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Water Scarcity and Work Constraints in Semi-Arid Agricultural Regions: Current Challenges and Future Intervention Strategies

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ABSTRACT

This paper assesses the sustainability of agricultural water management in two contrasting regions of Morocco and examines the economic and volumetric water productivity of various crops and livestock products. Considering examples from the oasis areas in the East (Drâa oases) to the sub-humid Saïss plain in the North, we find that sustainable water use for certain crops may not be achievable due to intensive groundwater depletion. Furthermore, we show that livestock economic water productivity is often limited compared to crops, which may hide complex interactions between crops and livestock. These interactions provide diverse and steady sources of income for farmers, ensuring the resilience of farms in the face of climate, biotic, and economic risks. Our findings also suggest that the labor requirements of farming activities are burdensome, particularly for family members. Given the significant constraints affecting the agricultural sector, it would be too risky to continue promoting it as the main driver of the country's economy. The challenges posed by climate change and the need for more environmentally friendly practices mean that simple solutions cannot be relied upon for the future.

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1. Introduction

Located in the North Western fringes of Africa, Morocco is mainly characterized by water scarcity since more than 80% of its area receives average annual levels below 400 mm. Consequently, in many regions of the country, particularly in its arid to semi-arid areas, water is already a severe limiting factor to increased crop and livestock production, as pointed out in many other regions [1]. In such areas, farmers often rely on a water mix, that is, several sources of water, rainfall (green water), irrigation from surface water and groundwater (blue water), as well as virtual water (the volumes of water needed for the production of off-farm feed resources elsewhere, mainly for livestock) to try to satisfy crop and livestock needs [2]. Water scarcity is already exacerbated by the global warming phenomenon, which can only increase social vulnerability, particularly for the agricultural sector workforce and rural dwellers [3]. To try to overcome the limits of water availability, Morocco has adopted since the early 1990s the promotion of more efficient irrigation systems (especially drip vs. furrow irrigation) through public subsidies, which is presented as a means to reduce water consumption [4]. There is still, in fact, an embedded idea within the collective imagination that irrigation allows for creating miracles by promoting steady exports of fruits and vegetables. However, most of the staple food needs (cereals, edible oils, feed for livestock like maize and soybean meals, etc.) are imported [5, 6]. This is mainly the consequence of a persisting appeal of the "California Agricultural Dream," deeply rooted in the country since colonization [7]. These recent developments have shown worrying consequences, exacerbated by the rapid expansion of agricultural plots equipped with drip irrigation: the amplification of groundwater use, resulting in its depletion [8], and even jeopardizing the drinking water service to large urban centers [9].

Water reserves in some large dams, particularly in Southern areas, are at most 10% of their capacity because of persistent drought. This has prompted the promotion of desalination to adapt to water scarcity. However, such a technology's collateral effects (substantial investments, energy costs, environmental impacts, etc.) have yet to be assessed [10]. Generalized groundwater use has accelerated rapidly, leading to groundwater depletion in many semi-arid and arid areas globally (North Africa, South Asia, Southern Europe, California, etc.) [11, 12]. From another viewpoint, many researchers working on 'blue' (irrigation) and 'green' (rainfall) water have questioned the effects of water use options on the sustainability of farming systems. There is a renewed interest in integrated crop-livestock systems in which rainfall is the primary water source [13]. In such systems, the numerous interactions between crops and livestock make it possible to reduce the detrimental effects of crop pests, reduce the use of pesticides [14], and increase farm resilience in the face of climate uncertainty and economic risks [15, 16]. Such systems are based on circularity principles, mainly advocated for coping with limited resource availability [17], as they also ensure significant work opportunities for rural dwellers. They necessitate daily efforts to maintain a diversity of activities within the same territory: from numerous plots supporting diverse crops to diverse herds and flocks - several species and breeds -. This diversification is crucial, allowing resilience in front of emergent diseases, the diversification of income sources, etc. [18]. This is of the utmost importance for most developing countries, given that the official data reveal that around 40% of the workers are still employed in farming [19], providing the bulk of their incomes. Providing decent work for these persons has undoubtedly become a top priority within the global agenda. However, there are still numerous questions about the limited incomes and the effective attractiveness of agriculture to employees [20]. About these two crucial resources for agriculture (i.e., water and work), we focus in this paper on the two issues of water productivity and work remuneration by this sector by adopting farm follow-ups in two contrasted regions. The objective is to use real situations assessments to draw perspectives for the near future when constraints related to both resources (water and work) are expected to increase.

