Assessment of Natural Resource Management for Enhancing Productivity and Feed Security of Dairy Livestock Value Chain in North Africa - Egypt, Mauritania, Morocco -

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Executive summary

The *Dairy livestock value chain* (DLVC) in North Africa has steadily increased its output in the recent decades augmenting the per capita consumption of milk and its derivates. Increase in yield also more than expansion of herds has contributed to this success, although their concentration in the more densely populated areas and prevalence of cow milk production show that producers face structural challenges to satisfy the market in the long run. Water scarcity prompts the dependence on imported concentrate feed and competition for its use is marginalize a broad share of potential dairy herds, especially small ruminants.

The climate change is adding its impact to the depletion of soil, water and forage resources. Public policies and the producers' organizations are collaborating in addressing the constraints to milk production but structural weaknesses and dependence on imported technology hamper the targeting of the priorities of the producers. Best practices have been recorded making possible the supply of milk to dairy factories by smallholder producers although without removing the constraints that rest efficiency to the Dairy livestock value chain. The capitalization of national and regional success stories is needed to mainstream innovation to the farmers.

Water scarcity is at the root of the slow growth of dairy livestock productivity in North Africa. An integrated approach is needed to reduce the impact of drought and to improve water productivity, involving a broad set of measures and not only the management of water. Reducing the amount of irrigated feed and animal water consumption are the two main strategies to reduce livestock impact on water scarcity in drylands. Other measures include disease control and animal health, livestock feeding management, mobility and stratification of production to reduce grazing pressure on drylands. Research and experience combined provide insights on best practices and opportunities to combine the yield increase with its sustainability.

The interventions for improving the DLVC are prioritized on the basis of their relevance for the DLVC development for the whole North Africa region, irrigated or rainfed areas, respectively.

Dairy production region-wide

Priority	*Practice*	*Explanation*
1	*Organization of consultation meetings of the dairy production value chain*	The top-down approaches have shown great limits in agriculture. Involving the producers, and above all the numerous smallholders in development policies is vital to increase milk output.
2	*Strengthening the governance of the dairy production value chain*	More negotiation spaces are required to discuss critical topics, such as value distribution (prices along the chain), milk characteristics monitoring and grading for payment, management of milk surplus in the rainy seasons, etc.
3	*Improving feed production efficiency*	Many setbacks hamper feed production of fodder crops. The adoption of good management procedures includes the economy of water in irrigation and rainfed fields, fertilization and sanitary and phytosanitary practices, as well as adaptation to the environment (harvest time, conservation means, etc.).

4	*Training and information of milk producers*	The average milk yield per cow, even for high genetic imported Holstein, is still far from its genetic potential. Training has to encompass all the aspects of modern dairy production, from fodder cultivation, to hygiene, reproduction management and balanced diets formulation.
5	*Breeding dairy livestock for yield and adaptation*	Imports of heifers and artificial insemination straws challenges the adaptation of cows to the environment. The breeding programs have to include local breeds and crossbred cows (local breeds x imported Holstein).
6	*Promoting co-operative milk collection schemes*	Milk collection centers source and grade raw milk. Their hygiene and management have to be upgraded to international standards through interventions encompassing producers in the collaboration schemes adoption of good management practices.
7	*Enhancing knowledge management systems*	Knowledge management covers all the DLVC elements. The development of knowledge management capacities to ensure the generation, access to and dissemination of information is conductive to rationalize and enhance the DLVC.
8	*Improving dairy livestock diet*	Regular monitoring of farms, especially the smallholder units is needed to ensure the adoption of adequate (enough dry matter) and balanced diets (no energy or protein wastes) in line with the cows genetic potential and physiological conditions.

