

## Understanding diversified oasis farms' economic performances through an analysis of labor uses and their relation to the invested capital

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### Abstract

In this study, uses of labor were characterized using the 'Work Balance' method in a sample of 30 farms representing the diversity of farming dynamics within the Drâa valley oases (South East of Morocco). The efficiency of labor was analyzed through the elaboration of work time uses per products' outputs (either crops or animal source food), as well as labor remuneration (i.e. Euros per day). The results showed that almost half of total uses of labor (48.8%) are devoted to livestock, while the remainders 51.2% are used for crops. The labor required to raise livestock was mainly provided by family members (72%), whereas that required for crops was mostly assumed (64.8%) by hired laborers. In all farms' types (either smallholder units, average or large farms), date palms constitute the most vital crop for the oasis farming system, given their contribution to incomes generation, as well as they enable positive synergies of crop/livestock integration, while adapting to the harsh climate conditions. At the opposite, livestock ensures variable roles, as it is mostly crucial within smallholder farms given their limited investment means, whereas large farms rear animals for diversification purposes. By contrast, large farms devote increased interest and investments to cash crops such as watermelon and date palms market varieties, with almost entirely hired workforce, and without any consideration for their ecological impacts, particularly on groundwater depletion. Return on investments rate defined as the annual incomes divided by the invested capital is only 10.1% in smallholder farms, whereas it reaches a value of 23.7% in large farms; average farms showing an intermediate value of 15.4%. Altogether, the results confirm that there is still for improvement of work uses and efficiency in the oasis farming system, taking into account the diversity of situations, and considering the existing constraints such as scarce water (exacerbated by the ongoing effects of the global warming) and land, as well as limited investment means in a majority of farms.



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### 1. INTRODUCTION

Oases 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 scarcity is frequent, implying further stresses for date palm trees (Carr, 2013), which are often the dominant species in farming systems. 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 animal source food, like milk and meat. The diversity of species

reared (small ruminants – goats and sheep – as well as cattle and even dromedaries) illustrate the numerous situations found in these regions, from relatively abundant fodder availability (in irrigation conditions) to desert conditions (with an erratic biomass in large rangelands) (Srairi et al., 2017). The oasis farming systems rely therefore intensely on crop/livestock integration, as a pillar of a circular economy principles, allowing biomass recycling and adding value to the existing assets (biomass, capital, land, water and work). 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 necessitate more labor. Even though diversification strategies are widely used by 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). 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 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 Servi re, 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). It may also explain the ongoing trends of the labor market, particularly in developing countries, where limited agricultural incomes may impede the attractiveness of this sector, implying further rural exodus to large cities (Arslan et al., 2020). Based on these elements, this article 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 crops and livestock rearing systems, including the emergence of extension areas where specific cash crops are cultivated, such as watermelon and date palms' market varieties, will help understand the choices made by oasis farmers faced with many constraints. We hypothesize that labor management strategies in line with farm assets may represent an opportunity to adapt to the structural characteristics of the oases, such as limited investment means, 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 Dr a 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 Dr a River, representing 26,000 ha of arable land (Fig. 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 30 farms representing the diversity of production situations was selected; in fact, according to local references, the average farm size does not exceed 1.7 ha (ORMVAO, 2018). 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.

Three kinds of farms were distinguished: very small farms ( $n = 10$ ) with an arable area not exceeding 2 ha, farms with an arable area between 2 to 5 ha ( $n = 9$ ) and large farms, where the average arable land was 11.8 ha ( $n = 11$ ). All farms were characterized by crop/livestock integration, often noted in the oasis context, at

the exception of four farms (all with more than 10 ha) which only cultivated cash crops (watermelon and date palms). The first category of farms mainly relied on date palms, fodder and cereals, with no means in investing in cash crops such as watermelon (Table 1). The other categories relied on investments in private means of irrigation (boreholes, basins for water storage, drip irrigation equipment, etc.) intended to enable the cultivation of understory cash crops.

The smallest farms (less than 2 ha) had fewer working family members (2.3) than larger farms (4 persons). Livestock either refers to small ruminants – mainly the prolific D'man sheep (on 27 over the 30 sample farms) and Drâa goat breeds (on 12 farms) - or dairy cattle (in 9 of the 30 farms, all located near the city of Zagoura where there is a dairy processing unit). 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, in addition to off-farm resources (purchase of feed). 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, a leguminous fodder crop. In addition, frequent irrigation of alfalfa satisfies part of the water needs of the date palm trees.

