Comparing the uses of available labor and capital in diversified farming systems in Drâa oases (Morocco)

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Abstract

In this study, uses of labor were characterized using the 'Work Balance' method in a sample of 17 oasis farms. The results showed that almost 44% of total uses of labor are devoted to livestock, while the remainders 56% are used for crops. The labor required to raise livestock was almost entirely (92%) provided by family member, whereas that required for crops was mostly provided by hired laborers. Date palms are the pillar of the oasis farming system and enable the positive synergies of this mixed crop/livestock system. Date wastes and cereal straw are used to feed the animals, while the livestock supplies the farmers with milk and meat, and their sale ensures the purchase of agricultural inputs in the period preceding date harvest. Our results show that labor is an essential component of oasis farming systems, as it provides opportunities to achieve a circular economy. Otherwise, on farms specialized in crops that have no livestock, the economic efficiency of labor is higher, thanks to higher investments. Taken together, these results suggest that there are ways to improve the efficiency of the uses of labor on oasis farms.

Keywords: *Crop/livestock integration, Incomes, Oasis, Uses of labor.*

1. Introduction

Even though diversification strategies are widely used by smallholder farmers in developing countries, they face several constraints: insufficient land, limited level of education, and lack of the financial means to purchase inputs and the machinery needed to increase crop and livestock productivity (Schiere *et al*., 2002). Although focusing on smallholder farms to increase feed and food output in Africa is necessary, unless labor productivity is significantly enhanced, it may not suffice (Collier and Dercon, 2014). Smallholder farms are also widely promoted as providing opportunities for food security and as being more appropriate for the implementation of ecologically friendly practices (Woodhouse, 2010). However, agriculture alone may not provide sufficient income to rural populations, particularly in areas where the bulk of farms are smallholder units (Guri *et al.*, 2016).

Generally, remuneration of labor through family farming is largely insufficient, because too many workers are trying to get steady incomes from agriculture with low productivity (Sraïri, 2005). Consequently, in many economies in transition, the number of laborers in the agricultural sector is decreasing, as they shift

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to jobs that pay higher wages (Tamura, 2002). These elements underline the growing tensions on the farm labor market: limited incomes that often lead to problems finding enough laborers, particularly during peak periods (crop treatments, harvest, etc.). In this context, labor has become a growing concern for farmers, particularly those who raise livestock (Dedieu and Servière, 2012), as it represents a heavy burden. The organization and payment of labor in mixed crop/livestock farming systems is hence emerging as a priority research topic in many areas worldwide, and may help understand farms' performances and enhance their sustainability (Lemaire *et al.*, 2014).

Oases are considered to be the scene of the emergence of several important human civilizations (Fassi, 2017). They are defined as areas with intense farming activities located in very arid environments, where conditions for human development are hostile (Jouve, 2012). As a consequence, water deficits are frequent, implying further stresses for date palm trees (Carr, 2013), which are often the dominant species in oasis farming systems. Different crops (fruit trees, fodder crops, and cereals) are cultivated under the date palm trees, that latter being considered as the pillar of the agrarian economy (Dollé *et al*., 1989). In addition, livestock has often been associated with the sustainability of the oasis farming systems, as it allows biomass recycling through manure, thereby increasing soil fertility (Liu *et al*., 2011), as well as providing draft power for cropping. Many studies have demonstrated the advantages of mixed crop/livestock systems in terms of economic sustainability (Ryschawy *et al*., 2013) compared to specialized farms. In fact, decoupling of crops and livestock is now severely criticized, as it has many undesirable consequences: excess use of fossil fuel, incomplete recycling of crop residues and animal excreta and vulnerability to price volatility (Garrett *et al*., 2020). However, such diversified agricultural systems require an increasing number of tasks, which in turn require more labor.

Following this trend, the present paper focuses on labor management in a sample of diverse oasis farms, as studies of labor use efficiency in these systems are almost inexistent. Previous studies in the area only calculated the profitability of labor and capital invested in animal production, failing to grasp the implications on the overall farming systems, in their diversity. Our analysis of the workload and the gross incomes obtained in diverse crop and livestock rearing systems will help understand the choices made by oasis farmers faced with many constraints. We hypothesize that diverse labor management strategies in line with farm assets may represent an opportunity to adapt to the structural characteristics of the oases, such as limited capital, land and water. The results of our study should help identify innovative approaches to enhance agricultural labor management and increase incomes in oases.

