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Forms of work organisation in farms

Work organization and its economic efficiency in oasis crop-livestock farms

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Abstract: *In this paper, we present how crop-livestock integration is a key concept to the resilience of the oases' farming systems. In these very arid contexts, irrigation is compulsory to allow crops' development. A limited number of crops are cultivated underlying date palm trees. Crops also benefit from the complementarities of livestock, directly through manure which improves soil fertility as well as indirectly, through atmospheric nitrogen fixation by alfalfa, which is the common fodder crop. In addition, households benefit from their herds with a supply of high quality protein as well as regular incomes from milk and live animals' sales. As farming is almost like garden maintenance, given the limited arable land area, work uses are vital to ensure the resilience of farms, but they need to be acurately characterized. To do so, and to determine work use economic efficiency in crops and livestock production, we selected six representative farms of the diversity of situations. We determined work durations needed for each crop and for livestock, according to the 'Work Balance' method. We also calculated gross margins achieved by these activities. We also followed water volumes used on-farm and their origins (rainfall, surface and groundwater irrigation, as well as virtual water corresponding to off-farm resources used to feed livestock). The results demonstrate that the association between date palms and livestock is crucial to the oases' farms as it mobilizes most of work time and water volumes, creating most of the incomes. We also demonstrated that intervention measures aimed at increasing incomes through products' marketing (particularly dates) and enhancing the animal performances (particularly livability of lambs in the prolific D'man breed) are crucial to the future of these fragile systems. At the opposite, the promotion of new crops, like watermelon in the expansion areas of the oasis is highly problematic, as it emphasizes water scarcity by depleting groundwater resources, and it is not systematically associated to higher work remuneration due to crops' prices volatility.*

Keywords: *crop/livestock integration, incomes, oasis, water uses, work organization*

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Introduction

Defined as cultivated spaces in very arid contexts (Jouve, 2012), the oases are extremely fragile areas. In these regions, which saw the emergence of several historical civilizations, the setup of sustainable development models is nowadays a challenging issue (Fassi, 2017), particularly because of the growing concerns induced by climate change which may put at risk the viability of farming systems (Schilling *et al.*, 2012). In these very arid contexts, irrigation is compulsory to allow crops' development. A limited number of crops are cultivated underlying date palm trees. Crops also benefit from the complementarities of livestock, directly through manure which improves soil fertility as well as indirectly, through atmospheric nitrogen fixation by alfalfa, which is the common fodder crop. In addition, households benefit from their herds with a supply of high quality protein as well as regular incomes from milk and live animals' sales. In this study, the goal was to characterize how the oasis farming systems cope with scarce resources, particularly land and water, and how work uses may allow farms' resilience. Another hypothesis of the study was that farming practices may be consuming a lot of time with limited remuneration and that would not ensure their attractiveness. In fact, the specificity of the oasis farming systems in many areas worldwide is the presence of underlying crops

(cereals, fodder, vegetables) in association with date palms which often constitutes the pillar of the agricultural economy, even if it often faces a severe water stress (Carr, 2013). Farms are therefore almost entirely dedicated to a crop-livestock integration to guarantee their resilience, although this may be threatening the sustainability of the whole resources' availability (Chelleri *et al.*, 2014).Hence, the assumption behind this research is that crop-livestock integration constitutes a smart association to ensure the resilience of the oasis farming systems, through agro-biodiversity (Lemaire *et al.*, 2014), but that would necessitate a significant work time. In fact, livestock have often been associated to the sustainability of the oasis farming systems, allowing biomass recycling through manure which increases soil fertility (Liu *et al.*, 2011). Altogether, the results were used to discuss the perspectives of the oasis farming systems' resilience through the crop-livestock integration. The present study was therefore designed to better characterize oases' farming systems with date palms. In fact, many studies have been devoted to such a topic (Toutain *et al.*, 1990; de Grenade, 2013), but few of them have studied the synergies between crops and livestock, as well as the performances on the farms.