## 2.2. Data collection and analysis

Each farm was visited several times a year, between September 1<sup>st</sup> 2020 to August 31<sup>st</sup> 2021. 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,

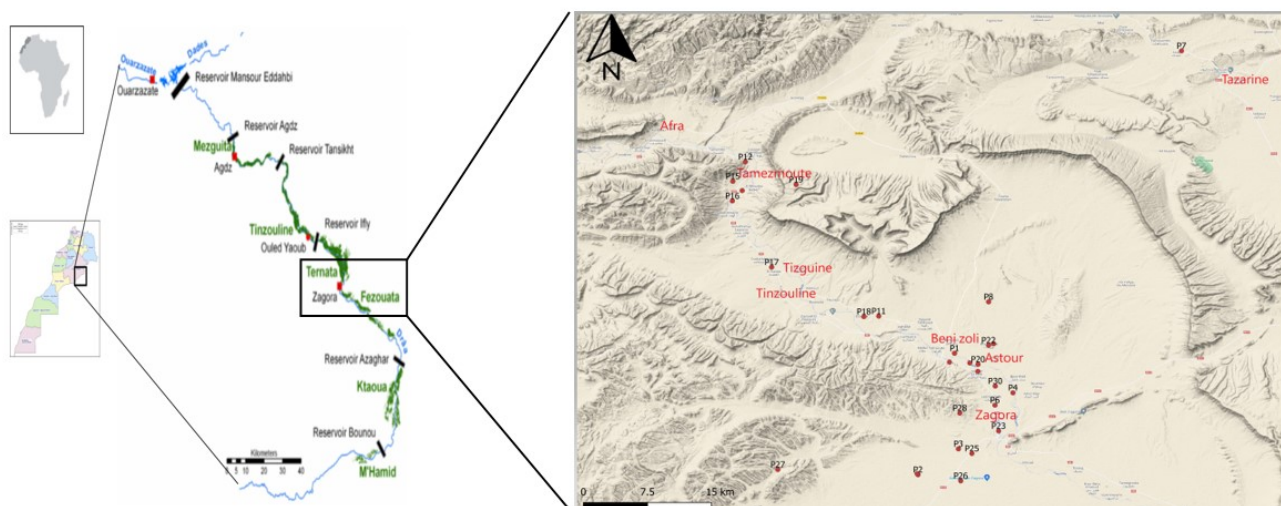


Fig. 1. Location of the study farms based on their GPS coordinates

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

Farms' type	Very small	Average	Large
Number	10	11	9
Average arable land (ha)	1.5 ± 0.3	3.9 ± 0.7	11.8 ± 8.1
Date palm trees	135 ± 88	459 ± 525	889 ± 996
Cereal (ha)	0.2 ± 0.3	0.9 ± 1.1	1.0 ± 0.9
Watermelon (ha)	-	0.2 ± 0.7	1.4 ± 1.4
Fodder (ha)	0.7 ± 0.6	0.9 ± 0.6	0.9 ± 0.7
Livestock Units	5.6 ± 4.9	5.7 ± 3.4	8.2 ± 6.0
Number of wells	1.7 ± 1.3	2.1 ± 0.4	3.0 ± 0.4
Family persons in farm labor	2.3 ± 1.4	3.8 ± 1.6	4.0 ± 2.3
Invested capital (Euros)	70,686 ± 43,648	158,223 ± 109,352	259,627 ± 260,307

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

Source: From the authors' calculations

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 get reliable data in order 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 animal species (1,500 Euros for a Holstein cow, 120 Euros for a D'man ewe, etc.). The gross margins corresponding to each animal (milk and live weight gain) and crop products were calculated by deducting during a whole agricultural campaign the respective costs of inputs used from the overall sales' values. Prices of inputs were determined using local references (retailers' prices with regards to seeds, fertilizers, pesticides, etc.). Products' prices corresponded to farm gate levels (milk and live

for crops and livestock products divided by the total days of work devoted to each of these activities. However, wages paid to hired labourers (from 7 to 10 Euros per day depending on the nature of the task), were included in the calculation of the gross margins. The incomes earned through off-farm activities were also determined by counting the number of family members involved and the wages they earned. Finally, we compared the organization of labor and daily incomes on farms, 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 27 livestock farms, routine uses of labor reached an average value of 547 hours per livestock unit (LU) per year (almost 68.4 days per year, based on an 8-hour working day), implying a daily requirement of 1.5 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 all farms adopt a 'zero grazing' system due to cultivated plots' crampedness), etc. Findings revealed that family members performed around 72.0% of this routine work (Table 2). In 8 of the 27 farms with livestock, family members were in charge of all the routine work tasks. In the remaining 19 farms, hired workers were used

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

Farms' type	Very small	Average	Large	Whole sample
<b>Annual routine labor (h)</b>	1560.0 ± 936.8	2507.5 ± 1119.7	3107.6 ± 1346.4	2404.6 ± 1258.0
<b>Annual routine labor/LU* (h)</b>	471.8 ± 379.1	638.8 ± 472.9	496.6 ± 237.9	547.0 ± 382.2
<b>Routine labor autonomy** (%)</b>	64 ± 41	80 ± 26	72 ± 37	72 ± 34

\*LU: Livestock Units

\*\* : Part of routine work duration accomplished y family members

Sources: from the authors' analyses

animals' sales, as well as crop products such as dates, vegetables, cereals, etc.). Public subsidies offered to farms contributing to breeding lambs of the local prolific sheep strain, the D'man, were included in the calculation of livestock gross margin. 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

and they were responsible of 1 to 68% of total routine work duration. It was noted that routine work autonomy increased from 64% in very small farms to 80% in average farms, and it diminished to 72% in very large farms. Otherwise, in all cases, hired laborers are particularly needed daily to cut the fodder and transport it to the herd. This tasks accounts for 78.6% of the total routine labor needed for the whole year, the remainder consisting in cleaning the barns (10.3%), watering the animals (5.3%)

and milking cows as well as delivering the milk to the processing unit (5.8%).

