Impacts of irrigation water management on consumption indicators and exposure to the vector of Zoonotic Cutaneous Leishmaniasis (ZCL) in Sidi Bouzid, Tunisia

Irrigation water management is usually evaluated using technical, economic and environmental performances indicators. The impacts on human health were not decision maker’s priorities. This research objective is to analyze farmers’ behavior in two irrigated perimeters (IP) in Sidi Bouzid (Tunisia) and evaluates the risk of their exposing to Phlebotomus papatasi, the vector of Zoonotic Cutaneous Leishmaniasis (ZCL). It is also aimed to assess the relationship between irrigation management and practices and the exposure risk. The used method is based on recording water use activity, the vector presence and the formulation of a parameter reflecting the simultaneous presence of both the farmer and the vector on the irrigated plots. Farmer opinions were assessment by a survey among almost 80% of them. Results showed in El Hichria IP that due to irrigation practices, farmers are exposed to the contact risk with the vector of ZCL. The Ouled Mhamed IP showed no exposure risk. In the first IP, it was demonstrated the increase of farmers’ exposure risk to ZCL from 2011 to 2013, linked to irrigation water management and not to water use. It is proven by the survey that water exportation outside this IP accentuates the exposure risk. Adopted solution by participatory discussions is the improvement of farmers’ welfare by increasing their income.

Key words: Water access, Irrigation, Farmer, ZCL, Phlebotomus papatasi, Exposure Risk, Sidi Bouzid, Tunisia

INTRODUCTION

In arid and semi-arid regions, development is constrained by availability of natural resources. In agriculture regions, soil and water are among the main components required to initiate and maintain sustainable development. Decisions makers, engineers and farmers are always trying to harvest water and conserve soil for agriculture production and to provide drinking water for peoples, animals and environment needs. When surface water is leaking, the cases of most of the arid (semis) regions, big efforts are deployed to take profit from groundwater. As direct result of this development approach, agriculture production is raised and economic activities established between production and consumptions regions. Each development approach can have medium and long terms negative impacts on the environment and the Human health.

However, water resources can be a source of numerous problems for people. Research on water resource management shows that the problems most often tackled are meeting demands for water (De Fraiture and Wichelns, 2010) when shortage characterizing the water balance, improving water productivity (Molden et al., 2010), water use efficiency (Namara et al., 2010), the effect of climate change on hydrological events (Bates et al., 2008; IPCC, 2013), the impact of population growth and the management options on aquifers behaviour (Haddad et al., 2013), aquifers depletion and, consequently, the increase in energy consumption by pumping (Fonseca et al., 2013), the waters quality degradation due to the salinization problem
as consequence of over pumping (Gholami et al., 2010), salts recycling by irrigation, water-rocks interactions processes (Mongelli et al., 2013) or seawater intrusion for coastal aquifers (Singh, 2014). Several research dealing with technical water resources management problems were published (Koutsoyiannis et al., 2003; Mysia et al., 2005; Rees et al., 2006; Khare et al., 2007; Letcher et al., 2007; Li et al., 2007; Giupponi, 2007; Moradi-Jalal et al., 2007; Prato and Herath, 2007; Van Cauwenbergh et al., 2008; Ayvaz, 2009; Coelho et al., 2012).

Healthy problem linked to water are mostly due to consumption of water with non-acceptable quality. Rich scientific literature dealing with impacts of water quality on human health is available. This research deals with a particular impact of the agricultural development of semi-arid region in central Tunisia (Sidi Bouzid) on human health. Agricultural development projects (irrigated perimeters) in the communities of El Hichria and Ouled Mhamed transformed the local landscape, ecology and the socio-economic context.

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 and thus the farmer is constrained to irrigate early morning or overnight, while the weather is still cool. Thus, he and those with him (children, wife or workers) 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., 1987). This parasite 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 sheep and cattle livestock farming. Raising animals holds a double interest for farmers. First, with livestock, farming becomes more profitable. Second, 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 favouring 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 surface, sprinklers or 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 behaviour 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 favour the simultaneous presence of both the vector of ZCL and people, in the same place. This would increase the workers’ risk of exposure to bites by the vector.