Methodology

The study was conducted in the Drâa Valley (Zagora Province, South East of Morocco), where annual rainfall average level does not exceed 110 mm and summer temperatures are often above 45°C. The valley consists in a series of seven palm groves along a distance of 200 km following the Drâa River, covering a total arable land area of 26,000 ha (Figure 1).

The crop component is dominated by date palm trees (1,421,900 trees), with a lower layer of fruit trees (apple, apricots and almonds, a total of about 107,000 trees), cereals (barley and wheat - 18,300 ha), and fodder, mainly lucerne, covering 3,600 ha (ORMVAO, 2018). According to Sraïri *et al.* (2017),four distinct types were identified to represent the oasis livestock systems, defined as follows: (*i*) *Multi species livestock* (sheep and cattle as well as sedentary goats), (*ii*) *Cattle based livestock*, (*iii*) *Sheep intensification* and (*iv*) *Range land systems*. In the present study, we selected six farms representing three of the identified types, meaning that we excluded the *Range land systems*, where crops are almost not practiced. The structural parameters of the farms (*i.e.* arable land, type of crops, number of livestock units, etc.) are reported in Table 1. The majority of farms among the study sample are mainly made of smallholder units, as the arable land did not exceed 5 ha. They also show the fragmentation of farms, which often cultivate more than 10 plots, with an average area of less than 0.2 ha per plot. The notable exception of farm 6 illustrates an example of a farm located outside the traditional oasis area, in the expansion of the oasis (*i.e.* desert areas where private irrigation means – wells and boreholes – have allowed farmers to plant trees and practice various crops), thus relying exclusively on groundwater for irrigation purposes. Another noticeable constraint is in relation to land tenure, as many farms have limited access to private land and they rent whether mortmain – *i.e.* land hold in perpetuity in one dead hand, which means the land owner would be the religious office of a mosque – or collective land. The farms' characteristics also reveal the important number of persons involved in agricultural tasks, as it varied from 2 (farm 5) to 7 (farm 6).

With regard to livestock, typical examples of multi specific herds are noted, with zero-grazing sheep, cattle and goats. Farms 1 and 2 illustrate the specialized flocks made from the prolific local breed, named D'man. Farms 3 and 4, with a contribution of cattle to total Livestock Units (LU) of almost 70% are examples of a livestock orientation to dairy production, as their milk output is sold to a local processing cooperative factory, situated in the city of Zagora. Finally, farms 5 and 6 constitute typical cases of non specialized animal production, in which livestock appears to be just a source of capital.

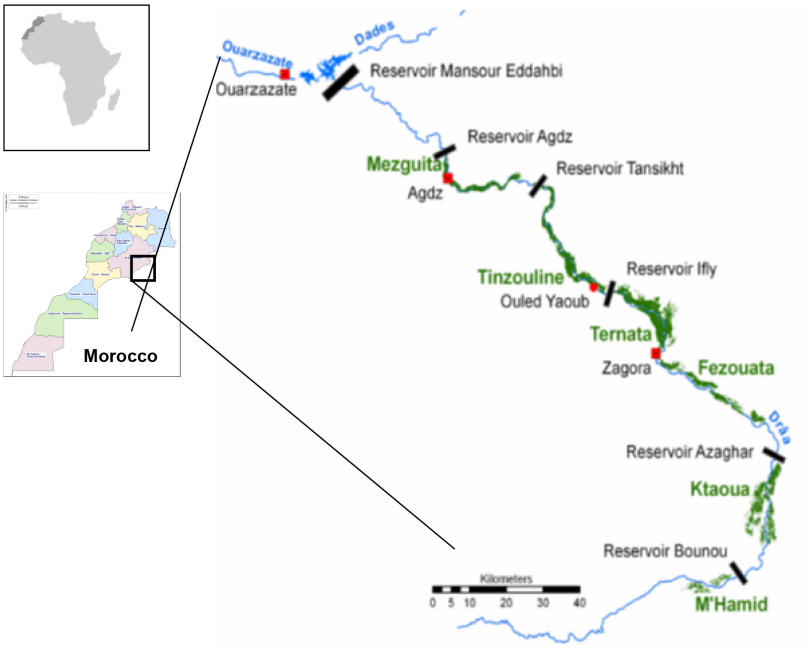

Figure 1. Geographic localization of the study area.