Regarding seasonal labor, it has to be classified in three categories: *i*) seasonal work devoted to livestock rearing, which groups the tasks in relationship to animal sales, artificial insemination, calving, etc., *ii*) seasonal labor devoted to fodder crops (sowing and irrigation), and finally *iii*) seasonal labor devoted to cash crops, i.e. all the tasks' durations for date palms, cereals, watermelon, etc.

The seasonal work duration devoted to livestock varied from 1 to 8 days/LU/year, with an average value of  $3.9 \pm 3.1$  days/LU/year. This result is explained by frequent sales of animals, as a serious drought impacted the area. This finding is also due to two successive prophylactic vaccination campaigns which were time consuming for farmers. The seasonal work duration devoted to fodder crops was represented by sowing, fertilizing, irrigating and treating alfalfa. It amounted to an average value of  $22.9 \pm 28.6$  days/ha/year. The seasonal work devoted to cash crops (i.e. date palms, cereals, watermelon, vegetables, henna and alfalfa - in farms where it is sold -) reached an average value per farm of  $305.5 \pm 282.2$  days/year, as it varied from 31.2 to 1310.7 days of work. Excluding the work load specific to date palms, sub-layer cash crops' work amounted to  $85.2 \pm 105.7$  days/ha/year, varying from 11.2 to 475.0 days/ha/year (Table 3). The autonomy of farms with regard to seasonal work requirements was limited to 35.2%, meaning that hired workers realized almost two thirds of the work time. The autonomy was particularly limited in large farms with important areas of newly planted date palms and/or watermelon, as well as in farms with limited family members. By crop, an average of 45 days are necessary for one ha of cereals, 34.7 days for one ha of henna,

28.3 days for one ha of vegetables and 26 days for one ha of watermelon. Seasonal work time varies among farms and crop types. Some crops occupy plots for more than 7 months (cereals), whereas others necessitate only 3 months (watermelon, given that all farms buy seedlings from specialized nurseries). Henna, a perennial crop, consumes more time during its first year as it necessitates transplanting towards plots. The final nature of the product also impacts work durations: cereals' harvest is particularly time consuming because of grains' threshing, as all farmers dedicate themselves to get stockpiles of straw, a much needed source of fiber to livestock. In addition to seasonal work destined to sub-layer cash crops, a significant amount of work is also dedicated to date palms. The results show an average duration  $0.6 \pm 0.6$  day per date palm tree/year, as this value varied between 0.1 to 2.6 days/date palm tree/year. This means that date palms' cultivation almost represent 68.7% of the total duration of seasonal work, implying the major role of this crop within the oasis farming systems.

From the previous results, total work duration can be calculated, with the share of routine work and seasonal work, with regard to farms' sizes and the type of crops they cultivate. The work duration per farm averaged 609.2 days per year, which was the equivalent of 162 days per ha and per year. It varied from 140.5 to 1318.1 days of work per farm. It was impacted by farm size (Table 4) as well as by the adoption of mechanization. In fact, despite the limited areas of cultivated plots, most of farms rent tractors for soil plowing. Milking is also done through small milking devices in four of the nine farms with a dairy herd. In addition, three farms have also purchased fodder mower, to decrease the significant work load associated to this daily task.

**Table 3.** A summary of seasonal work components among farms' types.

Farms' type	Very small	Average	Large	Whole sample
Seasonal work for livestock	$3.3 \pm 2.6$	$4.5 \pm 2.3$	$5.1 \pm 3.9$	$3.9 \pm 3.1$
Seasonal work for fodder	$18.8 \pm 24.3$	$31.8 \pm 35.0$	$16.4 \pm 13.4$	$22.9 \pm 28.6$
Seasonal work for cash crops	$102.9 \pm 81.5$	$262.3 \pm 226.8$	$511.4 \pm 368.1$	$305.5 \pm 282.2$
Seasonal work for cash crops	$86.8 \pm 120.1$	$102.4 \pm 132.6$	$69.1 \pm 27.4$	$85.2 \pm 105.7$
Seasonal work for date palms	$0.9 \pm 0.7$	$0.3 \pm 0.2$	$0.7 \pm 0.8$	$0.6 \pm 0.6$
Total seasonal work (days/ha)	$123.2 \pm 75.0$	$78.2 \pm 51.6$	$49.8 \pm 18.9$	$84.7 \pm 62.1$

Source: Authors' calculations

**Table 4.** Annual total work duration per farm type.

Farms' type	Very small	Average	Large	Whole sample
Total work duration (days)	$328.3 \pm 158.7$	$628.6 \pm 226.8$	$897.5 \pm 342.2$	$609.2 \pm 357.0$
Total work duration (days/ha)	$228.6 \pm 127.0$	$162.9 \pm 78.1$	$88.8 \pm 35.4$	$162.6 \pm 103.2$

Source: Authors' calculations

Routine work (i.e. devoted to livestock) represents 48.8 % of total work duration, implying that livestock necessitates almost half of total work volumes on-farm. This value varies from 25 to 71% in crop/livestock farms, and it even reached 93% of total work duration in the unique poultry specialized farm within our study sample. Routine work contribution to total work averaged a mean value of 52.1; 52.6 and 46.5%, respectively in very small, average and large farms (Fig. 2).