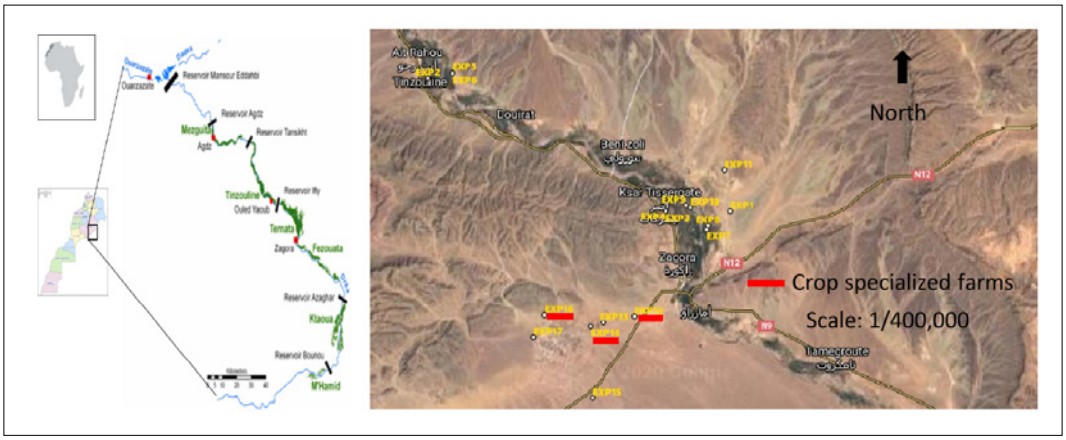
2. Method

2.1. *Study area*

The study was conducted in the Drâa Valley (Zagoura Province, Southeastern Morocco), where average annual rainfall does not exceed 110 mm and summer temperatures are often above 45°C. The valley consists in a series of seven palm groves spread out over 200 km along the Drâa River, representing 26,000 ha of arable land (Figure 1). Date palm (1,421,900 trees) is the main crop, 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 alfalfa, covering 3,600 ha. A sample of 17 farms representing the diversity of production situations was selected. Their main characteristics are limited average arable land (the majority of farms are less than 5 ha in size), the importance of crop/livestock integration, but also the emergence of farms in the expansion areas of the oases that are exclusively irrigated from private boreholes, at the contrary of farms within the traditional oases which have access to surface water (i.e. originating from an upstream public dam) with no charges, delivered five times a year (ORMVA, 2018).

Two kinds of farms were distinguished: 14 smallholder crop/livestock units and three larger farms specialized in cash crops (date palm and

Figure 1 - Location of the study farms.



watermelon) with no livestock (Table 1). The second category includes the cases of newly established farms in expansion areas of the 'traditional' oases, thus involving significant investments in date groves and fruit orchards (mainly varieties of dates with high market value) as well as private means of irrigation (boreholes, basins for water storage, drip irrigation equipment, etc.) intended to enable the cultivation of understory cash crops such as watermelon.

Farms that specialize in crops generally had fewer working family members (2.3) than crop/livestock farms (5.2). Livestock refers to either dairy cattle (in 4 of the 14 farms, all located near the city of Zagoura where there is a dairy processing unit) or small ruminants – the prolific D'man sheep (on all the farms) and Drâa goat breeds (on 5 farms). The dominance of sheep is attributed to the public incentives (50 Euros per animal) designed to select rams and ewes of the D'man breed. The only fodder crop is alfalfa (*Medicago sativa*), as farmers also use cereal by-products (straw and bran) as feed resources. The animals are also frequently fed with date wastes, following long-lasting practices in traditional oases based on full crop-livestock integration. In fact, crops also benefit from livestock through the use of manure as fertilizer, as well as the nitrogen supplied to the soils by alfalfa, the main leguminous fodder crop. In addition, the frequent irrigation of alfalfa satisfies part of the water needs of the date palm trees.

Table 1 - Structural parameters (arable land, herd and capital invested) of the different types of farms.

	Crop/livestock farms (n = 14)		*Crop farms (n = 3)*	
	Mean ± s.d.	*Max. - Min.*	*Mean ± s.d.*	*Max. - Min.*
Date palm trees	184.7 ± 106.2	320 - 0	581.7 ± 956.6	1685.0 - 0
Arable land (ha)	4.7 ± 2.6	9.0 - 0.5	7.7 ± 2.0	10.0 - 5.0
Area under cereals (ha)	2.3 ± 1.8	3.2 - 0.3	-	-
Area under henna (ha)	0.4 ± 3.5	1.2 - 0	-	-
Area under fodder (ha)	1.1 ± 0.6	2.4 - 0.2	-	-
LivestockUnits*	4.0 ± 2.8	10.6 - 0.3	-	-
N° of family laborers	5.2 ± 1.6	9 - 2	2.3 ± 1.4	3 - 1
Total capital (Euros)	96,215 ± 41,659	182,045 - 34,545	247,348 ± 189,403	464,772 - 118,181

** Livestock unit (LU): 1 cow of 400 kg live weight. One ewe of 40 kg: 0.1 LU*

2.2. *Data collection and analysis*

Each farm was visited several times, between September 1st 2019 and August 31st 2020. The first visit was dedicated to explaining the objectives of the study and to collecting information on the extent of agricultural land, farm equipment, herd size and composition, agricultural plots and crops, as well as the number of family members who were actively involved in farm work and information on hired labor. Additional visits were undertaken to quantify the duration of each task. The research protocol was based on the principles of the 'Work Balance' method of Dedieu *et al.* (1999), which aims to quantify the time devoted to each on-farm activity, annual profile of the workload and of the people responsible for these activities. The aim is to characterize the volume of labor over a full year: routine labor devoted to livestock, which is generally repeated every day, (feeding and watering the animals, milking, etc.) and seasonal work, i.e. work devoted to crop management (sowing, fertilizing, harvesting, etc.) that is not repeated daily.