		Farms					
		1	2	3	4	5	6
		Sheep intensification		Cattle based livestock		Multi species livestock	
Total arable land (ha)		1.8	4.7	3.0	1.4	1.1	15.5
Number of cultivated plots		12	8	16	9	9	10
Number of date palm trees		171	295	495	465	295	571
Average area per plot (ha)		0.14	0.59	0.19	0.16	0.12	1.5
Land tenure (%)	Private	60	83	100	100	100	-
	Mortmain	40	17	-	-	-	-
	Collective	-	-	-	-	-	100
	Cattle	-	-	8 (68)*	10 (69)*	3 (28)*	5 (15)*
Herd structure (number)	Goat	-	-		5 (10)*	-	27 (49)*
	Sheep	25 (100)*	45 (100)*	23 (32)*	24 (21)*	42 (72)*	34 (36)*
Family members involved in work		4	3	8	3	2	7

Table 1. Total arable land used per farm, land tenure and herd structure. *(100)* - Contribution of each species to the total number of Livestock Units (%).*

To achieve the goals of this study, six farms representing the diversity of herds' types located throughout the oasis in the Draa Valley (Central East Morocco) were selected, at the exception of pastoral systems (nomads with goats and camels), in which crops are quite inexistent. The sample study was limited to six farms only, given the efforts needed to get accurate and reliable data. In these farms, a year-on monitoring of livestock rearing as well as cropping practices was implemented. We

used the 'Work Balance' method to characterize total work durations devoted to each activity. We also characterized both the raw margins from crops and livestock, allowing us to calculate a work economic productivity indicator. We also determined the water volumes used for each plot, and this allowed us characterizing at each farm the entire volumes used. The research adopted the principles of the 'Work Assessment' method elaborated by Dedieu *et al.* (1999), whose main goals aim to quantify time devoted to each on-farm activity and the people responsible for these activities. For each farm, we began by testing the survey research protocol, and its possible applications in the specific context of the oases. The first visit was dedicated to explain the objectives of the study and to collect information about farms' structural parameters (*i.e.* agricultural land area, equipment, herd size and constitution, agricultural plots and the crops they support, etc.). During this occasion, the nature of the workers in the farm was determined: family members effectively involved in work and off-farm workforce (number, gender, etc.). Additional visits were then undertaken to quantify the duration of each task. We added, as a further step of the analysis, the gross margins generated by a single day of work, implying that we determined all the inputs used and the sums for their purchases. We also determined the incomes from crops and animal products' sales. The data gathered from the one year follow-up were then analyzed. It took into consideration work uses for crops (identified as seasonal work) and livestock (known as routine work, generally measured in hours per day, which mainly consists in daily tasks devoted to the herd - milking, feeding, cleaning the barns, etc.). The duration of routine work were converted to days, by considering that an average work day is made of 8 hours. The gross margins for each of the crops were divided by the total work devoted to each of these activities to calculate the economic efficiency of work for each crop and livestock in each farm. Then, the livestock gross margin was also divided by the work duration specific to herd management. This allowed determining an economic efficiency of work devoted to crops and livestock and to draw comparisons among farms. In each plot the water volumes used were characterized, either from the surface irrigation network managed by the local agricultural development agency or from private irrigation means (*i.e.* wells and boreholes). We determined simultaneously virtual water corresponding to feed purchases (Allan, 1999), by a close monitoring of dietary rations used by the herds and by converting the grains to water volumes, using international references (Hoesktra and Chapagain, 2007). Altogether, the results allow drawing a water mix in farms (*i.e.* the volumes used per ha and their origins: rainfall, surface or groundwater irrigation as well as virtual water). The overall results were finally used to characterize work uses in a context of water scarcity and the intervention possibilities in crop-livestock farms in the specific context of the oases and their consequences on work attractiveness in farming activities in such areas.