Within each farm, family members achieve around 49.0% of total work duration (Fig. 3). In the ten large farms specialized in cash crops, the contribution of family members to total work duration did not exceed 5%. Family members work some 292.5 days per year, which is the equivalent of 76.3 days per person per year. This value varies from 0 (3 cash crops specialized

reasons, seldom participate to tasks outside home. They are therefore more involved in routine work (i.e. livestock rearing). They can however be mobilized for dates' harvest and particularly sorting and packaging. Otherwise, men are more responsible for all cropping practices (irrigation, pests' treatments, fertilization, etc.), either for cash crops or fodder and cereals. Children seldom participate to agricultural work, because they go to school. However, they may help in dates' conditioning (as the harvest takes place during holidays, in late August and the beginning of September), as they can participate in animals' feeding.

### 3.2. Crops and livestock profitability

Date palms represent a strategic crop in the oases. As they are able to cope with the extreme weather (aridity and very high temperatures),

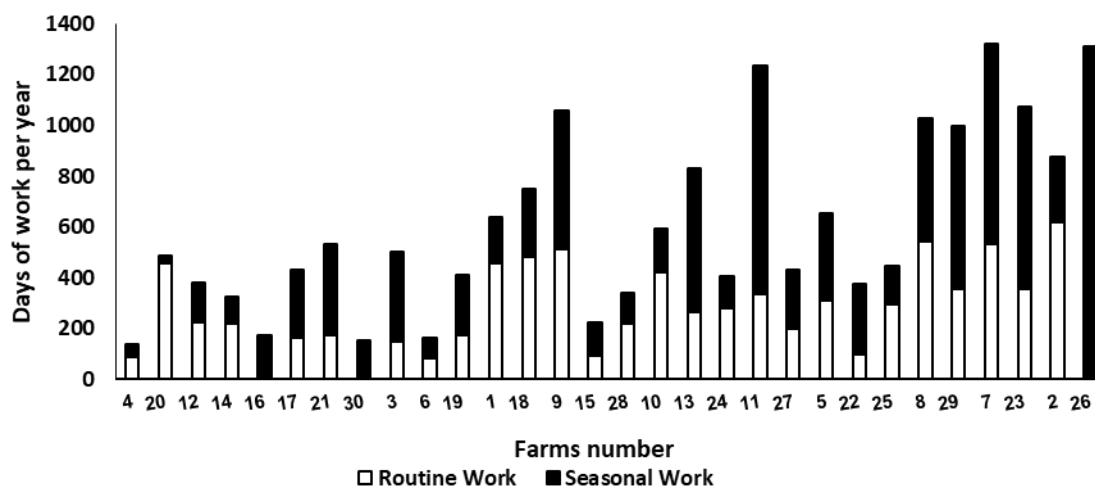


Fig. 2. The components of total work duration among farms.



Fig. 3. Share of family members and hired workers in total labor duration.

farms where the work is entirely done by hired workers) to 206 days per family member per year. This work volume is not equally endorsed by all the family members. Women, for cultural

they mobilize most of the production factors (water, land and labor). The average gross margin per date palm tree was around 31.1 Euros. The maximum profitability per tree was

109.1 Euros, in farm 11, due to the specialization in this crop and the market variety cultivated (*Nejda*). In farm 9, the profitability was negative, as farm gate price of date (0.35 Euros/kg) did not allow to cover production expenses, because of the limited market value of the varieties cultivated (*Boufeggous* and *Sayer*). The profitability of date palm trees increased from very small to large farms, as the latter category has generally planted high market varieties (Table 5).

Watermelon is only cultivated in average and large farms, with a minimum area of 2 ha per farm. This crop is particularly found in the extension area of the oases, where it is irrigated solely by groundwater sources. It has expanded, given its important turnover allowed by the earliness of the output, which is often imported. The average gross margin of watermelon per ha was 6006 Euros, varying between 1640 to 10,589 Euros. The maximum value was recorded in a farm where the yield amounted 50 tons/ha, sold at mean price of 0.27 Euros/kg. Watermelon gross margin varied mainly in relationship to farm gate prices. Precocious harvests (beginning of April) allowed the highest prices, up to 0.36 Euros per kg. Given the important amounts of water used to irrigate this crop in desert conditions, farmers have begun turning to solar energy to limit the energetic expenses used for irrigation.