2. Material and Methods

Study regions represent two contrasted agro-ecological areas of Morocco: the first site was located in the favorable Northern plain of Saïss (average annual rainfall level of 560 mm), and the second site was located in the desert oasis areas of Zagora (average annual rainfall of less than 50 mm). The location of the study areas is shown in Fig. (**1**).

In each region, we have chosen a study sample of farms representative of the diversity of the existing situations: variable arable land areas, crops, livestock species and number, family members involved in agricultural tasks, etc. Only four farms were retained within each region since a significant amount of on-farm reliable data is needed throughout the year: the annual water uses per cultivated plots and the work uses required for livestock rearing and crop production. Farms 1,2, 3, and 4 were located in the Saïss region, whereas farms 5, 6, 7, and 8 are in the oasis area. The required annual follow-up protocols necessitated a focus on water volumes (either rainfall from local meteorological stations or irrigation volumes), feed uses, and mainly feed concentrates which are entirely purchased and have to be considered as virtual water entering into the farm (using a conversion proxy from international references, i.e., 1 m^3 of water per kilogram of cereal grains) [21], and finally work uses. The structural characteristics of the studied farms in the two regions are shown in Table **1**.

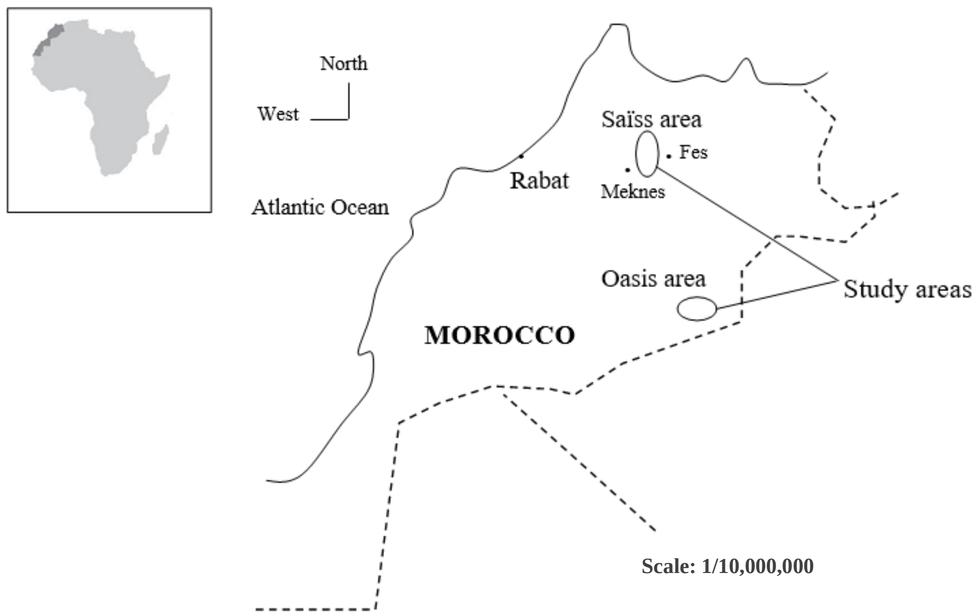

Figure 1: Location of the study areas.

Table 1: Structural characteristics of the study sample farms in the two regions.