Irrigated dairy production areas

Priority	*Practice*	*Explanation*
1	*Basin based irrigation water management*	The direct link between water and milk production requires the improvement of the water productivity, as its efficiency is low due to losses, especially where distribution canals are made of sandy soil.
2	*Improving crop residues management*	Enhance crop residues management as a feed resource for the dairy cows, especially cereal crops straws, may be upgraded through proper urea treatment and sound complementation. Comparative on-farm trials have to be done to ensure the fitness of these techniques to the environment.
3	*Improving soil fertility*	Recent agricultural policies sideline the loss of soil fertility. Its rehabilitation and conservation is needed for the sustainable agricultural production in which livestock and crops are associated.
4	*Integrating imported concentrates inputs in forage and straw based diets*	Comparative on-farm trials have to present the optimal mix of forage, straws and concentrates in each agro-ecological area. These trials have to explain the milk production and economic rentability effects of different combinations of feeds.

Rainfed dairy production areas

Priority	*Practice*	*Explanation*

1	*Ecological surveillance of pasturelands*	This practice has to be associated to the following ones
2	*Sustainable management of drylands natural resources*	This is an important element in drylands where dairy production is semi-intensive and extensive. Public private partnerships can be established with communities to run water-endowed forage reserves for drought years.
3	*Stabilising the agro-sylvo-pastoral systems*	The participation of livestock producers in the comparative testing and adaptation of dairy livestock rearing practices creates mutually reinforcing effects among different production systems.

A *North Africa natural resources management for DLVC support action* that strengthens the management of knowledge on natural resources management between researchers, service providers and dairy producers can trigger all these practices that concur to increase the productivity, resilience and sustainability of Dairy livestock vale chain in countries of this region. The outline of such an action is presented at the end of this document.

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1. Introduction

1.1 Background, purpose, scope

North Africa is a global net food importing region. The high and growing dependence on international markets for key staple food products has stimulated agricultural policies that reduce dependence on imports by subsidizing cereals production also in rainfed drylands that better fit agro-pastoral and pastoral production systems. Livestock production faces structural constraints (water scarcity, soil and vegetation poorness, distance from market) that discourage smallholders from investing thus increasing the productivity gap with the technology-driven farms that import high breeds, feed, drugs, dairy equipment, etc. Consequently, the expansion of the herds size – induced by price competition – produces overgrazing and increases the vulnerability of the producers to climatic variation. The fragmentation of production and import of powder milk further exacerbate these structural weaknesses of the dairy production that is unable to satisfy the growing need of consumers, in terms of quantity and of characteristics of the milk. The impact of climate change on the natural resources management is exacerbating drought cycles and eroding the water and feed basis of agricultural production.

The *Livestock Development Strategy for Africa* (Live2Africa) demands to the African Bureau for Animal Resources (AU-IBAR) to implement a *pilot supporting regional program for improved management of natural resources in North Africa* in the frame of the *Dairy Livestock Value Chain* (DLVC) consisting of as a major catalytic action made of:

- Valuation of the Region's Dairy Herd,
- Valuation of Natural Resources,
- Capacity Building.

This report assesses the current status of *natural-resource management* (land utilization; and production, conservation and utilization of feed and water resources) and *road map the improved management of natural resources* for enhancing feed security and improved productivity, resilience and sustainability of the Dairy Livestock Value Chain in North Africa, considering the impact of current challenging disasters, notably the impact of climate change and COVID-19 pandemic.

This study presents the current status of *Natural Resource Management for Enhancing Productivity and Feed Security of Dairy Livestock Value Chain in North Africa* (Egypt, Mauritania and Morocco), i.e.:

- the availability and utilization of water and feed resources
- the level of implementation and adoption of feeding programs for dairy livestock
- the gaps (needs) in feed and nutrients to sustain feed security and support improved productivity
- the challenges to be faced
- the opportunities for implementing a regional pilot upscaling plan for feed and water management for dairy livestock

- the applicability and adoptability of best practice under different production system in North-Africa' Member states.

This study is based on the analysis of dairy production value chains in Egypt, Morocco and Mauritania that represent the different livestock rearing practices of North Africa: irrigated mixed farming in the Nile valley, coexistence of mixed farming, dryland agro-pastoral and pastoral systems in Morocco, and desert pastoral and agro-pastoral systems in Mauritania. They joint analysis illustrates an extensive set of options for improving the management of natural resources in a diversified set of situation representative of the North Africa region.
Annex 1 presents the documents used in the preparation of this study.