The capital invested in each farm was estimated using local references for land (10,000 Euros for 1 ha), date palm trees (500 Euros for a tree of '*Majhoul*' variety, 200 Euros for other varieties) machinery and different animal species (1,500 Euros for a Holstein cow, 120 Euros for a D'man ewe, etc.). We further calculated the gross margins corresponding to the overall sales of animal (milk, live animals) and crop products during a whole agricultural campaign minus the respective costs of inputs used for each product. Prices of inputs and products were determined using local references, i.e. farm gate prices for crop products (dates, vegetables, etc.) and animal products (milk and live animals' sales), as well as retailers' prices with regards to inputs (seeds, fertilizers, pesticides, etc.). Self-consumed products of both of animal and plant origin were not included in the gross margin and the calculation did not also include the amortization of investments. In addition, the labor provided by members of the family was considered as free of charge, and its remuneration was defined as the gross margin for crops and livestock divided by the total days of work devoted to each of these activities. However, wages paid to hired laborers, i.e., a wage of 7 to 10 Euros per day was used depending on the nature of the task, were included in the calculation of the gross margins. We also calculated incomes earned through off-farm activities by counting the number of family members involved in these activities and the wages they earned.

Finally, we compared the organization of labor and daily incomes on crop/livestock farms and on farms specialized in crops, to draw conclusions regarding the real uses of labor and their impacts on the farm performances.

3. Results

3.1. *Labor allocations for livestock and crops and their seasonal variations*

In the 14 crop/livestock farms, routine uses of labor reached an average value of 796 hours per livestock unit (LU) per year (almost 99.5 days per year, based on an 8-hour working day), implying a daily requirement of 2.2 hours per LU per day. There was marked variation in this parameter due to the many different variables involved: the number of animals, species, distances from the barn to the fodder plots (as fodder is transported to the animals twice a day), etc. Findings revealed that family members performed almost all (92.0%) of this routine work (Table 2). In fact, hired laborers are seldom used for routine work, but may be used for specific tasks, which was the case on eight farms. Hired laborers are needed in particular to cut the fodder and transport it to the herd, as, given the particularities of the oases (no pastures because of the arid climate, and limited amount of arable land), all the farms used a "zero-grazing" system. This accounted for 69% of the total routine labor needed for the whole year, the remainder consisting in cleaning the barns (13.3%), watering the animals (9.3%) and milking cows as well as delivering the milk to the processing unit (8.4%).

Regarding seasonal labor (i.e. devoted to crops), results showed that its average duration was respectively, 519 and 1,008 days in crop/livestock farms and crop farms, with a mean

Table 2 - Characteristics of routine labor in the 14 crop/livestock farms.

		Mean ± sd	*Max.*	*Min.*
Annual routine labor (hours)	Total	3,184 ± 1,794	7,227	620
	per LU	796 ± 519	2,327	497
Share of family members in routine labor	%	92.0 ± 16.9	97.2	51.4

Table 3 - Analysis of seasonal labor according to the type of farms and kind of activities.

Type of farm	*Crop/livestock farms (N=14)*	*Crop farms (N = 3)*
Seasonal labor Total (days/year)	518.6	1,007.9
Seasonal labor for herds	5.5	-
Seasonal labor for fodder crops	96.0	-
Seasonal labor for cash crops	417.1	1 007.9
Average total seasonal work (days/ha/year)	90.5	74.5

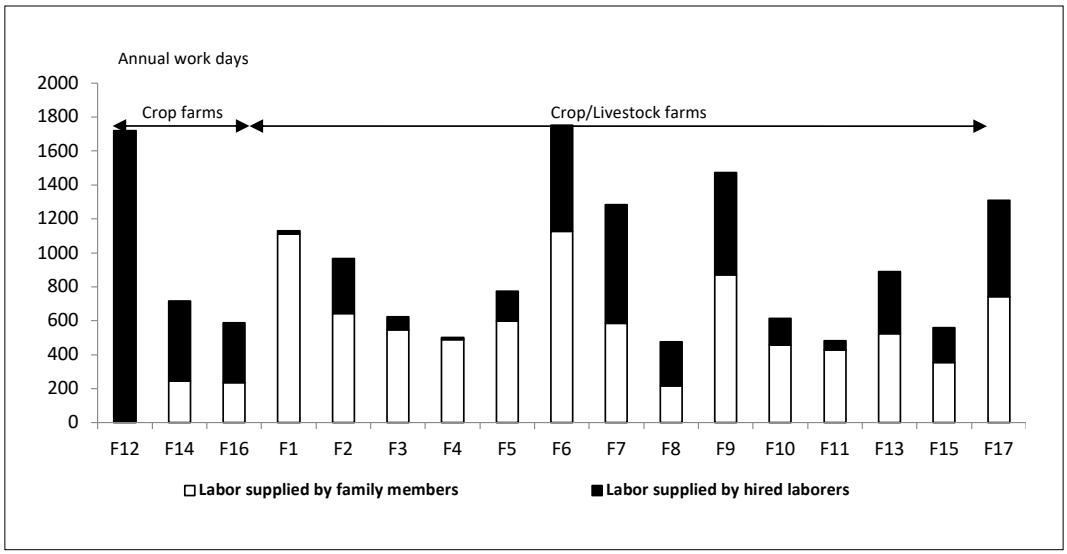
value of 90.5 days per ha (including the labor required for date palms), with significant variation among the farms (minimum: 24.8; maximum: 198.6 days/ha) (Table 3).

