« Analysis of the farmer's behaviors and the risk of exposure to the vector of Zoonotic cutaneous leishmaniasis in Tunisia »

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Abstract. This objective of this study is to analyze the behavior of farmers in two irrigated perimeters in the region of Sidi Bouzid (Tunisia) and evaluate the risk of exposing farmers to the vector of *Zoonotic Cutaneous Leishmaniasis* (ZCL). The method used is based on recording the periods of water use for irrigation. It is also based on formulating a parameter which reflects the simultaneous presence of both the farmer and the vector on the plot of land. The data collected showed that the El Hichria irrigated perimeter is saturated in its hydraulic infrastructure. The farmers are exposed to the risk of contact with the *Phlebotomus papatasi*, a vector of ZCL, of 0.25 on a scale of 1, associated with irrigation. The irrigated perimeter Ouled Mhamed showed no sign of saturation and no risk of exposure to the vector associated with irrigation. Studying the daily activity of the *P. papatasi* and generalizing the risk parameter to include different agricultural activities are two perspectives that could be used to improve the estimation of the risk of exposure of the farming population to the disease.

Keywords: Water, Irrigation, Farmer, ZCL, *Phlebotomus papatasi*, Risk

1. Introduction

People are drawn to places where there are water resources. The main reason for this behavior is because they provide Man, as well as animals, with drinking water. Farming, which ensures food for both humans and animals, can be considered as the second main reason that draws people to water. An analysis of the recent scientific publications on water resource management shows that the problems most often tackled are meeting demands for water (De Fraiture and Wichelns, 2010), improving water productivity (Molden et al., 2010), water use efficiency (Namara et al., 2010) and the effect of climate change on hydrological events.

However, water resources can be a source of numerous problems for Man. In addition to the extreme phenomenon due to climate change (flooding or drought), three types of problems related to farming can be specified. The first is that farming around water sources is generally marked by the development of irrigation. Farmers are thus required to respect certain restrictions related to crops and climate conditions. For example, it is not advisable to irrigate during the hottest periods of the day. The farmer is obligated to irrigate early in the morning, while the weather is still cool, or overnight. Thus he and those with him are exposed to bites from nocturnal insects, such as *Phlebotomus papatasi* (Rodhain and Perez, 1985), vectors of *Cutaneous leishmaniasis* (Killick-Kendrick, 1990). This insect, commonly known as a sandfly, is a dipterous insect of the suborder nematocera in the *Phlebotomidae* family, a proven vector of *Zoonotic Cutaneous Leishmaniasis* (ZCL) in Tunisia (Ben Ismail et al., 1987b, c). This parasitosis appears as skin lesions on the uncovered parts of the body which go away after a few months, leaving unsightly scars (Ben Ismail et al., 1985; Chahed et al., 1999). The second problem of intensive farming activity developing around a source of water is that it is generally accompanied by the development of ovine and bovine livestock farming. Raising animals holds a double interest for farmers. First of all, with livestock, farming becomes more profitable. Second of all, it becomes a source of organic matter (manure), essential to intensifying farming activity and protecting the fertility of irrigated soils. The conditions for collecting, storing and using manure on a large-scale farm, can, in the presence of enough humidity, provide favorable conditions for insects such as sandflies that are vectors of disease to develop, either directly, because shelter favoring their development is created, or indirectly, because a micro-climate favorable to their activities is created. The third problem of farming around water sources is that intensive crops irrigation is generally done using one of three types of irrigation techniques: the traditional method: Surface irrigation or the two newer methods: sprinkler irrigation and drip irrigation. Farmers' lack of training in irrigation techniques has always meant that large volumes of water are wasted on plots of land. High humidity is generally observed. Two consequences of this behavior can be seen: the first is the loss of economic profitability because water is being wasted; the second is the large amount of humidity present in the soil when it is enriched with manure at its surface, possibly meaning favorable conditions for the multiplication of sandflies which have a saprophytic larval phase (Rodhain and Perez, 1985). As a result of this, it is possible to propose that water resource management, in irrigated areas in particular, can on one hand, provide favorable conditions for sandflies to develop (Desjeux, 2001). On the other hand, it can favor the simultaneous presence of both the vector of ZCL and Man, in the same place. This would increase the workers' risk of exposure to bites by the vector.

This study has two main objectives. The first is to study the behavior of farmers in two irrigated perimeters (IPs) in the region of Sidi Bouzid (Tunisia) in relation to irrigation water use. The second objective is to propose a method that would allow the evaluation of the workers' risk of exposure to the vector of ZCL.