1.2 Analysis criteria

The study concerns the critical analysis of available data on natural resources (water, feed, disaster stressors) and capacities and actions concerning the management and improvement of the DLVC.

The analysis considers the boosters and the constraints to the enhancement of the Dairy livestock value chain (DLVC) in terms of inputs, market access and governance of this value chain. Its focus is on the integration of the elements that are critical for the production of mutual beneficial effects - i.e., the integration of the knowledge and skills of the key actors to ensure the participatory DLVC governance and to undertake joint actions at the national and regional level) -.

The analysis is based on a set of compatible of data whose aggregation and comparison ensures the consistency of the assessment. The information on livestock, milk production, water, feeds are quantitative. The data on the other elements contributing to the DLVC are mostly qualitative as the focus of the analysis is on their interaction rather, highly variable from country to country, than on their combined effect at the regional level.

The national consultants have triangulated the data obtained from the recorded sources by interviewing key informants representing policy / regulatory authorities, producers' organizations and service providers / academia in Egypt, Mauritania and Morocco and elaborated the correspondent National reports. This regional report combines the regional dimension of the DLVC with specific elements of the three national reports to illustrate the North Africa situation through concrete elements of the problems faced in managing natural resources for dairy production. This approach is consistent with the fact that the three studied countries include the different kinds of livestock rearing and milk production existing in the region.

In order to ensure the coherence of the data used for the regional analysis, the Lead consultant has adopted the FAOSTAT statistical data for population, land, herd size and milk production. Otherwise, the data used for the calculation of water and feed consumption and requirements are those calculated in the national reports along with the other information on livestock rearing practices in relation to the environment, the DLVC integration and milk prices, where the national consultants have elaborated their analysis on the basis of their respective survey and experience.

The report describes the individual and combined effects of the key elements of each factor (water, feed, stressors, programs, capacities, etc.) contributing to the DLVC. It has to be considered that while most herds in North Africa are reared for two or more purposes (milk, meat, traction and

transport) and may have also a status value – i.e., are traded as family assets - influencing the rearing practice, our study concentrates on thei5 contribution to dairy production. Reference to the other livestock economic uses is included in the analysis, whereas they impact on the DLVC.

Overall, the study provides the information that constitute the knowledge bases for elaborating a regional pilot upscaling plan for feed and water management for dairy livestock along with the management of the knowledge (building capacities, sharing experience) conductive to the adaptation and adoption of best practice under the production systems prevailing in North Africa.

1.3 Land and livestock in North Africa

The North Africa climate is dry to arid with scarce rains along the Mediterranean sea and in the Atlas ridge from autumn to winter and summer days extremely hot and dry (30-40^{0}C), desertic in the interior and along the Atlantic ocean, with slight rains in the Sahelo-Saharan Southern belt of Mauritania. As annual and seasonal weather variations are high, the region experiences drought, flash floods, landslides, windstorm and sandstorms that hamper the viability of agriculture. Human population and agriculture concentrate where precipitation (400 mm of rain per year) or rivers as the Nile and groundwater reservoirs storing the rainwater discharged on the mountain ridges, ensure water availability. A further source of water is the deep geologic reservoir extending under Libya, Tunisia and Algeria desert. The water pumping cost limits its use to intensive agricultural production, as date palm and horticulture. The vast steppes and Saharan lands restrict most of dairy production to the riverine strips and highlands endowed with surface- and ground-water used to produce vegetal biomass to feed animals, notwithstanding the vocation of its steppes for livestock rearing, in practice around cities and in mixed-farming areas. Fodder production faces water stresses and is highly dependent on irrigation that crop residues and pasturelands sustain the dairy livestock producing milk. In steppe and desertic areas, dairy production is quite exclusively devoted to satisfy the own needs of the herds and livestock growers.