The labor required for cash crops represented the biggest share of seasonal work, as seasonal work for herds (animal sales) and fodder crops only represented 20.2% of the total amount on the 14 crop/livestock farms. On the farms specialized in crops, the two latter components of seasonal labor are missing. As irrigation is compulsory, given the desert climate conditions, it is the most time-consuming task. In practice, only the three farms specialized in crops used drip irrigation, which only requires 12.0 days/ha on such farms, whereas on the remaining farms, where furrow irrigation is still practiced, an average of 35.9 days/ha are required. Labor requirements for date palms (around 1 day per tree per year for group pollination, harvest, sales, etc.) represent 45.2% of the labor devoted to crops. This is a clear indicator of the importance of dates in the economy of oasis farm systems.

The use of labor for the watermelon crop was relatively high compared to that required for other cash crops like cereals or henna (respectively 76, 48 and 62 days per ha), given the continuous attention required by watermelon during its vegetative cycle: sowing, frequent irrigation and treatments. However, the uses of labor for watermelon were rewarded as marketing conditions were favorable in spring 2020, despite some initial setbacks caused by the lockdown due to the Covid-19 pandemic. Mean annual total working time (i.e. total of routine and seasonal work) in the 14 crop/livestock farms was 916.6 days, whereas it reached 1,007.9 days in the three crop farms. In the crop/livestock farms, routine work represented on average 43.7% of total working time. The maximum time was reached on farm 6, where both sheep and goats are reared, and additional time is needed to care for the two different species.

Almost 60% of the seasonal labor was supplied by hired workers, corresponding to 51.7 days per ha. However, work autonomy, defined as the total amount of labor (the sum of routine and seasonal work) provided by family members varied across farm types: it reached a mean value of 67.2% on crop/livestock farms, whereas it did not exceed 17% on crop farms (Figure 2). This means that each family member on a crop/livestock farm worked an average of 111.5 days per year, whereas family members only worked 68.5 days per year on crop farms.

Figure 2 - Share of total labor provided by family members and hired workers across farm types.



The monthly distribution of labor over a whole year on crop/livestock farms is 'U-shaped', characterized by two peak activity periods (one in June and the other in August-September) corresponding, respectively, to cereals (for harvest in late spring) and to date palms (for harvest and sales in late summer). Fall and winter require little labor for crops. By contrast, routine work required for livestock remains almost the same all year round as the composition of the herd is steady. This is illustrated by the example of farm 5 (Figure 3).

On farms specialized in crops, peak labor periods are more marked than on crop/livestock farms, as watermelon requires specific actions (sowing, mulching, transplanting, irrigation, etc.) in December and January when the crop is sown, as illustrated by farm 14. Three to four months later, in late March and April, when the crop is harvested also correspond to a sharp in-

Figure 3. Monthly distribution of uses of labor in crop/livestock farms (example of farm 5).

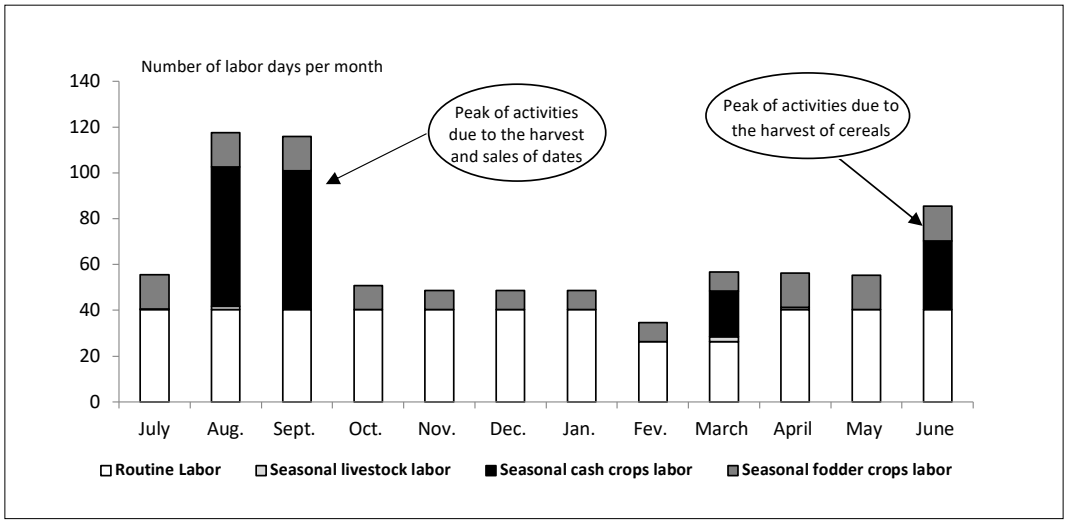
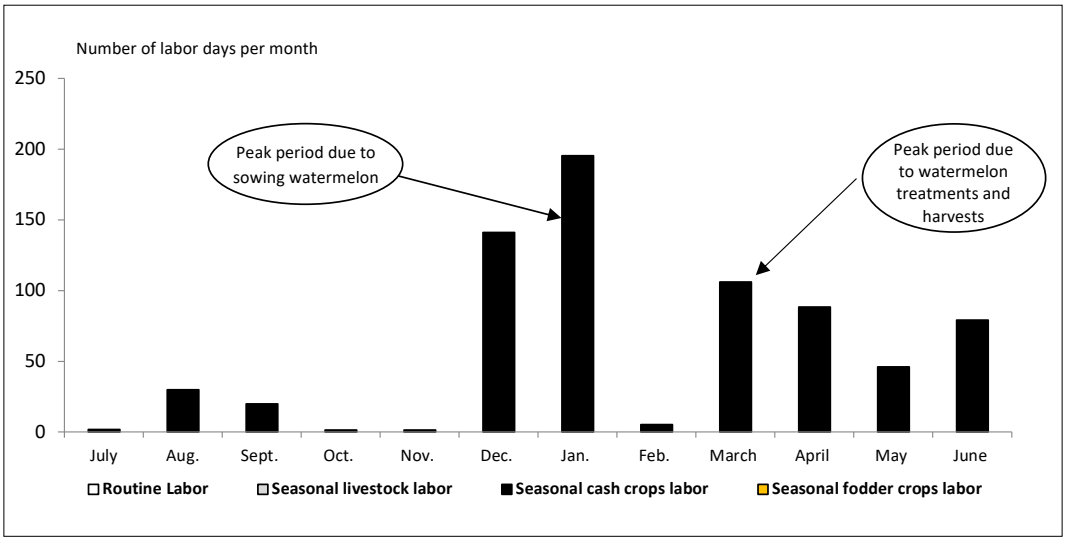