2. Methods

In order to meet the study's objectives, the behavior of farmers in relation to irrigation was analyzed. Given the organization of most farmers in the study area around Agricultural Development Groups (GDAs), and that the hydraulic function of the collective irrigation network is based on the use of individual irrigation terminals and thus reflects farmer behavior, the hydraulic function of two IPs, El Hichria and Ouled Mhamed, were monitored. In referring to official documents for reserving water towers set by the managers, a calendar of hourly irrigation schedules was drawn up for each IP. The El Hichria IP covers 163 ha, divided into four sectors, and has 163 farmers on it. Surface irrigation is used to meet the water demands of tree. The Ouled Mhamed IP covers a usable farming area of 76 ha, divided into three sectors, used by 60 farmers. The farmers of this IP use drip and sprinkler irrigation.

The water is pumped from a deep aquifer towards a holding tank. For the El Hichria IP, the water is distributed to the farmers by surface canals. In the Ouled Mhamed IP, underground pressurized water pipes bring the water to the irrigation terminals.

In order to evaluate the risk of exposure of farmers, as well as those who work with them, to *Phlebotomus papatasi*, a "risk" parameter was calculated which reflects the importance of the length of time that farmers and the vector of ZCL are together simultaneously in each IP. Equation (1) expresses this risk parameter:

$$Risque = \sum_{t=1}^{t=T\max} \sum_{h=1}^{24} \left(\frac{d(t,h)}{d_{\max}}\right) \times \frac{N_{ai}(t,h)}{N_{a\max}} \tag{1}$$

Where:

T_{max}: the calculation period of the risk parameter;

d(t, h): the density of the vector of ZCL during the day "t" at time "h";

d_{max}: the maximum density of the vector of ZCL in the study area;

$N_{ai}(t, h)$: the number of farmers irrigating during the day "t" at time "h";

N_{amax}: the maximum number of farmers who can irrigate at the same time.

The monitoring of farmer behaviour in the two IPs was carried out simultaneously during the months of July and August 2009. The IP risk parameter will thus be calculated for the two IPs for these 31-day periods. Within the framework of this study, and given the lack of local studies on hourly change in activity of the *Phlebotomus papatasi*, a hypothetical hourly modulation was drawn up taken from the scientific work of Morsy et al. (1995) and Coleman et al. (2007). It was taken into account that the activity of the vector starts heavily towards the end of the day (sunset), which was at 8 p.m. in the project area, and that it continued with the same intensity (100%) until midnight. From that time on, it was considered that the presence of sandflies decreased until reaching 0% around 5 a.m. during the months of July and August. Figure 1 details this modulation:

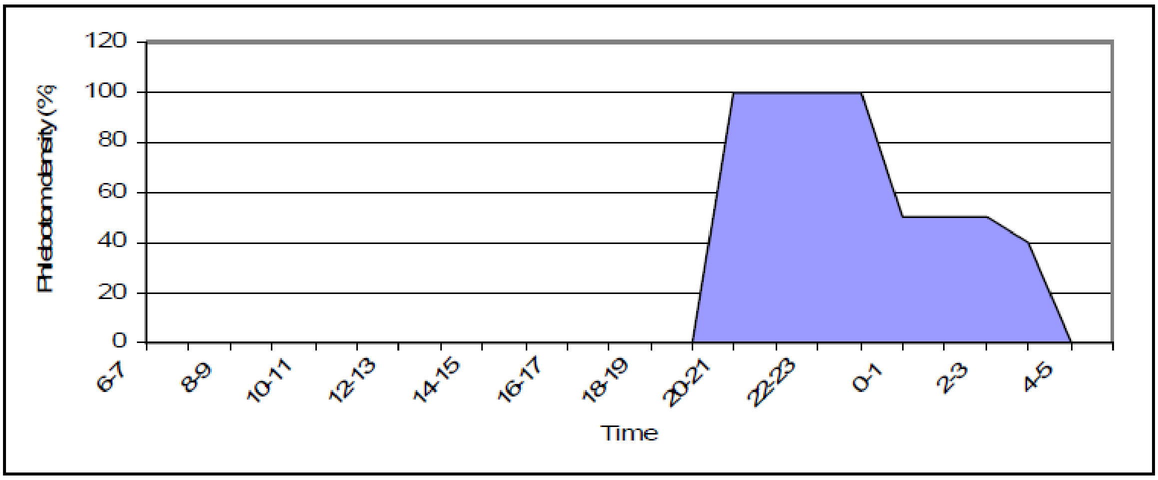

Fig. 1: Hourly modulation of the density of sandflies

The number of farmers working each day and at each hour is taken directly from the manager data base of each IP. The maximum number of farmers that can irrigate at the same time depends on the water distribution system of each IP. For the El Hichria IP, the collective network allows eight farmers to irrigate at the same time. For the Ouled Mhamed IP, the maximum number of farmers who can use water at the same time is 12.