	Oasis Region				Saïss Region			
	Farm 1	**Farm 2**	**Farm 3**	**Farm 4**	**Farm 5**	**Farm 6**	**Farm 7**	**Farm 8**
Arable land (ha)	1.8	4.7	1.1	15.5	4.0	4.5	7.4	14.2
Irrigation (ha)	1.8	4.7	1.7	15.5	4.0	0.7	1.9	5.8
Cereals (ha)	0.9	2.3	1.0	3.0	-	-	3.0	0.5
Fodder (ha)	0.8	2.5	0.1	3.5	-	4.5	2.5	7.5
Vegetables (ha)	0.1	-	-	9.0	-	-	1.9	1.2
Orchards*	171	295	295	571	4.0	-	-	4.0
Herd structure								
Number of cattle	-	-	3	5	-	11	9	14
Number of sheep	25	45	42	36	-	12	11	13
Number of goats	-	-	-	37	-	-	-	-
Livestock Units**	3.8	7.9	7.5	23.8	-	10.8	10.6	12.5
Irrigation means***	S, W	S, W	S, W	G	G	S	G	G
Family members****	4	3	2	7	1	3	4	6

* Orchards: Number of date palms in the oasis, mainly Rosacea (plums, peaches, nectarines, etc.) expressed in ha in Saïss region.
** Livestock Units: Determined as the sum of the live weight divided by 400.
*** S: Surface Water, G: Groundwater.

3. Results and Discussion

3.1. Water Agronomic and Economic Productivity in the Study Areas

3.1.1. Water Agronomic and Economic Productivities in Crops

The adopted methodology has allowed the calculation of water uses per ha and the origin of water (Table **2**). It appears logical that entirely rain-fed crops (barley, oats, hard wheat, and soft wheat) in the Northern plain of Saïss had consumed the minor volumes (around 4,480 m^3/ha). Conversely, summer vegetable crops such as onions or bell peppers had the highest water consumption (more than 20,000 m^3/ha), mainly sourced from groundwater.

Table 2: Water uses, crop profitability, agronomic, and economical water productivity in the study sample farms.

Region	Farm	Crop	Water Volumes (m^3/ha)	Water from Groundwater (%)	Profitability (Euros/ha)	Agronomic Water Productivity (m^3/kg of output)	Economic Water Productivity (Euro/m^3 of Water)
Oasis Region	1	Hard wheat	11,866	0	265	0.80	0.08
		Date palms*	11,866	0	8.4	5.06	0.26
	2	Hard wheat	12,050	0	590	1.42	0.06
		Date palms*	12,050	0	15.8	2.05	0.46
	3	Hard wheat	24,479	0	230	1.00	0.04
		Date palms*	24,479	0	18.3	1.67	0.69
	4	Soft wheat	5,482	88.1	694	0.40	0.24
		Date palms*	11,370	94.5	13.9	2.86	0.44
		Watermelon	11,370	94.5	900	0.16	0.06
		Henna	8,380	92.2	780	3.30	0.42
Saiss Region	5	Apricots	7,991	43.9	3,392	0.51	0.42
		Nectarines	9,431	52.5	4,701	0.45	0.57
		Peaches	9,431	52.5	5,370	0.49	0.50
	6	Barley	4,482	0	80	0.92	0.02
		Oats	4,482	0	270	0.59	0.08
	7	Hard wheat	4,482	0	50	0.53	0.01
		Soft wheat	4,482	0	743	0.27	0.16
		Bell peppers	22,489	100	1,826	0.84	0.08
		Onions	20,938	100	632	10.47	0.03
		Beans	10,542	100	577	0.35	0.06
	8	Soft wheat	4,482	0	1,704	0.20	0.38
		Faba beans	4,482	0	407	1.70	0.09
		Plums	9,560	53.1	20,327	0.40	1.58
		Grapes	9,560	53.1	8,331	0.30	0.96
		Onions	22,982	100	9,613	0.50	0.47
		Tomatoes	3,799	100	1,620	0.30	0.10

* Date palms profitability is expressed by the tree and not per ha.

In the oasis region, where rainfall is at most 50 mm/year, and given that date, palms are cultivated in association with sub-layer crops like wheat; it is difficult to assess the water consumed by each species precisely.

We assumed that each crop took the same volume, even knowing that almost 30% of date palms' water requirements may be directly sourced by the tree itself from its deep roots' system [24]. Another striking point from our fieldwork relates to the critical variability of water volumes used among farms, in the same region and for the same crop. This has to be linked to two distinct points: *i*) the access to different water sources (i.e., either surface water alone or a mix of surface water and groundwater), *ii*) the will of the farmer to save the water for a given crop or at the contrary to overuse that resource to ensure higher yields, since, in many oasis farms, groundwater has become a fragile pillar of the agricultural activities [25].