Figure 4 - Monthly distribution of uses of labor on crop farms (example of farm 14).



crease in labor requirements. In addition, there are no routine labor requirements, as these farms have no livestock (Figure 4).

3.2. *Crops and livestock profitability and its impacts on labor daily remuneration*

Regarding crop profitability, date palms represent 34% of the total crop gross margins for crop/livestock farms. The average gross margin per tree is around 20 Euros (range 4.5 to 42 Euros). This is explained by variations in yield as well as the effect of the variety grown: some varieties including '*Majhoul*' are sold for up to 10 Euros per kg, whereas other varieties do not fetch even 2 Euros/kg. The average gross margin per date palm tree is higher on farms specialized in crops, and can reach 32 Euros, thanks to drip irrigation and increased use of fertilizer. Differences between crop/livestock and crop farms were also recorded for watermelon, as cereals and henna were not grown on the farms that specialized in crops (Table 4).

By contrast, livestock profitability was limited compared to that of crops, averaging 113 Euros per farm for a whole year, which corresponds to 28.4 Euros per LU (Table 5). Profitability was also highly variable, ranging from 367 to 1,836 Euros/LU, reflecting differences in rearing practices and in animal performances, as well as the weight of public subsidies that benefit the prolific D'man breed. In fact, livestock was only profitable in four of the 14 crop/livestock farms, many of whom suffered from setbacks due to high mortality rates and insufficient feed autonomy, requiring the purchase of significant amounts of

Table 4 - Variability of crop gross margins among farm types.

	Crop/livestock farms	*Crop farms*
Gross margin for date palms (Euros/tree)	20.0 ± 17.3	31.9 ± 42.3
Cereals (Euros/ha)	198.5 ± 515.4	-
Henna (Euros/ha)	3,540.7 ± 3,313.2	-
Watermelon (Euros/ha)	5,269.4 ± 5,720.5	5,083.0 ± 1,746.7
Share of date palms in crop total gross margins (%)	34.1	27.8

Table 5 - Livestock profitability indicators in the study sample.

	Mean ± standard deviation	*Min. – Max.*
Routine work (days/farm/year)	499.5 ± 284.5	186.8– 1141.4
Gross margin (Euros/LU)	28.4± 574.8	- 367.2 – 1,835.9
Remuneration for livestock labor (Euros/day)	0.23 ± 2.42	- 3,76 – 5.12

feed. However, despite the apparent economic losses, livestock contributes to the resilience of farming systems in many ways: supply of manure to maintain soil fertility and improve soil structure, self-consumption of milk and meat (the sacrifice of a lamb in the religious Aïd El Adha festival and daily contribution to the households' supply in milk for farms that own cows), regular sales of milk in the case of dairy farms, etc. Taken together, our results show that in oasis systems, livestock has to cope with significant constraints such as heat stress, zero-grazing, reduced fodder areas, which can only hamper its profitability.

Off-farm incomes were only reported on four of the 14 crop/livestock farms (Farms 2, 3, 4 and 6). The total income from off-farm activities was produced by only six people, with an average annual sum of 1,486.4 Euros per year per farm. This represents an average 15% of the total annual gross margin of these farms, and these money transfers are crucial to cover the purchase of inputs in period when agricultural incomes are limited, particularly before dates are harvested (Figure 5).

Finally, for each farm, we calculated the gross income produced by one day of labor, either for care of the livestock (i.e. routine labor, plus seasonal labor for the herd, plus seasonal labor for fodder crops) or for crops (i.e. seasonal labor for date palms and other cash crops). Results showed that one day of labor on crop/livestock farms produced an average income of 8.7 Euros. By contrast, one day of work on farms specialized in crops produced more than 5-fold that figure: 44.4 Euros, thanks to the high investments made by these farmers. These average incomes varied considerably within each group, illustrating the marked differences in annual volumes of labor, as well as the equally marked fluctuations in livestock and crop gross margins (Figure 6).