The other crops practiced showed contrasted

Euros per ha (Table 6). It represents a dual purpose crop, used for both human (grains) and animal (straw and stubble) feeding, directly contributing to feed security of the oasis agricultural households, because of the auto-consumption of grains. The gross margin was even negative in 3 farms, because of limited yields (less than 1.6 tons of grains per ha in irrigation conditions). It was also noted that the average gross margin of soft wheat was limited in large farms (335.4 Euros/ha) in comparison to smallholder units (607.3 Euros/ha), as the latter allocate more interest to this staple food crop, whereas large farms dedicate more production means (water, capital and land) to cash crops (watermelon and newly planted market variety date palms). Henna was only cultivated in average and large farms, likewise watermelon. Its average gross margin amounted 3472.7 Euros per ha. It varied from 1281.8 to 5463.6 Euros per ha, the minimum value corresponding to a newly planted plot, where the output was limited. Otherwise, 5 farms cultivated vegetable crops such as onions and peppers. The area reserved for these crops was quite limited, from 0.5 to 1 ha. The gross margin reached 1899.6 Euros per ha. Finally, 4 smallholder farms cultivated alfalfa to sell its output as fodder for neighboring farms. These farms benefit from the agronomic impacts of this legume plant (fixation of atmospheric nitrogen in soils), which is often associated to date palms, implying that the latter has increased yields. The

**Table 51 .** Components of date palm trees' gross margin among farms' types.

Farms' type	Very small	Average	Large	Whole sample
Number of trees	135 ± 88	459 ± 525	889 ± 996	135 ± 88
Total expenses (Euros)	1181.6 ± 1451.5	2774.4 ± 1456.0	5740.8 ± 6001.5	2889.5 ± 3683.6
Turnover (Euros)	4748.5 ± 3906.9	31,917.7 ± 72,200.8	53,001.1 ± 67,230.9	29,108.3 ± 58,396.9
Gross margin/tree (Euros)	21.6 ± 17.5	32.2 ± 32.4	40.5 ± 24.7	31.1 ± 26.1

Source: Authors' calculations

**Table 6.** Gross margin of the different crops cultivated among farms' types.

Farms' type	Very small	Average	Large	Whole sample
Watermelon	-	5928.2 ± 2590.8	6040.5 ± 3389.6	6006.8 ± 3025.6
Soft wheat	607.3 ± 393.7	351.8 ± 446.7	335.4 ± 281.2	409.9 ± 380.5
Henna	-	1281.8	4568.2 ± 1266.4	3472.7 ± 2098.0
Vegetables	747.3 ± 1056.8	1393.6 ± 1328.1	3558.2 ± 4353.2	1899.6 ± 2469.8
Alfalfa	2050.0 ± 1878.9	-	-	2050.0 ± 1878.9

Source: Authors' calculations

gross margins. Soft wheat which was cultivated in 19 farms realized a gross margin of 409.9

gross margin allowed by alfalfa sales reached 2045.5 Euros/ha). One of the five farms even

sells alfalfa's seeds, allowing an increase in this crop's gross margin.

Livestock is present in 27 out of the 30 farms studied. Given the structural drought and the reduced fodder area, most of the farms do not reach feed autonomy, implying mandatory purchases of feed. It is noticed that livestock profitability is variable, as it was even negative in 7 out of the 27 farms with animal husbandry. The average annual gross margin was around 278.4 Euros/LU (Table 7).

Among farms' types, the highest gross margin/LU was noticed within average farms, followed by smallholder units and finally by large farms. Sixteen farms have benefitted from public subsidies, given that they adhere to an association which aims to breed the local prolific sheep strain, the D'man. A lump sum of 50.9 Euro per lamb is offered to farmers who manage to produce future rams and ewes. This has allowed these farms to realize a positive profitability. In addition, farms with a dairy herd all manage to get significant incomes from steady milk sales to the local dairy processor, at a farm gate price of 0.32 Euros/liter all year round. They also benefit from calves' sales, at an average price of 545.5 Euros. In addition to livestock products, the output of manure was not included in the calculation of gross margins, as it is however a vital component on the oasis farms, which have adopted since very long times the principles of a circular economy.

In addition to crops and livestock gross margins, 7 farms had access to off-farm incomes. This is the case in four smallholder and three average farms. These off-farm incomes correspond either

to labor done in neighboring farms (particularly in those cultivating watermelon with important peaks of activities during the plantation and the harvest of this crop) or labor in other economic sectors, such as retail and trade. In three of these seven farms, off-farm labor is even done outside the region, as the sons of the farmers have to migrate, given the limited employment opportunities available locally.