The overconsumption of water, particularly from groundwater origin, is particularly obvious for high-value cash crops: vegetables – onions and bell peppers – as well as orchards in the Saïss region and, of course, date palm trees and watermelon in the Drâa oasis context. This might be the first cause of groundwater depletion in arid to semi-arid areas, coupled with inefficient collective management rules [26]. Consequences of such choices are evident since the profitability of these cash crops is often much higher than cereals. However, it might be decreased by market risks (overproduction, export hazards, etc.), as was the case for watermelon from the oasis during the study period.

Our results also show higher economic water productivity (more than 0.5 Euro/m^3) in orchards (plums, grapes, date palms) as well as vegetables (onions) in both the Drâa oasis and the North Saïss region. Otherwise, other crops, such as cereals, had minimal economic water productivity, most times not exceeding 0.2 Euros/m^3. These results might be of vital interest to making crop choices in agricultural policies, particularly in water scarcity, as it may precipitate the trend of switching rain-fed crops (cereals and pulses) to irrigated crops (orchards and vegetables). They may help policymakers to arbitrate decisions about the support for different crops in the context of increased water scarcity [27]. In Morocco, for instance, this concept played a fundamental role in deciding cropping priorities (and hence the attribution of subsidies) in current agricultural policies. We argue that this concept is problematic for at least two reasons. First, most studies have only paid attention to a single product, generally not considering the integrative use of water resources on-farm. This is particularly problematic in the case of the typical smallholder family mixed crop-livestock systems, which are mainly dominant in emerging countries. These show many interactions, from coupling crops and livestock: the use of by-products like straw and stubble in livestock production, the manure produced by livestock maintaining soil fertility, and the complementarities in the revenues generated by dairy production (low but stable revenues all year round) and the sales of live animals [16]. Second, water productivity indicators often do not focus on the origin of water used to achieve production goals. In North Africa, where agricultural systems have become extensively reliant on groundwater, promoting high-value cash crops, including orchards, early vegetables, and intensive fodder production [28], most aquifers are threatened by depletion. This is the case, for example, in the Souss Massa area (Southwestern Morocco), where management plans (artificial recharge, seawater desalination, and wastewater reuse) have been adopted to restore groundwater imbalance or, at least, mitigate the recorded deficits [29]. Tailoring agricultural systems to the existing water resources will hence become increasingly crucial. The assumption that high-value cash crops (almost entirely based on extensive groundwater uses) generally allow better economic water productivity than rain-fed crops faces significant risks, mainly from an ecological and economic viewpoint [6]. Recent developments have shown difficulties in marketing fruits destined for exports and linked to ensuring the water needs of the recently planted orchards because of groundwater depletion. This has reached disastrous consequences, such as prompting the uprooting of recently planted orchards, benefitting from public subsidies in many arid areas. Controlling water withdrawals more precisely at the farm level and ensuring fair payment of this resource is therefore highly recommended to ensure that it is not depleted.

3.1.2. Water Agronomic and Economic Productivities in Livestock Husbandry

Water volumes used to produce fodder crops (lucerne - *Medicago sativa* - in the Drâa oasis and berseem - *Trifolium alexandrinum* -, barley and oats in the Northern plain of Saïss) and crop residues (wheat straws and stubbles) have been recorded. Herd performances (milk volumes from cows and live weight gains from cattle and small ruminants – goats and sheep -) were also monitored. Livestock was practiced in 7 out of the 8 farms of the research protocol, as farm 5 (located in the Saïss region) specializing in orchards, with no animals reared. In the same study sample, livestock rearing profitability was monitored by determining the economic values of inputs used and the sales of animal products. The results of this research protocol are presented in Table **3**.

Table 3: Total physical and economic water productivity in milk and live weight gain in the sample farms.