Figure 5 - Share of animal products, date palm trees, cash crops and off-farm incomes in total revenues.

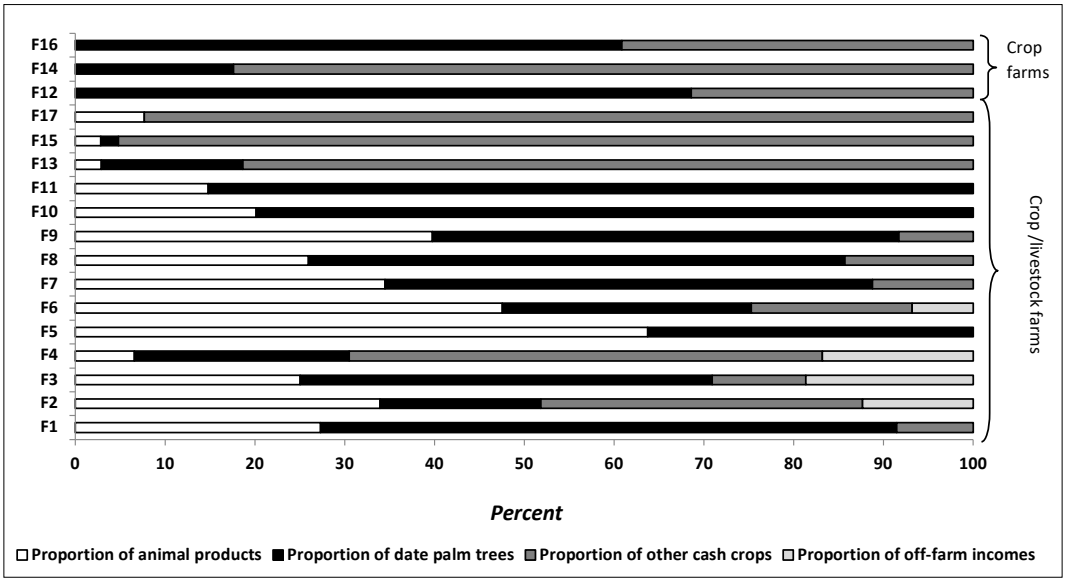
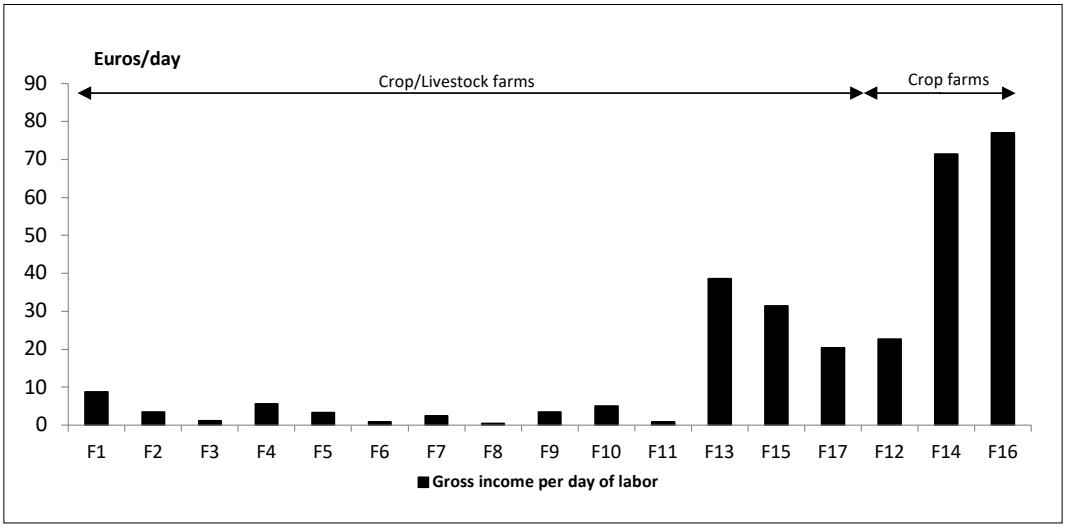


Figure 6 - Gross income per day of labor (Euros).



The results also revealed differences in the capital invested: on most of the crop/livestock farms, the total investments did not exceed 100,000 Euros, thereby hindering the economic efficiency of labor (less than 10 Euros per day). However, three farms (F13, F15 and F17) in this category managed to obtain better results thanks to higher investments than the average (in two farms, the capital exceeded 100,000 Euros) and/or the excellent raw margin of certain cash crops, such as henna and watermelon. Otherwise, none of these three farms showed a positive livestock raw margin. Finally, the gross data concerning the allocation of labor per farm also allowed us to calculate the total time available per person, which corresponds to the number of hours per year in which the family members are not involved in farming activities. This indicator reached an average of respectively, 1,787 and 1,956 hours per family member per year for crop/livestock farms and for farms specialized in crops.