Results

The determination of crops' gross margins shows that date palm trees constitute the pillar of the oases' farming system as they represent in average more than 80% of the crops' total gross margin (Figure 2). Differences between farms are related to crop diversification (farm 6 was the only one which cultivated watermelon and henna, and therefore date palms' contribution to the overall crops' raw margin was the lowest) and to the number and varieties of date palms; in fact, in farms with most date palm trees of Majhoul variety (*i.e.* farms 3 and 4), the one which fruit is sold almost 10 US$/kg, the contribution of date palm trees to the overall crops' raw margin is the highest.

The determination of livestock gross margin shows that it is quite limited with comparison to crops. In farm 6, it was even negative, implying economic losses (Table 2). The maximum value was recorded

in farm 4 which mainly relied on milk sales. Farms 1, 2, 5 and 6 were involved in the selection of the local D'man breed lambs or Draa breed kids, which is subsidized by the public authorities. In farm 2, these subsidies represented almost 55% of livestock raw margin in this farm, implying that they are crucial for the profitability of this activity. It could also be noticed that farms had a variable feed autonomy indicator (*i.e.* the amount of feed net energy produced on-farm divided by the total feed energy ingested). Generally, farms with the lowest feed autonomy (less than 60%) had limited profitability (farm 6) and that was also exacerbated by lambs' abnormal mortality rates (above 16%), but the exception of farm 4 illustrates a case where feed purchases are efficiently converted to milk, implying a maximum profitability.

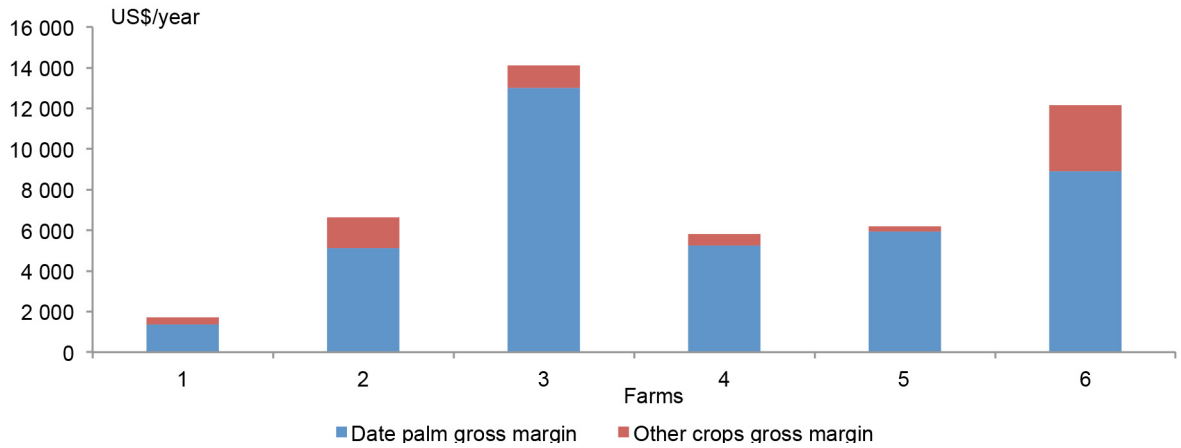

Figure 2. The contribution of date palms to the total crops' gross margin.

	Farms					
	1	**2**	**3**	**4**	**5**	**6**
Milk sales	-	-	4149	11488	673	810
Live animals' sales	4100	6700	5150	7870	11460	4250
Subsidies	1410	2109	543	-	2207	2114
Total expenses	2245	4985	5746	11502	8562	9851
Feed autonomy (%)	75	86	64	52	63	55
Livestock raw margin (US $/Livestock Units)	844	508	550	737	777	- 108

Table 2. Livestock annual expenses and sales (US $) in the sample of farms studied.