ZCL is a public health issue for the Mediterranean region (Ebehalt et al., 2014). It is a major and growing public health issue in Tunisia. More than 100,000 cases have been reported since its emergence in the early 1980s (Toumi et al., 2012). The most important foci of disease is in the Sidi Bouzid Governorate in central Tunisia (Figure 1), which reports 25-30% of ZCL cases annually (Salah et al., 2007). In this region, 41.7% of the population are involved in the agriculture activity.

In order to contribute to the efforts to resolve this “Eco-Health” problem, the objective of this work is the analysis of irrigation water management performances and the assessment of the relationship between the exposure risk of farmer’s, and their families members and workers, to ZCL and water management.

The novelty of the proposed research is its transdisciplinary approach driven along about five years to understand the problem, to assess partner’s opinions and to discuss the situation and solutions with stakeholders. Agronomy, water resources management, entomology, epidemiology and socio-economy specialities were involved in this research.

METHODS

Study area

The study area is composed by two IP situated on either side of the Garat Njila seabka (Latitude 34°52’17.54”N, Longitude 9°29’36.69”E), a saline land that is home to a large population of Psammomys obesus, the rodent reservoir host. It plays a critical role in sustaining the stable endemic-epidemic pattern of disease here (Figure 2).

The El Hichria IP (Latitude 34°52’33.92”N, Longitude 9°26’40.35”E) covers 163 ha, divided into four sectors, and has 163 farmers on it. Surface irrigation is used to meet the water demands of olive tree, the main agriculture activity of both IP. The access to water is set to 10 hours/ha per month equivalent to 720 m3/ha per month and one irrigation by 15 days. The Agricultural Development Groups (GDA) has the role to allocate water between farmers according to their demands. When a farmer plans to irrigate
his plot, he must first pay a water bill and then the GDA schedule his irrigation.

The Ouled Mhamed IP (Latitude 34°52'15.23"N, Longitude 9°30'35.16"E) covers 76 ha, divided into three sectors, used by 60 farmers. Farmers of this IP use mostly drip and sprinkler irrigation. The supply system is a pressurized network and each plot is equipped by a valve that allows farmer to irrigate at any time (on-demand system). At the end of each month, the water bill is communicated to farmers for payment.
The irrigation water is pumped from a deep aquifer towards a holding tank. In cold and moderate periods (autumn, winter and spring) the irrigation activity is scheduled during the day. In hot periods (summer), irrigation usually performed along the day and by night due to high water demand by farmers, especially in El Hichria IP.

The average rainfall of the region is about 300 mm/year (± 118 mm). More than the half (53.0%) of the rain is recorded in the moderate and hot periods (March to September). Figure 3 resume the yearly rain (top) and monthly average rain (bottom) of the pilot study from 1971-72 to 2007-08 hydrologic years:

**Analysis of irrigation water management performances**

Given the organization of most farmers in the study area around (GDAs), and that the hydraulic function of the collective irrigation network based on the use of individual irrigation terminals and thus reflects farmer behaviour, the hydraulic function of two irrigated perimeters (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 number of farmers working each day and at each hour is taken directly from the manager data base of both IPs. The maximum number of farmers that can irrigate at the same time depends on the water distribution system. 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.

Irrigation water management is evaluated based on two performances indicators computed on the peak irrigation water consumption period (July and August):

- The duration of irrigation per month, that can be converted on water consumed by irrigated plot using the flow rate 72 m³/h.
- The irrigation frequency: the duration between two successive irrigations for the same plot.

These two parameters can evaluate the water management performances of the GDAs and estimate their governance capacities.