Figure 1 North Africa countries

Agricultural land represents about one fifth of the total land areas of the North Africa Region, with arable land constituting 3%. The difference between these values constitutes the extensive steppe grazing land devoted to extensive livestock production. Soils used for farming are severely degraded

to the point where their productivity can be estimated to have been lost up to one third of its potential productivity. The degradation of rainfed farming soil depends on wind and water erosion, while the farming practices adopted in irrigated systems contribute to soil salinity and sodicity, i.e. to loss of fertility that accounts for the majority of the region rainfed cropland. Soil erosion is also visible in the steppes devoted to extensive livestock rearing,

Farms are relatively small in North Africa and not specialized, i.e. low capital intensive and low yielding. They have a comparative advantage in labor-intensive crops that exploit the family's labour but with little propensity to adopt new technology. Mixed farms constitute a diversification strategy to lower risk, ensure a minimum income and provide for direct consumption. Irrigation schemes exploiting surface water have been established since the early twenty century, although Egypt has a much longer tradition in irrigation water regulation. They are mainly piloted by state authorities who manage large dams and sell water to farmers. With the increase of water demand and available of new pumping technologies, groundwater exploitation for agricultural and residential uses has sharply increased since the second half of the XX century, with the risk of agriculture basin depletion due to a significant decrease in water reserves. Water availability is a significant constraint for the agricultural sector, as its sustainability is jeopardized by decreasing groundwater storage capacities, particularly in the most arid areas.

Table 1. Land usage, 2016-2018

Country	*Total land area*	*Agricultural land*	*Arable land*	*agricultural/ total land*	*arable/total land*
	000 Ha	*000 Ha*	*000 Ha*	*%*	*%*
Algeria	238.174	41.351	7.460	17	3
Egypt	99.545	3.802	2.870	4	3
Libya	175.954	15.350	1.720	9	1
Mauretania	103.070	39.661	400	38	0
Morocco	44.630	30.079	7.495	67	17
Tunisia	15.536	9.730	2.593	63	17
Total	676.909	139.973	22.537	21	3

Source: FAOSTAT

The Saharan desert defines the boundary agriculture, bordering with steppe pastures. On the Atlantic and Mediterranean coast, the temperature is nuanced by the presence of breezes that moderate the climate. Agriculture concentrates in the dry Mediterranean and dry tropical belts at the Northern and Southern extremes of the region, where rainfall exceed mm 400. The rains regime defines the productivity of the pastures and their seasonality the periods of exploitation along with the pastoral and transhumant patterns of livestock migration. Riverine surface water is regimented and used for irrigation, as along the Nile, Sebou and Senegal River, creating the condition for fodder production and intensive livestock rearing, sometimes specialized as in the case of the mega-dairy farms of Morocco, but usually in mixed farming systems of variable size (commercial and smallholder producers). Crops residues and forages are produced in mixed farming systems as land fertility is restored by planting legume forages (berseem, alfalfa, etc.) or through fallow practices, depending on the water availability. Groundwater has grown in importance thanks to the growing availability of drilling machinery and electric pumps alimented by thermic, electric and more recently solar sources of energy. The depth of the water source and cost of extraction define its convenient use for growing intensive crops and sometimes forages. Rainfed cropping systems including cereals, forages and fallow lands transit to the steppe pasture lands that host transhumant and nomadic pastors. Irrigated mixed farming characterizes intensive sedentary agro-pastoral

systems while rain fed mixed farming usually coincide with semi-intensive nomadic agro-pastoral systems. The former include both commercial and smallholder livestock production, depending on the history of land ownership. Commercial mixed farm and livestock growers may be urban dwellers that contract farmers and herders to rear their livestock. They may invest in dairy production, as in Mauritania urban areas, or opt for two purpose meat and milk production as in Morocco by investing in technology to intensify yield. Smallholders mixed farmers are the most fragmented and diversified group of dairy producers. They range from intensive to semi-intensive production and their livestock can be used for one to three purposes (meat, traction, milk), i.e. their commitment to dairy production is determined by the diversification of the sources of income rather than by investments in technology to intensify the yield. The desert oasis microclimate host intensive crops – from one to three stages - and herds of small ruminants exploiting the fallow land and patches of irrigated forage fields. The continuity of the climate makes possible the overlapping of different agricultural systems, typified by the transhumant shepherds.