Farm		Oasis Region				Saïss Region		
		1	2	3	4	6	7	8
Milk	Volumetric water productivity (m³ of water/kg)	-	-	1.21	1.62	3.02	1.17	2.25
	Economic water productivity (Euro/m³ of water)	-	-	0.08	- 0.11	- 0.01	0.07	0.09
Live weight	Volumetric water productivity (m³ of water/kg)	11.1	19.8	14.28	20.11	7.36	12.1	9.84
	Economic water productivity (Euro/m³ of water)	0.11	.02	0.09	0.05	0.18	0.19	0.16

The results confirm the critical volumes of water to get marketed milk and live weight: around 1.85 m³ and 15.76 m³ of water, respectively for 1 liter of milk and 1 kg of live weight. These findings are higher than the international references published for these products [21], implying less efficient water conversion, due to setbacks throughout the production functions involved, from irrigation volumes, fodder outputs, and animal performances (because of insufficient and imbalanced feed rations) [30]. As a consequence of these setbacks, the results reveal limited economic water productivity of livestock rearing: an average value of 0.02 Euros/m³ used in dairy production and 0.11 Euros/m³ of water used for live weight gain.

These values of economic water productivity in livestock outputs appear closer to the ones allowed by rain-fed crops rather than to irrigated crops (orchards and vegetables). Although obtained on a limited sample study and in contrasted areas, these results illustrate the complex issues related to water productivity analysis, as a "crop needs more than a drop" [31]. What is meant by this citation is the fact that crop/livestock coupling hides very complex interactions, which have to be considered whenever analyzing farming systems from a water viewpoint. It is not only income generation and the highest gross margins per ha but also the resilience of these systems in front of economic and biotic shocks. For instance, soil fertility has to be mentioned, as in the oasis example, livestock production allows direct producing manure which is returned to plots, and also indirectly it contributes to the fixation of nitrogen through the symbiotic activity of microorganisms within the root system of the legume fodder, i.e., lucerne [32]. Compared to specialized crop farms, crop/livestock coupling also ensures regularity of incomes throughout the year. In most areas, livestock adds value to rainfall through grazing spontaneous rangeland species. However, it necessitates significant work along supply chains sourcing and valuing agricultural byproducts, etc. [33].

3.2. Managing the Work Constraints in the Study Sample

Monitoring all the work used around the year in the study sample farms has necessitated the application of the 'Work Balance' method. We have thus determined the routine work (i.e., the duration of daily work necessitated by the tasks repeated throughout the year to take care of livestock: chopping grass and transporting it to the animals - which are almost always in a zero-grazing system - preparing dietary rations, milking cows, etc.), which is expressed in hours. We then assumed that one day of work corresponds to eight hours. We also determined the amount of seasonal work used (i.e., the duration of crop-related tasks) and which is expressed in days. The results of these investigations are reported in Table **4**: the amount of work for livestock and crops in each farm and assessment of the actual work (i.e., routine work plus seasonal work). We also determined the share of work assumed by the farmers' family members and the work achieved by hired workers (generally involved in tasks demanding specific skills).

The results show that an important volume of work is needed for livestock rearing: an average of 59.7 days per Livestock Unit per year. This is explained by the necessary daily routine tasks, which cannot be reduced, even if the number of animals is reduced: cleaning the barns, preparing dietary rations, etc. The volume of work is primarily dominated by tasks related to chopping grass and feeding the animals, which represent almost 90% of total routine work in farms without milking cows (oasis farms 1 and 2) and more than 75% of total routine work in farms with lactating cows (Saïss plain farms and farms 3 and 4 in the oasis). Our results agree with the findings of other authors in diverse areas (Latin America- Uruguay -South East Asia - Vietnam -, etc.), which all reveal the significant amount of family work to take care of animal wealth [34-36].

Table 4: Work uses for livestock and crops in the study sample farms.