**Evaluation of the exposure risk of farmers, their families and workers to ZCL**

In order to evaluate the risk of farmers exposure, as well as those who work with them, to the vector of ZCL: *Phlebotomus papatasi* (PP), we propose in equation 1 a formulation of a dimensionless "risk" parameter “ER\_LCZ” which reflects the importance of the length of time that farmers and the vector of ZCL are in the plot simultaneously due to agriculture activity.

\[
ER\_LCZ = \sum_{plot=1}^{N_{plot}} \left( \sum_{t=1}^{T_{max}} \sum_{h=1}^{24} \sum_{a=1}^{N_{a}} \frac{d(t,h)}{d_{max}} \times \frac{N_{w}(a,t,h)}{N_{a \text{ max}}(a)} \right)
\]

Where:
- plot: indices of plots in an IP,
- \(N_{plot}\): Number of plots in an IP,
- \(t\): indices of days,
- \(T_{max}\): the calculation period of the risk parameter;
h: indices of hours,  
\( a \): indices of an agriculture activity,  
\( N_a \): Number of agriculture activities,  
\( d_{\text{max}} \): the maximum density of the vector of ZCL in the study area;  
\( d(t, h) \): the density of the vector of ZCL during the day “t” at time “h”;  
\( N_{\text{max}} \): the maximum number of farmers who can be in the plot at the same time.  
\( N_w(a, t, h) \): the number of workers present in “plot” during the day “t” at hour “h” for the activity “a”;

If an agriculture activity (irrigation, planting, seeding, pruning, harvesting, maintenance, fertilisation) requires that “\( N_w(a, t, h) \)” workers to be present in the plot on day “t” to perform tasks in some specific hours “h” when sandflies density “\( d(t, h) \)” is positive, there is an exposure risk. Its value depends on the number of persons on the plot and the PP density. Equation (1) allows the evaluation of the exposure risk of workers in the “nplot” of the IP for different time intervals (hour, day, month and year or more).

For the present case study, agriculture activity is based mainly on olive and pomegranate production. The only task that requires workers presence by night is irrigation. Farmers’ behaviour monitoring was carried out simultaneously during the months of July and August 2009, 2011 and 2013 when the irrigation and the vector activity are at the highest levels due to hot temperature. Morsy et al. (1995) and Coleman et al. (2007) underlined that the activity of the vector PP starts heavily towards the end of the day (sunset), which was at 8 p.m. in the study area, and that it continued with the same intensity until midnight. In the present research, we conducted an entomological survey in El Hichria IP in order to determine the spatial-temporal distribution of PP over a five-day period in August 2010.

**Farmer’s opinion assessment**

In order to involve farmers in the problem discussions and the potential solutions elaboration, it was conducted in 2014 a survey among El Hichria IP farmers, where the highest exposure risk to ZCL is recorded, representing about 100 ha of the irrigated area. After discussions with the GDA, participants to the survey were chosen if they are owner of the land and according to water consumption and their availability in the IP. Therefore, 130 farmers (80%) were considered.

Most of the farmers’ plots (74%) concerned by the survey have surfaces less than 0.75 ha and 47.3% have area less than 0.5 ha.

The survey questionnaire was discussed by the research team before being tested. It try to collect data about agriculture activity (crops, animals, inputs, yields and outcomes), water management by the GDA (water satisfaction, frequency, prices), occurrence of ZCL in their families (number, location, treatment, results) and the relationship between their daily activity and ZCL. Farmers are also asked about their preferences to improve the socio-economic situation of their community.

Three investigators were trained and committed to carrying out the surveys during the period May, 12 to 23, 2014. A data base was built using Excel and descriptive Analysis was performed.

The survey results were presented for the community and discussed with stakeholders (farmers, GDA members, non-government organisation (NGO) and regional agriculture administration).