With regard to seasonal work (*i.e.* work devoted to crops), in average, each date palm tree necessitates a single day of work per year, and this figure is quite steady among farms. This amount of work includes the pollination of trees, then the harvest, the conditioning and the marketing of fruits. There is also date palms' dry branches' pruning at least once a year, otherwise it may accelerate fire spreading throughout the whole oasis. For the underlying crops, cereals necessitate almost 70 days of work/ha, whereas lucerne necessitates 51 days of work per ha (mainly irrigation needs, as regular cuts are counted as routine work devoted to livestock). Finally, with regard to watermelon and henna,

only cultivated in farm 6, these crops necessitated 116 and 87 days of work/ha. Watermelon was relatively more time consuming, given the numerous operations required, particularly during its installation: sowing, frequent treatments, etc. Altogether, the results show that the average duration of seasonal work per ha was around 168 days per year. This figure varied from a minimum of 88 days per ha in farm 1 (4 family members with 1.8 ha) to a maximum of 293 days per ha in farm 5 (2 family members with 1.1 ha). In this farm, an important share (64%) of the total work devoted to crops is attributed to hired workers. This is also the case in farm 2 (75%, with only three family members on 4.7 ha), whereas in the remaining farms less than 30% of the seasonal work (*i.e.* devoted to crops) was assumed by hired workers (Table 3).

The routine work (*i.e.* work devoted to livestock) is dominated by feeding the animals (which means time to cut and transport daily the fodder to the animals as all farms practice 'zero-grazing' given the constraints induced by limited land) (563 hours per year) and this constitutes an average of 77% of the whole duration needed by a Livestock Unit (considering an average live weight of 400 kg per livestock unit). This is followed by milking the cows, in farms 3, 4, 5 and 6 which have dairy animals (15% of the total duration of work) and by cleaning the barns (the remaining 8% of total routine work). The routine work is quite totally assumed by family members, at the exception of farms 2 and 5 which use hired workers to cut lucerne. Therefore, the average routine work autonomy reached 91%.

	Farms					
	1	**2**	**3**	**4**	**5**	**6**
Seasonal work (crops)						
Total annual work duration (days)	150	540	628	313	311	1670
Total annual work duration per ha (days)	88	115	209	195	293	108
Work autonomy (%)*	78	25	82	70	36	95
Remuneration per day of work (US $)	12	11	22	19	20	10
Routine work (livestock)						
Annual work duration per livestock unit (hours)	473	495	622	813	465	510
Remuneration per day of work (US $)	13	7	7	8	10	- 2

Table 3. Seasonal work and routine work and the remuneration they allow in the sample of farms studied.
** Work assumed by family members/Total work duration.*

The overall analysis of on-farm work uses shows that livestock mobilizes, in most cases, more work than crops. This is particularly true in farms with a very limited arable land area (farms 1, 4 and 5 with less than 2 ha) and this means that work is used as a mean to cope with land and capital constraints. In larger farms, the situation is characterized by a balance in the uses of work between crops and livestock (Figure 3).

With regard to work use efficiency, the incomes allowed by each day of work are higher (almost 15 US $) in farms with better crops profitability, particularly the one of date palms (farms 3 and 5), or the good results of livestock (farm 1). This is also due to limited hired workers in these farms, which use only on-farm family workers. In contrast, the income per day of work did not exceed 5 US $ in farm 6, due to the poor profitability of watermelon and the negative gross margin of livestock, which mobilizes almost 1300 days.

The results also confirm the limited amount from rainfall (not exceeding 1150 cubic meters per ha), and the importance of irrigation (Figure 4). Farms 4 and 5, with important numbers of animals relied

intensively on feed purchases, implying large volumes of virtual water. The results show that the economic water productivity was the highest for date palms (almost 0.6 US $ per cubic meter) in comparison to cereals (less than 0.1 US $ per cubic meter), whereas the poor economic gross margin of watermelon in farm 6 due to marketing difficulties induced by an important offer concentrated in the same period resulted in a bad economic productivity (less than 0.1 US $ per cubic meter). With regard to animal products (milk and live weight gain), their economic water productivity were quite limited (and even negative in farm 6), but the regularity of the incomes they allow may be strategic to farms, as they ensure the payment of day to day expenses until dates are harvested.