### 3.3. Analyzing work remuneration in different farms' types and its relationship to the invested capital

Within the whole study sample, one day of labor in crops allows a remuneration of  $84.1 \pm 94.2$  Euros. There is a marked gap between labor remuneration in crops among farms' types, as it does not exceed 27.2 Euros per day in smallholder units, whereas it reaches 78.4 and even 154.2 Euros per day of work in average and large farms (Table 8). Date palms allow an average labor remuneration of 68.8 Euros/day. This finding varies among farm types and that can be attributed to date varieties, as well as to the number of trees: a positive correlation is noted between the daily remuneration of work and the number of date palms per farm. Watermelon allows an average daily labor remuneration of 151.7 Euros. This value is quite steady among farms' types, and it illustrates the relative stability of yields and the favorable marketing conditions, which were due to the precocity of the harvest, almost entirely destined to exports. By contrast, cereals' labor remuneration does not exceed 9.2 Euros per day. Work remuneration by livestock was even worse, not exceeding 4.3 Euros.

**Table 7.** Profitability of animal husbandry among farms' types

Farms' type	Very small	Average	Large	Whole sample
<b>Profitability (Euros/LU)</b>	246.9 ± 5 235,5	475.6 ± 692.7	74.3 ± 414.4	278.4 ± 566.1

Source: Authors' calculations

**Table 2.** Average remuneration of one day of work in livestock and crops among farms' types (Euros/day).

Farms' type	Very small	Average	Large	Whole sample
<b>Livestock</b>	4.3 ± 6.9	7.7 ± 7.6	0.2 ± 7.9	4.3 ± 7.9
<b>Date palms</b>	31.9 ± 31.0	82.2 ± 81.6	93.4 ± 99.2	68.8 ± 77.7
<b>Watermelon</b>	-	152.4 ± 102.1	151.4 ± 44.1	151.7 ± 63.4
<b>Cereals</b>	14.4 ± 9.8	6.4 ± 8.2	8.6 ± 5.6	9.2 ± 8.1
<b>Vegetables</b>	72.9	20.5 ± 27.7	175.4 ± 233.3	93.0 ± 141.1
<b>Henna</b>	-	22.7	113.4 ± 32.1	83.1 ± 57.3
<b>Crops</b>	27.2 ± 27.5	78.4 ± 79.4	154.2 ± 117.4	84.1 ± 94.2
<b>Crops and livestock</b>	19.3 ± 13.1	40.3 ± 51.5	76.0 ± 55.1	44.0 ± 48.3

Source: Authors' calculations

Among farms' types, livestock work remuneration was the worst in large farms. At the opposite, smallholder and average farms had higher work daily remuneration in livestock. In fact, in smallholder farms, livestock represents more than 50% of the annual total incomes, explaining its vital roles for relatively limited investments, whereas in large farms this contribution does not exceed 2% (Fig. 4). Therefore, in the latter category of farms, livestock is more used as a diversification activity, with minor economic roles in comparison to cash crops like market date palms varieties as well as watermelon. In addition,

crop/livestock integration remains important, as livestock supplies manure to maintain soil fertility and it can also add value to crop residues (date wastes, unsold watermelon, etc.), as well as it can contribute to overpass financial troubles (important expenses due to crops' plantation) by sales of live animals (lambs or calves).

In all the farms' types, date palms represent the most important source of incomes. In addition, watermelon has also an important contribution in incomes generation, particularly in average and large farms. By contrast, in smallholder

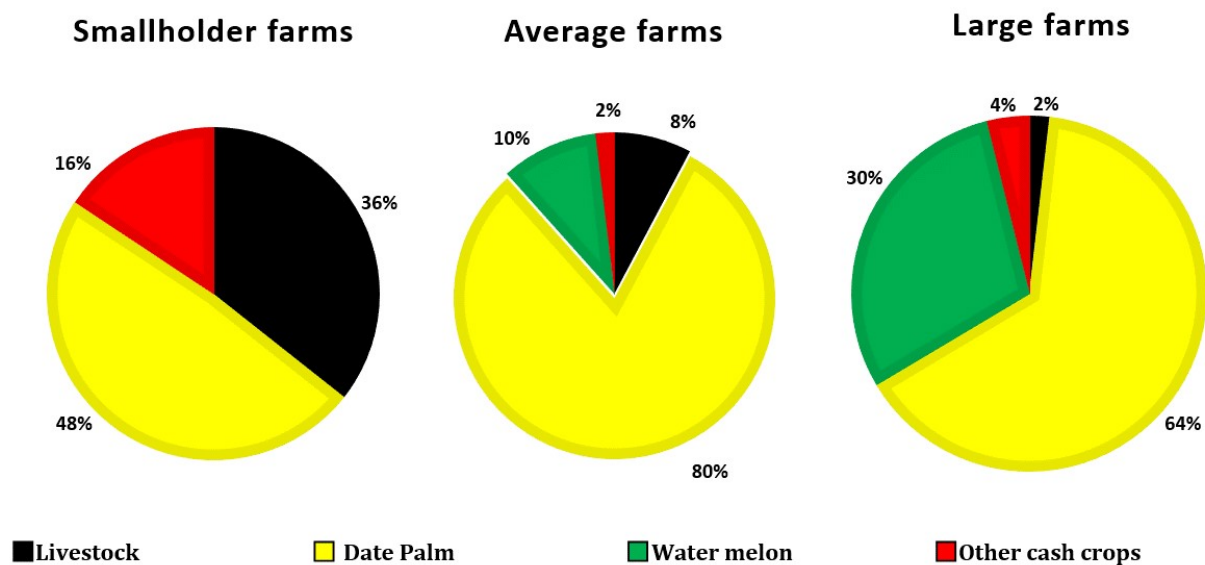


Fig. 4. Sources of incomes in farms' types (Source: Authors' calculations)