**RESULTS AND DISCUSSION**

The monitoring of farmer’s behaviour in the El Hichria IP, from the 1st to the 7th of July 2009, shows that irrigation starts around midnight and goes on until 7 p.m. The graph in Figure 4 shows that the number of farmers irrigating simultaneously in the El Hichria IP varies between 0 and 6. The same behaviour is observed in August 2009. 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 “ER LCZ” parameter in the case of the El Hichria IP made it possible to draw up daily graphs for July and August. Figure 5 shows the hourly activity of farmers who were irrigating and the risk of their exposure to the vector of ZCL on July, 3, 4 and 5, 2009, corresponding to Friday, Saturday and Sunday, respectively.

The graph in Figure 5 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, present with high density in that part of the night, according to the entomological survey. The maximum hourly risk is estimated at 0.5 on a scale of 1. For these days, taken as examples, the total daily exposure risks are estimated to 2.00, 2.00 and 2.04 for July 3, 4 and 5, respectively. Calculation of the “\( ER_{LCZ} \)” parameter for July and August 2009, characterized by the highest irrigation activity, showed that it rose to 64.63 and 35.24 in the El Hichria IP in July and August 2009, respectively.

Analysis of farming activity in this IP revealed a large amount of two crops: olive and pomegranate trees, both of which require irrigation during the summer season (June, July, August and September). The surface traditional irrigation used in this IP also favors water loss by infiltration along channels between the tank and the irrigated plots. This increases the length of time required to irrigate with the necessary amount of water. As first conclusion, 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 (Ismail et al., 2007).

For the farmers in the Ouled Mhamed IP, irrigation activity holds no risk of exposure to ZCL. In fact, the
Figure 4: Farmer activity hours of irrigation process in the El Hichria IP from July 1st to 7th, 2009.

Figure 5: Farmer activity hours of irrigation process in the El Hichria IP and the risk of exposure to ZCL on July 3, 4 and 5 2009.

“ER_LCZ” 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. In addition, the dilapidated state of the hydraulic network of the IP, as well as the economic aspects of farming, discourages farmers from investing in intensive farming. There is a high risk of network failures and the impact of such events on annual crops yields is important, especially in hot periods. Most are
likely to maintain only olive orchards. Moreover, the collective network as well as the used irrigation techniques (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 night-time’s irrigation. Seen the absence of exposure risk to ZCL associated to irrigation activities in Ouled Mhamed IP, the remaining research activities were carried out only in EL Hichria IP.

In order to follow the tendency of the exposure risk to ZCL in EL Hichria IP, the “ER_LCZ” parameter was computed for a set of three days, corresponding to the same days (Friday, Saturday and Sunday), in July 2011 and 2013. Figure 6 details the number of farmers that irrigate in the same time in EL Hichria IP, the vector density and the ER_LCZ for July, 1, 2 and 3, 2011.

The graph in Figure 6 confirms the exposure risk to ZCL in EL Hichria IP. In fact, they are estimated to 2.10, 1.04 and 0.00 for July 1 (Friday), 2 (Saturday) and 3 (Sunday), respectively. As a third assessment of the exposure risk, the ER_LCZ was computed for equivalent days on July 2013. The graph in Figure 7 presents the results. It confirms that the pressure on irrigation water at the El Hichria IP is increasing from 2009 to 2013 and the GDA uses more night hours to satisfy farmer’s water requests. This situation leads to the increase of the ER_LCZ to 3.46, 3.15 and 2.73 for July 5, 6 and 7 2013, respectively.

The first results of the present research demonstrate that there is a relationship between agriculture activity (irrigation) and the exposure risk to ZCL. Table 1 presents the importance of the irrigation water and the computed ER_LCZ for July and August 2011 and 2013:

Results in Table 1 provide the information that the exposure risk to ZCL was not linearly linked to the
irrigation water consumption. Indeed, while the water consumed in July 2011 was the most important on 2011 and 2013, the maximal exposure risk was recorded on July 2013, corresponding to almost the half of water consumption of July 2011 (75,801 m³). The same conclusion can be argument by the ER LCZ value of August 2013 (44.37) higher than that of August 2011 (39.15) when the water consumption was higher. Therefore, in addition to the saturation of the hydraulic system, another parameter impacts the exposure risk of farmers and their families and workers to ZCL.