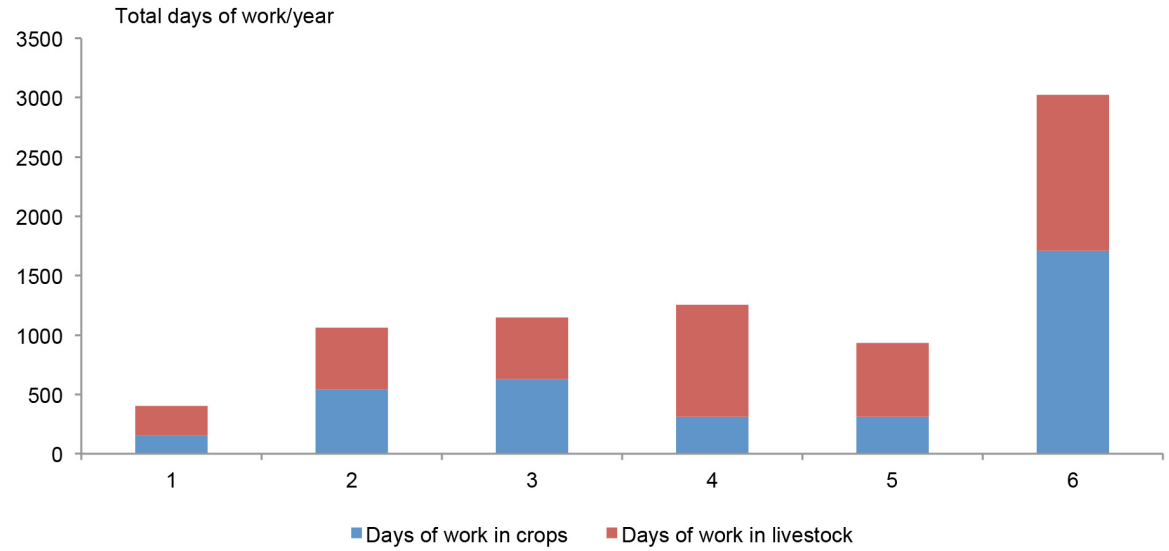

Figure 3. The share of routine (livestock) and seasonal (crops) to total work duration in the sample study farms.

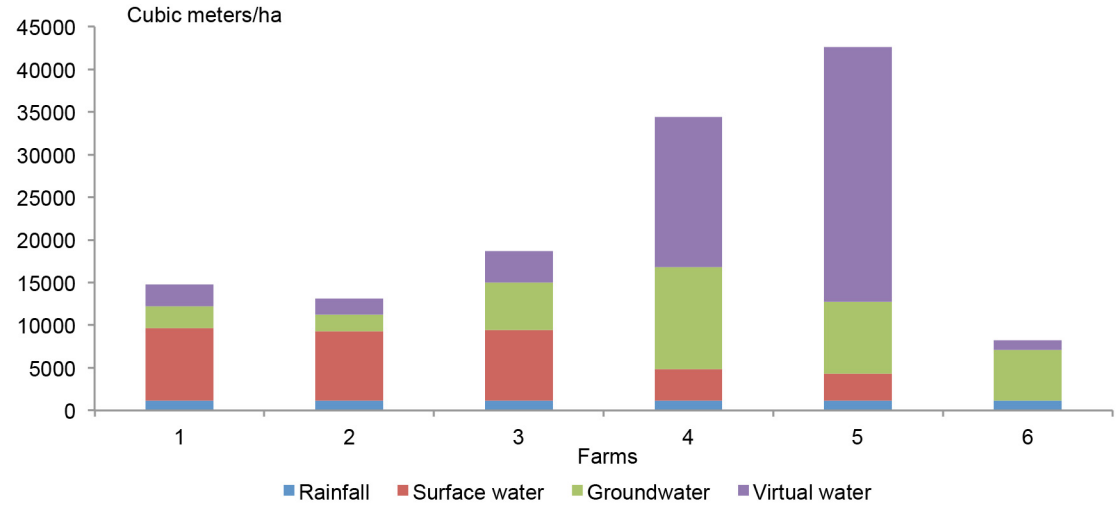

Figure 4. Water mix in the studied farms.