3. Results and discussion

Figure 2 shows the monitoring of farmer behaviour in the El Hichria IP from the 1st to the 7th of July 2009. The farmers worked at about the same rate during the two months studied. Irrigation is started around midnight and goes on until 7 p.m. (Figure 2).

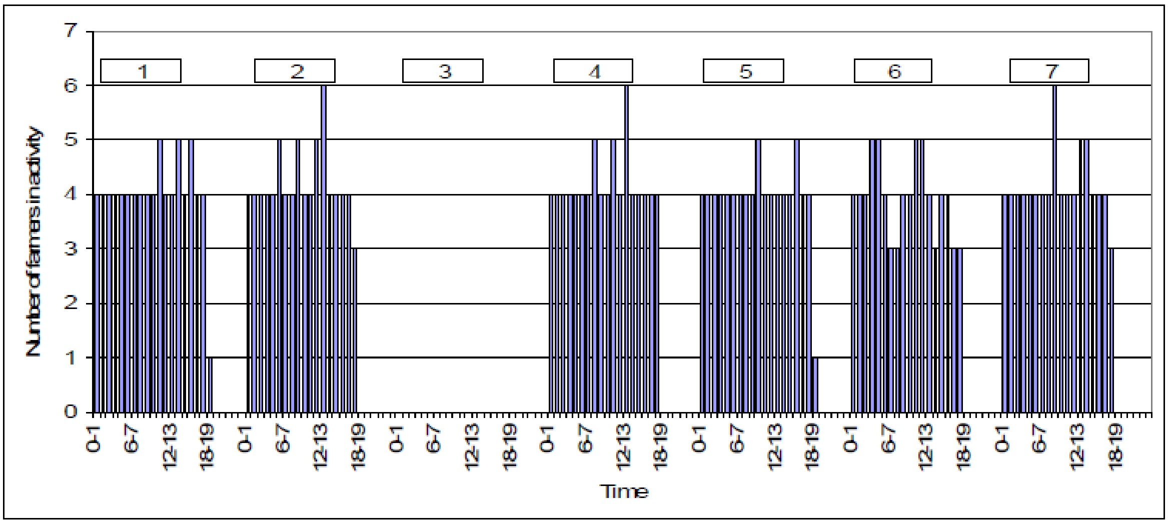

Fig. 2: Farmer activity in the El Hichria IP from July 1st to 7th, 2009

The previous graph shows that the number of farmers irrigating simultaneously in the El Hichria IP varies between 0 and 6. The same behaviour is observed in the month of August. As for the Ouled Mhamed IP, irrigation is shown to be generally carried out between 6 a.m. and 6 p.m. in July and between 5 a.m. and 4 p.m. in August. The calculation of the "risk" parameter in the case of the El Hichria IP made it possible to draw up daily graphs for the two months of study, namely July and August. Figure 3 reflects the hourly activity of farmers who were irrigating and the risk of their exposure to the vector of ZCL on August 1st, 2009.