	Oasis region				Saïssregion			
	Farms							
	1	2	3	4	5	6	7	8
Routine work (hours/LU/year)								
Feeding and watering	283	226	207	153	-	138	103	115
Cleaning barns	41	20	56	15	-	45	49	59
Chopping grass	149	249	182	238	-	226	185	215
Milking	-	-	23	104	-	99	28	33
Total routine work (days/LU/year)	59.1	61.9	58.8	63.8	-	63.5	45.6	52.8
Share of the routine work done by family members (%)	96.2	99.5	98.6	79.5	-	95.4	89.6	87.4
Seasonal work (days/ha/year)								
Wheat	69	70	85	62	-	-	56	60
Oats and barley	-	-	-	-	-	58	-	-
Date palms*	0.5	1.3	0.8	0.7	-	-	-	-
Henna	-	-	-	87	-	-	-	-
Watermelon	-	-	-	116	-	-	-	-
Bell peppers	-	-	-	-	-	-	107	-
Onions	-	-	-	-	-	-	112	136
Beans	-	-	-	-	-	-	99	-
Faba beans	-	-	-	-	-	-	-	65
Tomatoes	-	-	-	-	-	-	-	107
Apricots	-	-	-	-	68	-	-	-
Nectarines	-	-	-	-	68	-	-	-
Peaches	-	-	-	-	68	-	-	-
Grapes	-	-	-	-	-	-	-	152
Plums	-	-	-	-	-	-	-	128

* Duration of work about date palms is expressed in days per single tree

Routine labor by farmers' family members represents in average, 92.1% of total routine work: the 7.9% of total routine work assumed by hired workers is mainly associated with fodder chopping in some farms, where the available family workforce might not always be interested in working in farming tasks, as more lucrative crops (watermelon in the oasis region or onions in the Saïss area) necessitate steady attention.

About seasonal work (i.e., work needed by crops), a significant difference is noted between work used for cereals (wheat) and pulses - Faba beans - (mainly rain-fed in the context of Saïss plain) which are highly mechanized, from sowing to harvesting, as they necessitate less than 70 days per ha per year. It is also the case of common orchards (peaches, nectarines, etc.) in farm 5 (Saïss plain), which also rely on highly mechanized tasks (plowing, drip irrigation, etc.) without significant work durations. On the opposite, vegetables (onions, tomatoes, etc.) and some high-value orchards (plums, grapes, etc.) require significantly more work (100 days and more per ha). It is also the case for the specific example of date palm trees, which also require a significant amount of work: an average of one day (8 hours) per tree, as has also been reported by other authors in the same areas [37]. This is an emblematic tree of the oasis areas, able to cope with the high levels of day-time summer temperatures (above 45°C during four months), providing shadow for the sub-layer crops and allowing a significant share of the farming incomes.

The share of seasonal work assumed by family members (65%) is less important than their involvement in routine work. Some crops' specific interventions (for instance, fruits and cereals harvesting) require work peaks, which may not be available on-farm. This is also the case of some specific operations, like tree pruning, which necessitates highly skilled workers, who are also only sometimes available on-farm.

We calculated Total Work (TW) as the sum of routine and seasonal work by assessing the work used on-farm. We expressed that in total days per farm per year (Fig. **2**). The results clearly show that some farms are mainly oriented towards livestock production since routine work largely exceeds seasonal work. This is mainly the case in smallholder farms, with limited arable land and capital means, like Farms 1 and 2 in the oasis area and Farms 6 and 7 in the Saïss plain). In contrast, other farms devote more interest to cash crops like orchards and vegetables (the remaining farms).

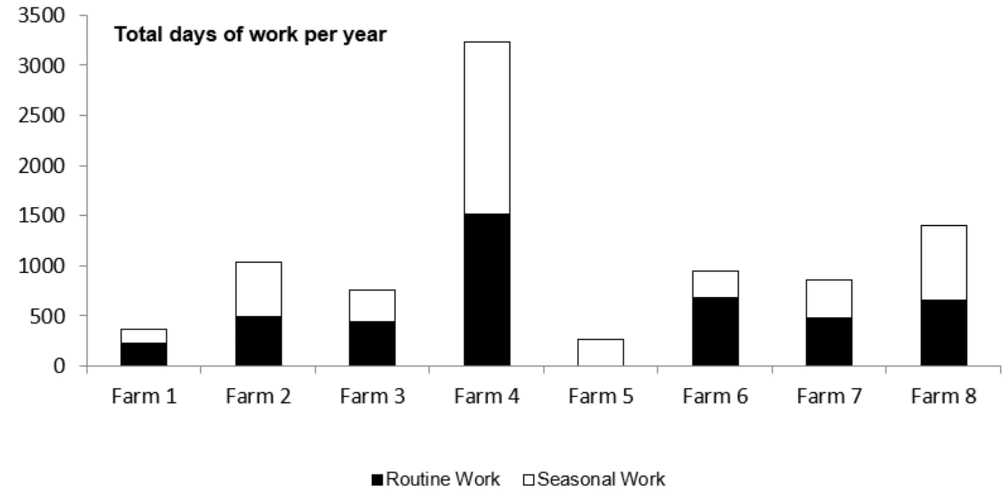

Figure 2: Share of routine and seasonal works in the study sample of farms.