The results also show that crop-livestock integration is crucial to the oases' farming systems resilience. In fact, in very small farms (1, 4 and 5, with less than 2 ha), livestock ensures more than 50% of the total gross margin. In larger farms, crops are more decisive. However, in all kind of farms, at the exception of farm 6 (which is very special in our study sample, as it is not located in the oasis and it has an area larger than 15 ha), the association livestock/date palms mobilizes more than 60% of the total water uses and almost 85% of the work. It also allows a large part (more than 90%) of the overall incomes (Table 4).

	1	2	3	4	5	6
Arable land (ha)	1.8	4.7	3.0	1.4	1.1	15.5
Livestock contribution to total incomes (%)	63	38	23	54	50	- 19
Date palms' contribution to total incomes (%)	31	53	72	42	48	74
Livestock + date palms uses of total water (%)	58	67	70	93	90	37
Livestock + date palms uses of total work (%)	83	85	89	95	89	27
Income per day of work (US $)	12.6	9.1	15.0	10.6	13.2	4.5

Table 4. Main indicators of water and work uses in the study sample farms.

Discussion

We have made as an initial hypothesis, that in the oases' farming systems, work uses might help overpass the existing constraints. First, we have tested the 'Work Balance' method which proved quite adapted to this specific context. The initial characterization of the farms proved that the sample study was in fact well reflecting the diversity of the existing situations in the area: limited arable land (a majority of farms with less than 5 ha), and integration between crops and livestock. Then we have calculated work needs for crops (*i.e.* seasonal work). The results have shown that at least one day of work is needed per each date palm tree, implying that this is the real pillar of the farming system, as it also creates an important share of the income. Such a finding has also been reported by Skouri (1990), who also insists that the whole farming systems in the oases are organized around date palm trees' production. The other finding about seasonal work is the important amount devoted to both cereals and fodder. This also confirms previous works' on the oases' farming systems which recognize that, in addition to date palms, cereals and fodder constitute the most important crops (Oumata *et al.*, 2020), as they are used to feed humans and animals. In addition to these 'traditional' and more common crops, we also found new crops such as watermelon. This is mainly developing in the expansion area of the oasis, around the philosophy of conquering new land with exclusive groundwater uses (Hamamouche *et al.*, 2018). These trends are however creating growing conflicts around water and land (Carpentier and Gana, 2017), exacerbating the scarcity of resources as the rhythm of water exploitation is not sustainable anymore (Benaoun *et al.*, 2014), and this can even jeopardize the supply of water to the urban centers. Work uses for watermelon were relatively the highest (116 days per ha) in comparison to other crops, given the continuous cultural operations required, during its vegetative cycle: sowing, frequent irrigation and treatments, etc. However, such work uses were not efficiently remunerated as the crop suffered marketing problems during the study year (spring 2019): an abundant harvest meant that prices were down, not allowing farmers to get the profitability they sought. As a consequence, work economic efficiency for that crop was one of the

poorest (less than 5 US $ per day of work) in comparison to other crops: an average 22 and 8 US$ per day of work, respectively for date palms and cereals.