In order to better understand the origin of the problem and to able to propose and discuss potential solutions, it was analysed water use records and the irrigation schedule applied by the GDA in July and August 2011 and 2013. Results show that water consumed by farmers varied between 412 and 1012 m³/ha per month (the recommendation is 720 m³/ha per month and one irrigation by 15 days). In 2013, it is recorded that 39.0% of farmers received more than their rights of water, 29.0% less and 32.0% equal to their rights.

When analysing the irrigation frequency in July and August, it is demonstrated that farmer do not reach their right in 2011 and in 2013. Indeed, the average irrigation frequency is estimated to 0.875 and 0.500 irrigation in 15 days for 2011 and 2013, respectively, lower than the farmer's right. The frequency varied between 0 and 5 irrigations by 15 days in 2011 and 2013. According to the applied irrigation schedule, it is proved that 62.0 and 70.0% of farmers irrigated with a frequency less than the average of the IP in 2011 and 2013, respectively.

The previous results confirm that there is water shortage and management problem constraining agriculture production and farmers welfare. Indeed, both components of water access (volume and frequency) were not respected by the manager (GDA). As consequence, farmer will not be able to control the soil moisture and it is expected negative effect on trees yields (Allen et al., 1998). Due to high pressure on water, irrigation may be scheduled by night and therefore farmer will be exposed to ZCL vector. For that reason, it was conducted a survey among 130 farmers of the El Hichria IP in order to assess their opinion on the agriculture production system and its relationship with ZCL incidence.

Data collected during the survey demonstrated that 50.0% of the farmers have plots outside the IP and export water to growth annual crops (mainly green pepper). Water consumption of the 130 farmers is about 975,744 m³ in 2013 and almost 30.0% are exported to the external plots. Considering the official access for water of 864,000 m³, there is a water consumption excess of about 13.0%. When asked about the irrigation frequency and the water management by the GDA, half of farmers declared that they loosed their irrigation ranks because of the pressure on the water resources (18.0%), their financial problems (18.0%), management problems and equity (7.0%) and because of equipment maintenance ensured by the GDA (4.0%). About 33.0% of farmers loosed their irrigation for more than three times. In term of irrigation practice, more than 8.0% of farmers declared that their children’s take care of the irrigation. For about 22.0% of cases, workers are used to irrigate plots in the IP. Almost 70.0% of farmers irrigate by themselves.

50 farmers (38.5%) have experienced the disease in their families and 87 cases of ZCL were declared. There are 63 old cases, between 1975 and 1999, and 24 new ones between 2000 and 2013. Children's accumulate 63.0% of ZCL cases, probably due to more frequent exposure of boys to sandflies bites during their playing outdoors (Nezhad et al., 2012). 24.0% of cases are observed for farmers and 13.0 % for women. Reithinger et al. (2010) demonstrated that risk of active Cutaneous Leishmaniasis (CL) was positively associated with household members' age, particularly age groups of 19 years of age and younger. The authors reported that CL prevalence typically increases with age up to 15 years, after which prevalence levels off, presumably because of the acquisition of immunity (Reithinger et al., 2007).

ZCL scares are not easy to accept, especially for women and when it happens in the face. The survey allowed estimating the farmers with scares that disappeared without treatment to 24.1%. 36.78% of them still have scares while treated. The most embarrassing situation with scares in the face was recorded for 26.4% of farmers.

