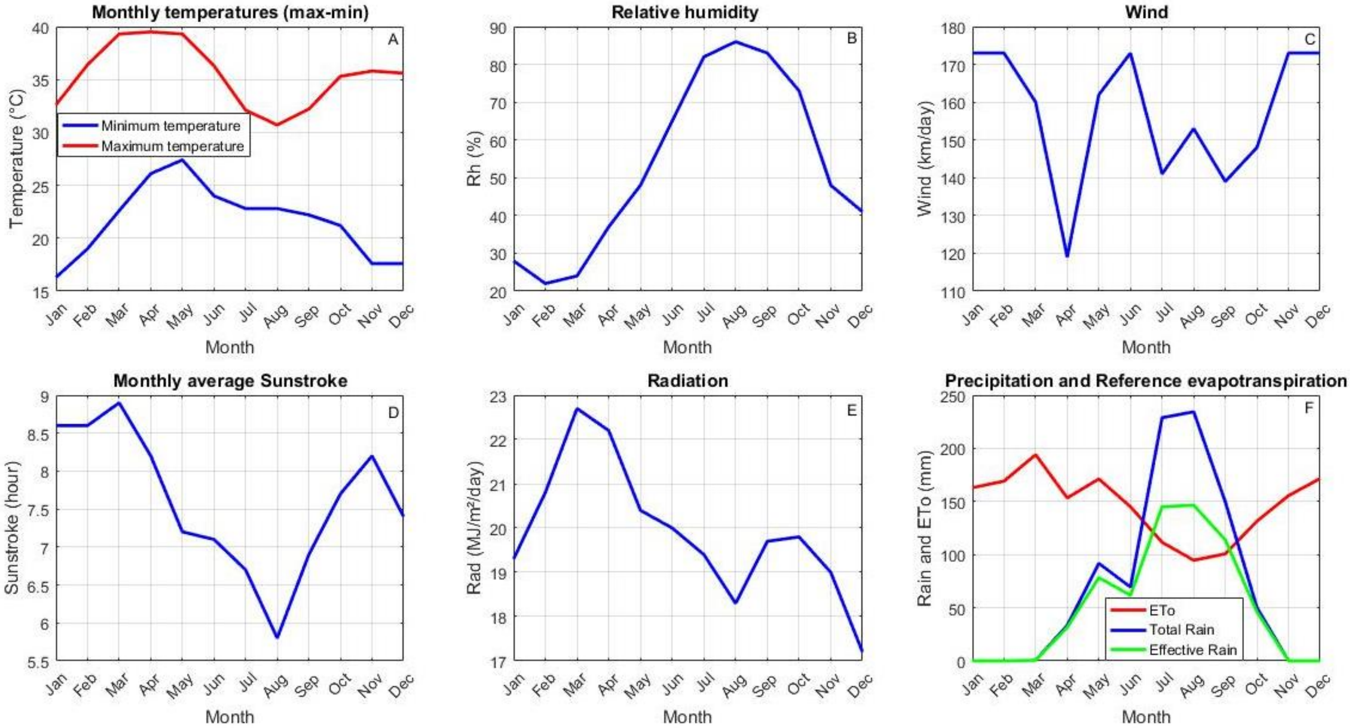

Fig. 2 − Seasonal variation of climatic parameters recorded at the study site in 2020

The irrigation calendar is a tool allowing farmers to organize themselves for water monitoring of their field over time in order to avoid errors in the quantity and timing of water supply to the crop. Table 1 provide the quantity of water needs to irrigate rice in each dekade from the nursery to the end-phase. Such calendar should be implemented for saving irrigation water and to avoid rice suffocation by overflooding which reduce yield. However, the irrigation infrastructure needs to be adopted and the irrigation technicians must be trained for implementing the scheduled irrigation calendar. Unfortunately, neither of these two measures is available at the OPIB.

Table 1 presents the quantity of water to bring to the rice during its cycle per decade to compensate for the deficit of the soil water stock. This result expresses the very crucial water requirement in the 4th dekade after the start of the planting with a quantity of irrigated water of 297.8 mm/dekade against plant water requirement of ETc = 61.1 mm/dekade. This high difference between plant water needs and irrigated water requirements is due to the immense water need for the mud formation of the soil and the transplanting of the rice seedling. After this date, the irrigation water requirement remains equal to the plant water needs ETc until the end of the 2nd dekade of mid-season and beyond this date, the ETc slightly exceeds the irrigation water requirement of the rice, which decreases towards the end of the crop cycle.

Table 1 − Water requirement scheduling at dekadal scale for planting start by the second decade of December

Month / dekade		Dekade from planting	Phase	Kc coeff	ETc	ETc	Rain eff.	Irr. Need
					mm/day	mm/dekade	mm/dekade	mm/dekade
December	2nd	1st	Nursery	1.15	0,63	1,9	0,0	1,9
December	3rd	2nd	Nursery	1,15	0,62	6,9	0,0	6,9
January	1st	3rd	Land preparation	1,15	1,65	16,5	0,0	69,6
January	2nd	4th	Initial	1,15	6,11	61,1	0,0	297,8
January	3rd	5th	Initial	1,15	6,21	68,3	0,0	68,3
February	1st	6th	development	1,18	6,86	68,6	0,0	68,6
February	2nd	7th	development	1,23	7,34	73,4	0,0	73,4
February	3rd	8th	development	1,28	8,20	65,6	0,0	65,6
March	1st	9th	Mid-season	1,33	8,63	86,3	0,0	86,3
March	2nd	10th	Mid-season	1,35	8,91	89,1	0,0	89,1
March	3rd	11th	Mid-season	1,35	7,67	84,4	0,6	83,8
April	1st	12th	Mid-season	1,35	7,26	72,6	0,0	72,6
April	2nd	13th	Late-season	1,33	6,04	60,4	27,8	32,6
April	3rd	14th	Late-season	1,23	6,63	66,3	1,0	65,3
May	1st	15th	Late-season	1,12	6,40	64,0	2,8	61,2
May	2nd	16th	Late-season	1,04	5,25	26,3	1,2	25,1