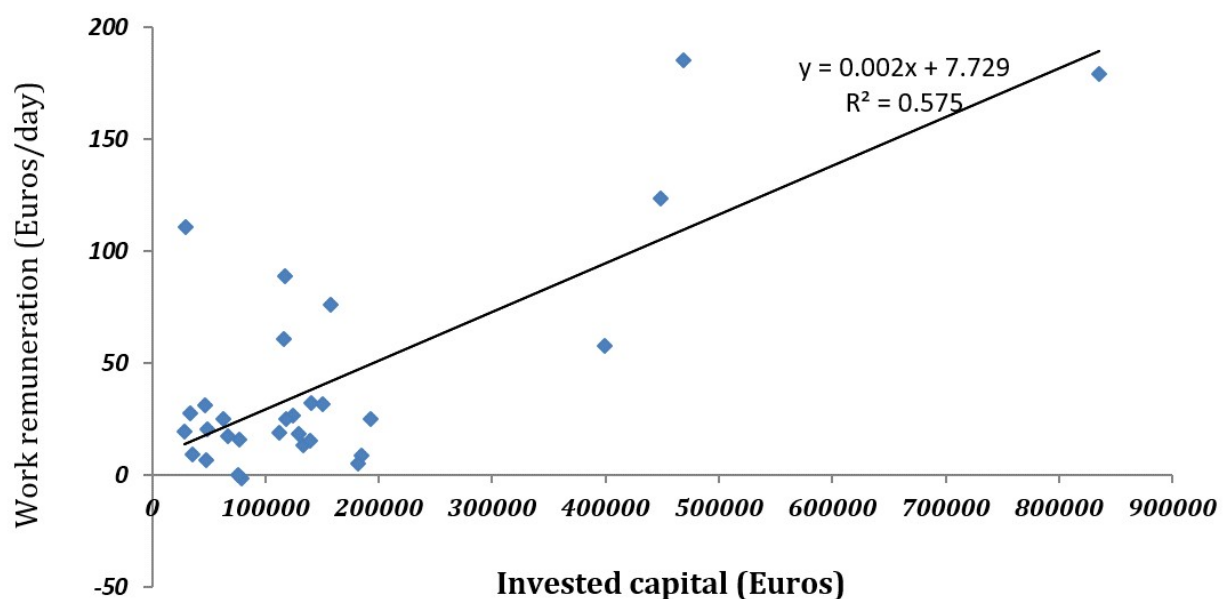


Fig. 1. Relationship between the daily work remuneration and the invested capital (Source: Field data and authors' calculations)

farms, it is mainly livestock and cereals which contribute to incomes (in addition to date palms), as the investments to cultivate watermelon are not available.

Work daily remuneration is positively impacted by the invested capital. Return on investments rate defined as the annual incomes divided by the invested capital is only 10.1% in smallholder farms, whereas it reaches a value of 23.7% in large farms; average farms showing an intermediate value of 15.4%. The use of machinery, the drip irrigation equipments and large herds allow as well as a larger arable area allow a higher daily work remuneration (Fig. 5). Such economies of scale illustrate that higher capital invested allows minimizing work uses and/or generating higher incomes. In fact, all the daily work remunerations above 45 Euros are recorded exclusively in large farms, at the exception of two medium farms, where high value date palms are cultivated.

Our results have also characterized the gender dimension of work in the oasis farming systems. We have found that women and youngsters involvement in agricultural labor is vital, particularly in smallholder and average farms. Women who hardly get out the household, because of cultural reasons, are consequently in charge of all the activities related to livestock (feeding and milking). They are also involved in date palms' conditioning, in September, as men are all mobilized for the harvest. Youngsters, who generally go to school, might however help in the daily routine work (mowing alfalfa, distributing feed to animals, etc.), when available. It is particularly striking to note that youngsters and even women have all expressed their dissatisfaction with agricultural labor. In all cases, they feel that this is a very hard work, for which they are not paid, as it is generally done within the household with no direct income. As a consequence, both categories wish to gain increased autonomy by having access to their own income generating activities (either within the farm, mainly for women - such as some animals like D'man ewes -, or outside the farm, mainly for youngsters when they quit school - such as working in neighboring farms or even migrating to large cities -).