In order to evaluate the leak of knowledge about ZCL and to identify extension needs, farmers’ opinions were assessed about the origin of ZCL. 60% of them know that the sandfly PP play the main role but only 7% recognize that the animal manures is important ring of the ZCL transmission chain. 7 % of farmers asked know that the rodent play a role. To reduce the incidence of ZCL, most of farmers (81%) underline that the improvement of their welfare, by increasing their economic income, is the efficient way to break the ZCL chain of transmission and

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<tr>
<th>Month</th>
<th>Consumed water (m³)</th>
<th>ELCZ</th>
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<tr>
<td>July 2011</td>
<td>150,408</td>
<td>53.80</td>
</tr>
<tr>
<td>August 2011</td>
<td>113,616</td>
<td>39.15</td>
</tr>
<tr>
<td>July 2013</td>
<td>75,801</td>
<td>67.63</td>
</tr>
<tr>
<td>August 2013</td>
<td>60,696</td>
<td>44.37</td>
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to reduce the epidemic.

Results of the experiments, data collection and analysis and the survey clearly show that the risk of exposure to ZCL depends on the irrigation schedule, the hydraulic infrastructures and the activity of the vector. It is also associated to sanitation and environmental education (Petney, 2001; Ul Bari, 2006).

Nezhad et al. (2012) underlined that parental education is important to improve the socioeconomic status and standard of living and this may confirm the importance of health education in the disease control program.

Irrigation inside the IP is not in fact the determining factor. Instead, it is water exportation outside the IP, the structure of the hydraulic system and how the water is managed by the GDA which must be adapted in order to limit the exposure risk to ZCL.

Results discussion with officials, regional NGO as well as farmers leads to the identification of compromise solutions. The rehabilitation of the hydraulic system, to reduce losses and increase flexibility, and the enhancement of the irrigation efficiency are proposed to reduce the exposure risk. The improvement of the animal manure management, by the introduction of individual compost units for example (that have to be monitored by a professional), can help to break the sandfly reproduction cycle in addition to the improvement of organic matter quality. The improvement of the olive value chain is proposed to increase the farmer’s incomes and to enhance the regional development. The problem of water exportation to external plots cannot be faced until the economic income from the IP increased.

Based on the right for water, farmers’ opinions, the hydraulic system capacity and the water needs of olive trees in the region, an irrigation schedule is proposed to the GDA in order to improve water management performances and to reduce the exposure risk to the vector of ZCL.

The schedule uses 10 hours of irrigation (04 am – 10:00 am and 17:00 pm – 21:00 pm) and offers 792 m³/ha per month and 1 irrigation by 15 days to each farmer in the IP El Hichria. This schedule ensures an ER_LCZ equal to 14.66, largely lower than those recorded in July 2011 and 2013 equal to 53.8 and 67.63, respectively.

The agriculture production under health constraint is proposed as perspective of the present research. Other activities need to be analysed to assess their impacts on Human health and how to palliate to such a constraint.

CONCLUSION AND RECOMMENDATIONS

This study showed that the behaviour of farmers in relation to irrigation is imposed mainly by the GDA management, the water system and the used irrigation method. In the El Hichria IP, the high water demand imposed night irrigation in summer months. This situation led to important exposure risks in July and August. In the Ouled Mhamed IP, the farmers’ water demand 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 when the vector of ZCL was present.

For El Hichria IP, where the exposure risk to ZCL is the greatest and increasing, irrigation water exportation to external plots used by farmers to growth annual crops constitute the main constraints for the GDA to respect the water use right. The hydraulic system itself and the irrigation technique need to be revised to allow more farmers to irrigate at the same time and to overcome night activity.

It can be concluded that in El Hichria IP, the water governance is not excellent and needs improvement. Water use as well as irrigation frequency need to be adjusted among farmers according to the right for water. Results of the proposed schedule example allow concluding that optimizing water allocation can satisfy crops water needs and contribute to reduce the healthy risk associated to irrigation. This can enhance farmers’ confidence in the GDA and stimulate farmers to improve their irrigation techniques and practices. We also conclude that the first farmer’s occupation is to maximize their income. Water shortage and the ZCL incidence were not their priorities.

An extension effort is required to improve farmers’ capacities on irrigation, manure management and how to face the ZCL epidemic. The GDA needs to play a main role in this activity with the support of the regional administration of agriculture, other NGO and the agriculture research center in Sidi Bouzid Governorate.

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