Figure 3 reveals that the amounts of irrigation water are higher for earlier planting dates as the crop water requirements are higher. Indeed, the last phases of the off-season coincides with the first rainy events in the study area. As the planting date delate, the rice season will extend to get closer to the rainy season and the effective rainfall increases in the rice field which covers a large part in irrigation water needs. Hence, a reduction in real irrigation water needs could be achieved by delaying the transplanting to the end of January or early February. The fraction of useable water is slightly higher for the planting dates of 3rd dekade of January, 1st decade of February. These two dates of planting are best compromised reducing the net irrigation water with increase water usability.

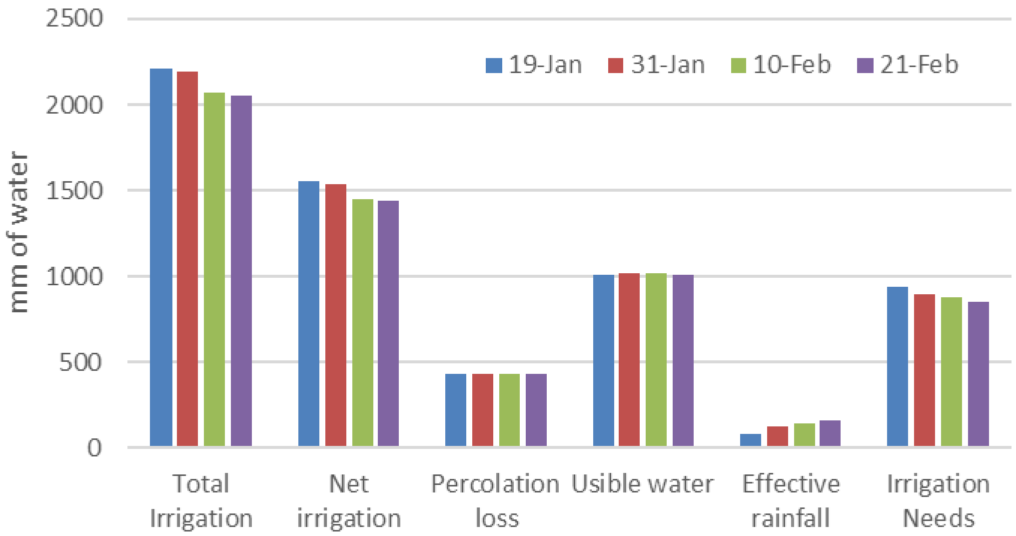

Fig. 3 – Rice irrigation parameters during the off-season of 2020 in OPIB

The crop coefficients used in this study were taken considering FAO recommendation [12]. Those Kc values depended strongly on the soil cover increased linearly from 1.0 for 10–70% soil cover and to 1.25 for 100% soil cover. This change of Kc is related to the peak of evapotranspiration observed during the period between development and Mid-season phases of rice. This peak of ETc is about 8.91 mm/day which is relatively higher than the value obtained elsewhere [12].

The amount of water needed to saturate the soil profile was estimated to 297 mm/dekade confirming the important water use of levelling at initial phase. After that, the water needed for irrigating rice field is not up to 90mm/decade and varies according the calendar established based on the amount of water loosed by the crop. CROPWAT is a powerful tools planning irrigation calendar. The seasonal irrigation water amount for transplanted rice found in this study varies according to the planting date from 1400 mm for the latest date to 1500 mm for the earliest date. The obtained values are higher compared to previous study with values up to 1110 mm [13]. Rice Irrigation planting date around 20 February gave the best option for using less irrigation water in OBIP. Nevertheless, very late starting of off-season may affect the field preparation for the coming rainy season. Unfortunately, the existing irrigation practice at OPIB does not consider a such irrigation schedule and the fields are continuously flooded. The height of the water layer under the rice plant was maintained at higher level about 5 to 15 cm above ground while the recommended depth of water to be maintained during different crop growth stages of rice is about 2-5 cm [8]. This situation observed at the OPIB could be explained by the absence of adequate irrigation infrastructure and lack of tools necessary for irrigation control.

4. Conclusion

This work fills a gap in the knowledge on estimating the water requirement of rice cultivation and the successes of applying the knowledge of water requirement on rice cultivation for irrigation projects is strongly linked to the creation of an enabling environment. Results of this study highlight the technical weakness in both irrigators and farmers organizations of the irrigated land to ensure the proper management of irrigation infrastructure and irrigation water. With the continuously flooding practice, the amount of water used for irrigation is much higher than the water required by rice (i.e 900 mm) during the off-season cropping in OPIB. Investigations revealed that the irrigator is in control of his irrigation schedule and 100% of the water applications to the plot are done without any estimation. The total irrigation is estimated to 2000mm which represents two times the useable water in the field (900 mm) demonstrating the extent of the water loss. These factors have a negative impact on the proper management of irrigation water in the irrigated land of Baguineda. Effort needs to be deployed to have adequate irrigation infrastructure. Irrigation control and scheduling tools must be provided to technicians in charge of irrigation.

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Conflict of Interest

None declared.

Конфликт интересов

Не указан.

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