We have also determined the monthly distribution of work within some representative farms in the study sample to show periods of the peak of activities (mainly related to crops) and periods of relative calm (mainly dominated by routine work – i.e., care for the animals). This is illustrated in Fig. (**3**), with contrasted situations, one with an association of cereals, livestock, and date palm trees - typical for the oasis area - (Farm 2), and another example from the Saïss plain with livestock and fodder crops (Farm 6). Both farms have around 4.5 ha, and the family working group comprises three persons.

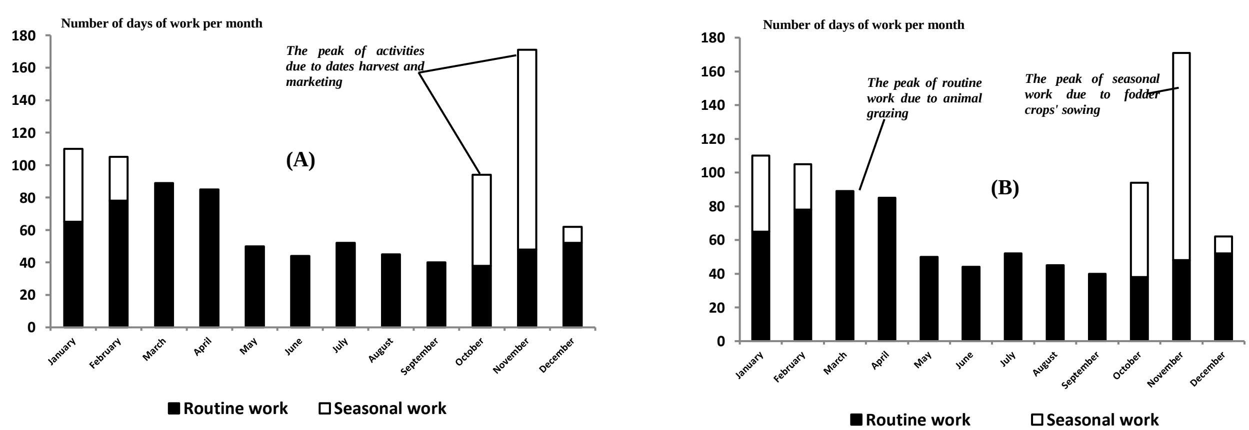

Figure 3: Monthly distribution of routine and seasonal work in two forms: (**A**) oasis area, (**B**) Saïss area.

Finally, we have calculated the amount of total work per ha. The remuneration of this production factor was then defined as the sum of the gross margins of livestock and crops divided by the number of days of total work. The results are shown in Table **5**. The results clearly show an important variability among farms, with a general pattern of more work per ha in the oasis farms compared to the Saïss plain. This is easily justified by the more intensive farming system in the oasis areas, with sub-laying crops (mainly lucerne and wheat) under the date palm trees, as such crop association is not found in the Saïss area. The intensification is a way to overpass arable land limits, although it requires important water sources and more work in a particularly arid environment [38].

The results emphasize the significant weight of orchards in adding value to work, as they allow all kinds of farms (in the oasis areas and the Saïss plain) to create an economic return of 50 Euros per day of work. This is due to their relatively limited work needs since most farming interventions are mechanized (like irrigation which is achieved through drip systems) and to their important gross margins (sometimes above 20,000 Euros per ha). Otherwise, in systems with limited capital means, where most activities still rely on livestock and rain-fed cereals, the return for one day of work may not exceed 5 Euros per day. 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 [39], our results confirm most farmers' acute economic vulnerability in crop/livestock systems. These results are in total agreement with previous studies on the agricultural work economic productivity conducted in several areas of Morocco, which also reveal limited incomes per day, thus implying a low attractiveness of this sector [40, 41]. The results also show that the time spent on routine labor (i.e., devoted to livestock) is often longer than 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 5 ha), where livestock is considered as the "wealth of the poor" [42].