4. Discussion

Our results show that most routine farm labor (more than 90% of the total amount) on crop/livestock farms is provided by family members, confirming previous results in other regions in Morocco, Europe, and South America, where animals are reared by their owners (Sraïri and Ghabiyel, 2017; Cournut *et al.*, 2018; Dieguez *et al.*, 2010). This is even truer in times of crises, like that caused by Covid-19, when incomes are limited (Ragkos *et al.*, 2018). In addition, our findings show that the average time devoted to a single livestock unit in the oases was around 796 hours, which is the equivalent of 100 days of work. The average time calculated by Sraïri *et al.* (2013) in a rain-fed agricultural region in Morocco with mixed crop-livestock systems was 419 hours (52 days). The differences between these two situations can be explained by the nature of the oasis livestock systems, based on zero-grazing, which increases the work load required to cut and transport fodder to the animals twice a day. It may also be linked to the limited size of the herds as well as its frequent multi-species composition (most of the farms simultaneously rear sheep and goats in a 'zero-grazing' system, and some even raise cattle) which precludes economies of scale in the amount of labor needed to care for the different animal species. In addition, off-farm employment opportunities are limited, unless people migrate to large cities, such as Marrakech and Casablanca, 300 to 500 km away from the oases. Farmers may thus waste working time, particularly while caring for their animals.

In contrast to family labor for the care of livestock, seasonal crop labor was provided by hired

laborers. Most of the time, these are people from neighboring farms, at the exception of hired workers involved in watermelon harvesting, which often originate from far regions, following the retailers' lorries which will transport the product to large cities. The use of hired workers for cash crops is explained by the need for skilled people to carry out specific tasks in a limited period (like pollinating the date palm trees, removing dead leaves from these trees, and harvesting the dates, sowing, mulching and harvesting watermelon, etc.) and the fact family members are not available as they are often occupied by the routine tasks required by the livestock. The labor requirements per date palm tree in our study are similar to those reported by Sraïri and Bentahar (2021) in the same area. Another interesting finding concerning seasonal labor is the amount devoted to both cereals and fodder in crop/livestock farms. This also confirms previous works on the oases' farming systems reporting that, in addition to date palms, cereals and fodder are the most important crops (Oumata *et al.*, 2020), as they are used to feed both humans and animals. In addition to these 'traditional' and commoner crops, watermelon is mainly cultivated in the expansion area of the oasis, with the goal of conquering new land based on the exclusive use of groundwater (Hamamouche *et al.*, 2018). However, this trend is creating growing conflicts around both water and land (Carpentier and Gana, 2017), exacerbating the scarcity of resources as the rate of water exploitation is no longer sustainable (Benaoun *et al.*, 2014). Given the rapid turnover of watermelon (since it is a crop of a cycle not exceeding 4 months), even investors from outside the region have been tempted to rent collective land and sow this crop, once they secure the access to groundwater. This rapid expansion of the area sown in watermelon has already jeopardized the supply of water to the urban centers, as frequent water disruption is reported in Zagoura, the chief town in the oasis valley, particularly in summer, when the average temperature exceeds 45°C.

Labor productivity for watermelon, which was grown on all the farms specialized in crops in the present study, was higher than that of henna or cereals (respectively 68.1, 22.2 and 3 Euros per day). Even the economic return per day of labor for date palm was lower than watermelon, as it did not exceed 19.1 and 42.7 Euros, respectively, on crop/livestock and crop specialized farms. Despite the high volatility of farm gate prices for watermelon (due to oversupply or reduced marketing possibilities, as well as variable export opportunities according to Sraïri and Bentahar, 2021), high profits encourage farmers to expand their watermelon area. This mainly takes place in the oasis extensions (where groundwater is more readily available to satisfy the crop's high water requirements) and by abandoning the integrated livestock-crop system, raising concerns about the sustainability of this farming system. Indeed, the decoupling of crops and livestock is currently criticized worldwide (Garrett *et al.*, 2020).

The average remuneration for a single day of routine labor on crop/livestock farms remains almost 42 times lower than the average remuneration on crop farms: 0.2 vs. 8.5 Euros. This may mean work dedicated to the herd is not attractive for local farmers. Indeed, such levels of income per day are often below the guaranteed minimum wage (6.3 Euros per day of labor) in the agricultural sector in Morocco, which is regulated by official decree. Given that this daily income is just above the poverty line (Chen and Ravaillon, 2004), our results confirm the acute economic vulnerability of farmers who raise livestock. Our results also showed that the time spent on routine labor (i.e. devoted to livestock) is quite as long as the time spent on seasonal labor (i.e. devoted to crops), and that it is particularly true for very small crop/livestock farms (less than 2 ha). This finding confirms that, in environments with limited assets, livestock rearing remains the only livelihood option for many farmers, as the 'wealth of the poor' (Duteurtre and Faye, 2009), given its limited needs in capital investments in comparison to cash crops such as orchards. In practice, the capital invested in livestock is limited, i.e. less than 15% of the total capital, when land, trees and machinery are included in the calculation. However, the synergies between crops and livestock in integrated systems are much more complex than implied by this simple comparison, and the entire oasis farming system is based on exchanges of biomass, water and even

labor between crops and livestock (Dollé, 1990). It therefore seems that there is a direct transfer of profitability from livestock to date palm trees thanks to water (Sraïri *et al.*, 2019), as manure as well as nitrogen fixation in soils through legume fodder (alfalfa) allow an increase in fertility and secure crop yields.