We have also noticed that the routine work (*i.e.* work devoted to livestock) constitutes an important share of the total annual work time. It is in majority assumed by family members (more than 90% of the total amount), confirming previous results in numerous areas worldwide (Sraïri and Ghabiyel, 2017; Cournut *et al.*, 2018; Dieguez *et al.* 2010). In addition, our findings in the oasis show that the average time devoted to a single livestock unit was around 470 hours, which is the equivalent of 59 days of work. Such a finding is a little bit higher to the one calculated by Sraïri *et al.* (2013) in a rain-fed agricultural region in Morocco, with crop-livestock integration: 419 hours (52 days). The difference might be explained by the specificities of the oases' livestock production, which entirely relies on 'zero-grazing', implying an important burden of daily fodder cuts and transportation to the animals. With regard to work uses per livestock unit, the results of our study are almost similar to the one reported by Hostiou *et al.* (2010) in Vietnam: 58 days. This is not surprising, even though the contexts might be totally different (extreme aridity in the Moroccan oases and tropical conditions in Vietnam), as they are both characterized by smallholder units with limited arable land and mainly with limited or zero-grazing situations. In addition, the multi-specific composition of the herds (cattle and small ruminants - sheep and goats -), in the oases adds pressure on the farmers to devote more work time and care for their animals. The results have finally demonstrated that routine work (*i.e.* devoted to livestock) durations are almost more important than the seasonal work (*i.e.* devoted to crops), and that was particularly true in very small farms (less than 2 ha). This finding supports the fact that in environments with limited assets, livestock remains the unique option of livelihood for many farmers, constituting the 'wealth of the poor' (Duteurtre and Faye, 2009). However, the average remuneration of a single day of work within the herd remains almost 2-times lower than the one in crops: 7 vs. 16 US $. Considered as such, this result may mean a limited attractiveness of routine work to local farmers. In fact, such levels of income per day of work with the herd equal the minimal guaranteed wage in the agricultural sector in Morocco, as regulated by the official legislation (6.3 US $ per day of work). These results confirm the acute economic vulnerability of such activities, given that the daily incomes are just above the poverty line (Chen and Ravaillon, 2004). However, the synergies between crops and livestock in integrated systems are much more complicated than this simple comparison, and the whole oasis farming system is in fact organized on the exchanges of biomass, water and even work between crops and livestock (Dollé, 1990). When feeding his herd, the farmer surely knows that this is a task consuming a lot of efforts and work time, daily, due to the use of the zero-grazing to feed the livestock in the oases. However, keeping animals in pens implies a steady return of manure to plots, which improves soils' fertility. In addition, the nitrogen availability in soils is increased, as the main fodder crop used in the area is lucerne, which is often associated with date palms, implying that these trees also benefit from the symbiotic atmospheric nitrogen fixation by the legume. Finally, by irrigating lucerne, the farmer also irrigates date palms, as these are the pillar of the whole system: providing shade, allowing the most important share of the incomes and also supplying the herd with dates' wastes (*i.e.* dates not sold because of insufficient quality).

Our results also show that in a context of an acute aridity, irrigation is compulsory, as well as the use virtual water (off-farm resources) to feed the animals. Similar ideas have been developed for the whole Middle East North Africa region, as reported by Antonelli and Tamea (2015). The results also confirm the pivotal economic role of date palms to add value to water irrigation, although its actual uses of

water volumes may be difficult to assess exactly, given the contribution to groundwater to a direct supply to roots (El Khoumsi *et al.*, 2017) and its association with underlying crops.

Conclusion

The present paper confirms that crop-livestock integration is a key component in the resilience of the oases' farming systems. In fact, date palms and livestock production represent the pillar of the incomes of the farms, and they mobilize important parts of the available scarce resources, particularly land and water, through an important share of the work used in farms. In this specific agricultural context the crop-livestock integration is at its utmost achievement. These results also justify why in the oasis, visitors are traditionally welcomed by milk and dates. This does not only refer to the nutriments' synergies from such an association (fiber, minerals and carbohydrates from the dates and high value proteins as well as fat from milk) but it is emblematic of the main efforts supplied by farmers in such hostile environments, allowing to add value to scarce resources. The results of this study also show that intervention measures to promote the agricultural output and in such a fragile area have to be tested with caution. In fact, encouraging new crops with important water requirements, such as watermelon should be envisaged very cautiously, given the risks associated to such practices, like groundwater depletion and prices volatility. By contrast, improving date palms' yields and valorization through better marketing channels would be more effective. This would also be the case of the promotion of livestock productivity, by avoiding animal losses and by improving milk yield in lactating cows through balanced dietary rations using local feedstuffs. Altogether, the results of this research imply that further efforts are needed to better understand the complexity of the oases' farming systems in order to promote the incomes of the farmers and to slow down the exodus of its inhabitants.

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