#### 4. DISCUSSION

The results show that most routine farm labor (more than 72% of the total time amount) on the oasis 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 et al., 2018; 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 547 hours, which is the equivalent of 68.4 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 a large share (64.8%) of seasonal (crop) labor was provided by hired laborers. 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 this particularly true in large farms, where these cash crops are highly strategic with regard to incomes' generation. By contrast, in smallholder units, hired workers are also used, given that family members are not available as they are often occupied by the routine tasks required by the livestock. The annual labor requirements per date palm tree (almost 0.6 days) in the present study are quite close 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 smallholder farms. This also confirms previous works on the traditional 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 commoner crops, watermelon and date palm trees of market varieties are 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). This trend is of course based on intense capital uses in comparison to smallholder farms within the oases. However, it is exacerbating conflicts around vital resources such as water and land (Carpentier and Gana, 2017), amplifying their scarcity, as the rhythm of water exploitation is no longer sustainable (Benaoun et al., 2014). Given the rapid turnover of watermelon (since its cycle does not exceed 4 months), even investors from outside the region have been tempted to rent collective land and cultivate this crop, once they secure the access to groundwater. Watermelon's profitability may however be hazardous because of farm gate prices volatility (Sraïri and Bentahar, 2021), but this has not discouraged investors who seek rapid capital turnover. The ongoing 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 daily remuneration for watermelon, which was grown on all the large and average size farms (more than 2 ha) in the present study, was higher than that of henna or cereals (respectively 151.7, 83.2 and 9.2 Euros). Even the economic return per day of labor for date palm was lower than watermelon, as it did not exceed 68.8 Euros. Among farms' types, the economic remuneration of work in date palms' trees was variable; it reaches a maximum value of 93.4 Euros per day in large farms, whereas it only amounts to 31.9 Euros per day in smallholder farms. The difference can be attributed to varieties cultivated, as large farms privilege market types, such as Mejhoul, which is sold up to 10 Euros/kg. Such choices have however amplified groundwater depletion in many parts of the Drâa region, particularly downstream the valley (Moumane et al., 2022). 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 Naqach, 2022), 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 such a 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 (i.e. labor devoted to livestock) is almost 20 times lower than the average remuneration of seasonal labor (i.e. reserved for crops): 4.3 vs. 84.1 Euros. This implies that work dedicated to the herd may not be 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 Ravailon, 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). However, one must keep in mind the levels of capital invested in both situations. In fact, in smallholder units (less than 2 ha), where the total capital invested does not exceed a mean value of 71,000 Euros, livestock rearing remains the only livelihood option for many farmers, as it has been described as the 'wealth of the poor' (Duteurtre and Faye, 2009). In such situations, the average annual return on investments rate is only 10.1%, almost entirely achieved by the profitability of animal husbandry and its coupling with staple food crops (cereals and even date palms). By contrast, in very large farms (more than 5 ha), the average annual return on investments rate is more than double, as it reaches 23.7%. Quite similar findings have been noted for this proxy in the same area by Sraïri and Naqach (2022), and that is certainly in relationship to the favorable market conditions for watermelon produced in the oases (mainly destined to export due to its early harvest), which have allowed farms cultivating such a crop realizing a very high profitability/ha. However, crop/livestock integration effects are much more complex than a single comparison of economic returns and, in fact, the entire oasis farming system is based on exchanges of biomass, water and even labor between crops and livestock (Dollé et al., 1989). 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.

Among all farms' types, the average remuneration of one day of agricultural labor reaches a value of 44.0 Euros. There are important differences between farms' types, the highest value (76 Euros per day) being recorded in large farms with cash crops such as watermelon, whereas in smallholder farms this value is limited to 19 Euros per day. These mean values mask considerable variability within each group of farms, as labor remuneration on three smallholder farms in our sample was close to that recorded on large farms. One explanation is the performance of livestock (particularly in farms benefitting from public incentives to breed the local prolific sheep strain - the D'man -). 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 mow 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 are mainly due to the level of investments, as well as the better crops profitability obtained by the larger farms, particularly those of date palms' market varieties and watermelon. 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 smallholder farms manage to obtain a similar income from a day of labor as that obtained by larger 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, particularly in a context of smallholder units constitute the majority of farms.

If the remuneration for agricultural labor is not significantly improved, particularly in smallholder farms, it may prompt young generations to migrate, which, in turn, might further exacerbate existing labor problems in oases, particularly in peak activity periods (harvest of dates). This is also the case for daily routine activities like alfalfa cuts and transports

to barns, which are very time consuming and generate limited incomes. Migration of youth might have however also 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 during other agricultural campaigns. A particular emphasis on women and youngsters involvement in agricultural labor is also urgently required, given their crucial contribution, particularly in farms with limited assets (land and capital). This is in fact a trend which is noticed at a global scale, and which is of the utmost concern for the future of the agricultural sector, as it might hamper all the development efforts that are made to increase the global output of food (Dedieu et al., 2022).

## 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. The combination of milk and dates is in fact emblematic of the main efforts made by farmers as well as the resources (capital, land and water) they mobilize 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 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. This would be in line with the principles of a circular economy, which are proving highly adapted in a context where the prices of external inputs (particularly fertilizers) have soared. 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 20 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 smallholder farms, this kind of logics 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, which are already directly impacted by the effects of the global warming as they have triggered several large scale fires that have destroyed many palm date groves, a close monitoring is needed to enhance the performances of farming systems and to guarantee their sustainability. 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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