The total available time per person reached an average of respectively, 1,787 and 1,956 hours per family member per year in integrated crop/livestock farms and crop farms. These figures indicate that in both systems there is marked underemployment of family members, as the available time per person should not exceed 1,000 hours per year (Beguin *et al.*, 2011). This underemployment in the farming sector is very common in Morocco and was already documented by Pascon (1980), who emphasized its features: limited opportunities to shift to other economic sectors, and periods of low labor requirements particularly in summer, when drought and water scarcity frequently prevent cropping.

Agricultural labor only produces an average income of 8.7 Euros/day on crop/livestock farms and this limited value is a direct consequence of underemployment in oasis farming systems. On crop farms, the average income is 44.4 Euros/day. However, these mean values mask considerable variability, as labor remuneration on four crop/livestock farms in our sample was close to that recorded on crop farms. One explanation is the performance of their cash crops (henna and watermelon). Another hypothesis may be their use of small-scale agricultural machinery that has been suggested as a way to sustain oasis agricultural systems (Garbati Pegna *et al.*, 2018). This is mainly evidenced by the small cutters used to cut the alfalfa, which requires considerable time every day, all year round.

The differences in labor remuneration between smallholder diversified crop/livestock farms and larger farms specialized in crops are mainly due to the level of investments, as well as the better crops yields obtained by the farms specialized in crops. Indeed, our results point to a positive link between the daily labor income share and the total investment per farm. It therefore appears that some crop/livestock farms manage to obtain a similar income from a day of labor as that obtained by crop farms. This means that further research is needed to find an optimal combination between uses of labor and investments, to design agricultural production systems that optimize work efficiency and that are sustainable from the standpoint of oasis resources use.

If the remuneration for agricultural labor is not significantly improved, particularly in smallholder crop/livestock farms, it may prompt young generations to migrate, which, in turn, might further exacerbate existing labor problems in oases, particularly in peak activity periods, but might also have advantages, as migrants from these areas are generally keen on investing in the agricultural sector in their home regions (Rignall, 2015; De Haas, 2001). Finally, we conclude that the analysis of the organization of labor and productivity in the different oasis production systems requires an interdisciplinary approach. This was highlighted in a recent review by Malanski *et al.* (2021) emphasizing the complexity of agricultural work analysis, that requires the involvement of diverse disciplines. Further research is needed to confirm the trends identified in this study in a larger study sample and to check their robustness in other agricultural campaigns.

5. Conclusion

The present paper reveals the complexity of analyzing uses of labor in oases, given the diverse types of farms, the range of crops and the presence or not of livestock. The results which are based on the mobilization of diverse disciplines like economics, ergonomics, social issues for rural development and livestock farming systems as well as agronomy, justify why in the oasis, visitors are traditionally welcomed by milk and dates. This combination of livestock and fodder as well as cash crops does not only refer to the nutrient synergies of such an association but it is emblematic of the main efforts made by farmers in such hostile environments. It is also symbolic of the symbiosis between crops and livestock that benefit from each other and guarantee the resilience of the farming system. Our results confirm the weight of date palms as a key component of the oasis farming systems, although the study sample was quite limited (only

17 farms) and the follow-up of farms only focused on a single year. The association between date palms and livestock in fact constitutes the pillar of the oases' farming systems, as it mobilizes most of the volumes of work as well as producing a large share of gross margins. One of the future research perspectives of the oasis farming systems' analysis would be to better characterize the interactions between crops and livestock, within the principles of a circular economy, by quantifying the amounts of biomass benefitting to livestock (cultivated fodder, crop byproducts such as straw and dates' wastes, etc.), as well as the volumes of manure used on-farm to maintain soils' fertility. The results also show that most of the traditional smallholder farms located within the original perimeter of the oases have limited incomes per day of labor (often not exceeding 10 Euros). This is due to numerous constraints (poor animal performances, limited crop yields as well as variable gate farm prices for most of the outputs, combined with a limited level of capital investments). Some farmers have tried to overcome these constraints by seeking public subsidies (mainly for rearing D'man sheep) or by farming land outside the oasis perimeter, digging boreholes as well as adopting drip irrigation (which is also subsidized) to grow high value cash crops. The integration of crops and livestock no longer exists in this group of farms. Even though the remuneration for one day of labor appears to be higher than that on crop/livestock farms, this kind of farm may be vulnerable to many agronomic and economic factors including price volatility, groundwater depletion, and declining soil fertility. Taken together, our results also show that there is considerable scope to improve agricultural labor incomes, to reduce underemployment and to add value to the existing workforce. This can be achieved through the promotion of networks of farms, to implement collective tasks and to provide opportunities of employment in rural non-agricultural services. Policy makers need to be aware that in such vulnerable areas, close monitoring is needed to enhance the performances of farming systems and to guarantee their sustainability, particularly given the challenges induced by global warming which has already triggered several large scale fires that have destroyed many palm date groves. Promoting decent work within the oasis, by encouraging mechanization as well as increasing labor remuneration through sound investments destined to sustain higher crops and livestock yields might be necessary to ensure labor attractiveness for young generations and avoid extensive migration.

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