Table 5: Total work uses per ha and economic return per work day in the study sample farms.

	Oasis Region				Saïss Region			
	Farms							
	1	2	3	4	5	6	7	8
Total routine work uses (days/year)	225	489	441	1,518	0	686	483	660
Total seasonal work uses (days/year)	148	544	321	1,717	272	261	373	736
Total work uses (days/year)	373	1 033	762	3 235	272	947	856	1 396
Area (ha)	1,8	4,7	1,1	15,5	4	4,5	7,4	14,2
Annual work uses per area (days/ha)	207	220	693	209	68	210	116	98
Livestock annual gross margin (Euros)	2,934	3,340	5,589	- 2,342	-	2,482	1,961	3,551
Crops annual gross margin (Euros)	1,675	6,018	4,439	18,899	16,855	700	3,122	76,420
Economic return for work (Euros/day)	12,3	9,1	5,8	5,1	62,0	3,4	5,9	57,3

The results show an important variability in work constraint management in crop/livestock systems. Even if specialized farms (like Farm 5 with no livestock at all and only orchards) show the minimum use of work and the highest return per one day of work, they cannot be praised as being a model of resilient farming practices: no value added to the weeds produced, intensive use of groundwater, a limited resilience to economic and biotic (emergence of a new disease, etc.) shocks [16]. Finally, it can be noticed that this research confirms the ongoing global thinking on the attractiveness of agricultural work and its direct consequences on the maintenance of vital territories within rural areas [43]. In addition, it has also to be mentioned that our paper needs to address the specific case of highly capitalized farms, with intensive investments from newcomer players, often encouraged by public loans and subsidies. These farms have been identified as actors amplifying water scarcity and reducing value distribution to local populations [44]. Therefore, in order to get a broader picture of the actual water uses and work remuneration at a given waterscape, additional research efforts would be needed, encompassing larger samples of farms, and relying on successive years follow-up, to integrate the inter-annual climate variations and their effects on farming practices and incomes' generation for various categories of actors involved in the agricultural sector.

4. Conclusion

This paper is written in a context where the thinking on the future of the Moroccan agricultural sector is facing a humbling backdrop due to severe structural water scarcity, exacerbated by the effects of global warming, even in the most favorable areas. This is already challenging farming work attractiveness for future generations. Our results confirm the excessive water needs by the most profitable crops (i.e., orchards and summer vegetables), implying overexploitation of groundwater, thus questioning the sustainability of the expansion of the cultivated areas devoted to these crops. In addition, they also face market hazards (overproduction, export limitations, etc.), which may not satisfy economic water productivity. Otherwise, the farming activities which mainly add value to rainfall (i.e., cereals, autumn fodder crops like barley, berseem, and oats, as well as livestock husbandry), though not dependent on groundwater, have limited incomes. They may need to allow generating more income to ensure that the people involved in these activities consider themselves as having decent work.

Consequently, most young people in rural areas prefer to abandon farming activities and migrate to large cities, seeking less demanding jobs and higher and steadier incomes. Indeed, livestock needs significant amounts of work every day throughout the year due to its daily routine tasks. The absolute zero-grazing pattern amplifies this in smallholder family farms because of limited and fragmented agricultural area plots. Getting out of this crisis mindset, which the worrying effects of climate change might worsen, indeed entails mobilizing innovative territorial thinking. First, this has to be linked with reasonable agricultural goals, decided in priority from a sustainable water uses viewpoint. This can be achieved by water conservation techniques and the promotion of eco-friendly practices, such as the recycling of manure to optimize water reserves in soils. Secondly, it is crucial to avoid massive rural exodus to ensure the yearly maintenance of territories. This can only be reached by promoting nonagricultural activities (services, agro-ecological tourism, etc.) - which are not water dependent - in rural areas since they can be substantial incomes generating jobs for local dwellers.

Conflict of Interest

The authors declare no conflicts of interest.

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