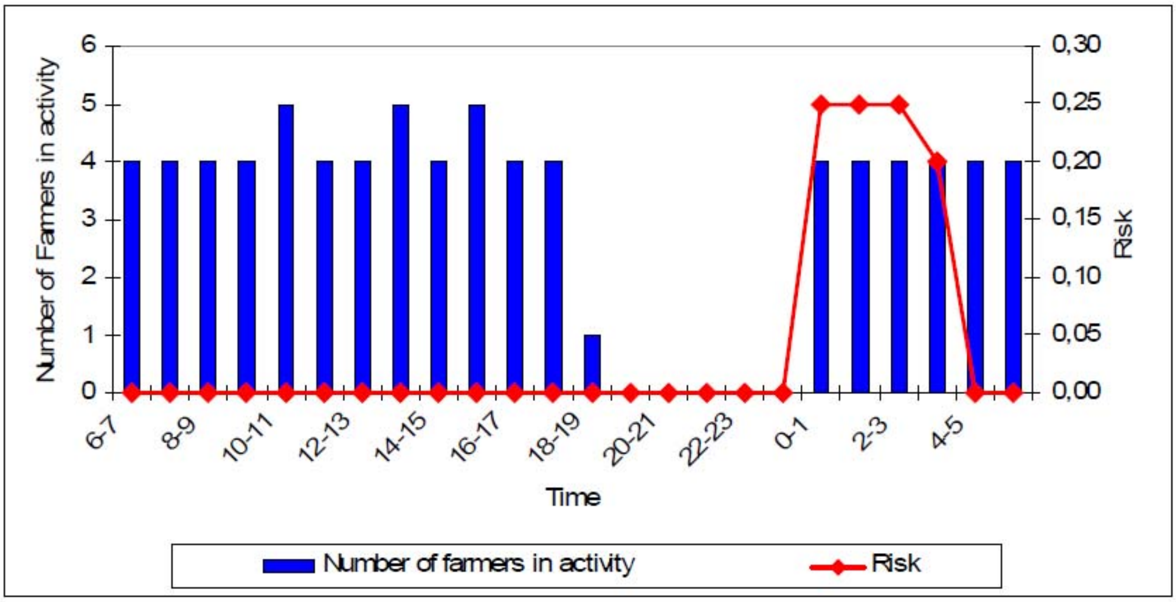

Fig. 3: Farmer activity in the El Hichria IP and the risk of exposure to *Phlebotomus papatasi* on August 1st, 2009

The above graph clearly shows that farmers in the El Hichria IP were relatively exposed to the disease. In fact, irrigating between the hours of 12 midnight and 5 a.m. greatly promotes contact with sandflies, and the maximum hourly risk is estimated at 0.25 on a scale of 1. For this day taken as an example, the total risk is estimated at 0.95. Calculation of the "risk" parameter for the months of July and August, characterized by the highest irrigation activity, showed that it rose to 28.6 and 16.7 in the El Hichria IP in July and August, respectively, compared to a maximum risk of 182.9. Analysis of farming activity in this IP revealed a large amount of two crops: olive trees and pomegranate trees, both of which require irrigation during the summer season (June, July, August and September). Seasonal truck farming in the area surrounding the IP is another cause of the high demand for irrigation water in the summer. The irrigation technique used in this IP also favours water loss through infiltration between the tank and the land plots to be irrigated. This increases the length of time required to irrigate the plots with the necessary amount of water. This farming and hydraulic situation has created a saturation of the water distribution system and has forced those in charge to schedule nighttimes hours for irrigation. This result suits most farmers who are aware of the fact that, in the summer, daytime irrigation can have an effect on production.

For the farmers in the Ouled Mhamed IP, irrigation activity holds no risk of exposure to ZCL. In fact, the "risk" parameter is zero for both July and August. It is important to note that farming activity in this IP is centred on olive trees. Seasonal truck farming is not very well developed, and the most active farmers in the IP are more interested in end-of-season farming. Added to this, the aging state of the IP hydraulic system, as well as the economic aspects of farming, discourages farmers from investing in intensive farming. Most are likely to maintain only olive orchards. Another point to add is the collective network as well as the irrigation techniques used (sprinkler and drip) which positively alleviate the system of saturation by reducing water loss. These aspects minimize the need for irrigation water. Therefore, it is not necessary to resort to nighttime's irrigation.

These last results clearly show that the risk of exposure to ZCL depends on the schedule for managing available water resources, hydraulic infrastructures and the activity of the vector. Irrigation is not in fact a determining factor. Instead, it is the structure of the hydraulic system and how the water is managed by those in charge of the IP which must be adapted in order to limit exposure to ZCL associated with irrigation.

4. Conclusion and recommendations

This study showed that the behaviour of farmers in relation to irrigation is imposed by the nature of the agricultural activity, by the hydraulic system and by the method of irrigation used. In the El Hichria IP, the high demand for water imposed an operation of 19 hours, a part of which was overnight. This situation led to risks estimated at 28.6 and 16.7 for the months of July and August, respectively. In the Ouled Mhamed IP, the farmers' demand for water was satisfied after a maximum of 12 hours of operation of the irrigation system. This made it possible for the farmers to stay away from the plots of land during the hours when the vector of ZCL was present. This study could be greatly improved by characterizing the seasonal and hourly activity of the vectors during a typical day in the study area. In addition, it may be possible to generalize the "risk" parameter proposed here to take into account all farming tasks, the most important being threshing, hoeing, pesticide treatments harvest. These activities generally start early in the morning and usually end after sunset and involve a greater number of people.

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