1.4 Dairy production

The North Africa countries have differentiated the modalities of livestock rearing to match the needs of the growing population. Intensive livestock management in irrigated farms producing fodder and mixed-farming or agro-pastoral systems producing crops residues sustain sedentary, intensive and semi-intensive livestock herds that produce a regular milk surplus available for sale. Transhumant agro-pastoral and pastoral and nomadic pastoral systems allow the extensive rearing of herds whose dairy potential is barely sufficient to maintain their growers and to feed small trade or barter with the sedentary population.

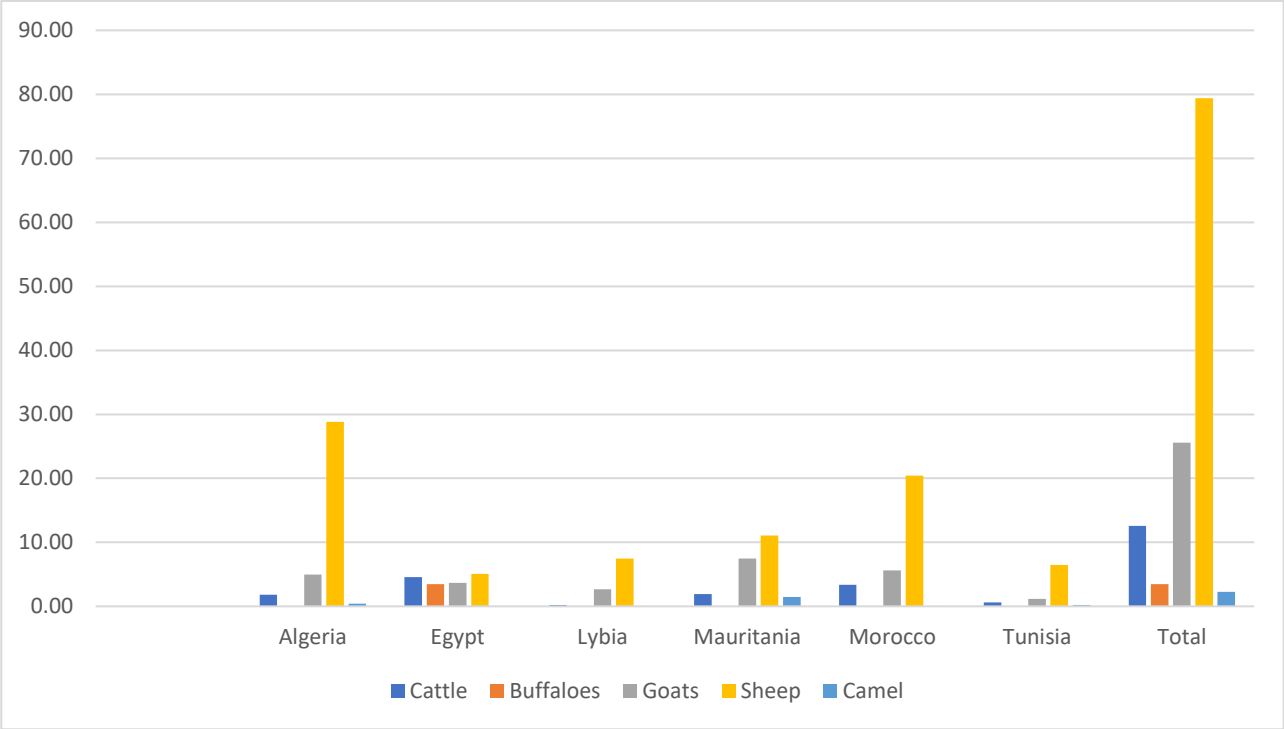
Table 2. Change (%) of livestock heads from 1994-1997 to 2017-2019

Country	*Cattle*	*Buffaloes*	*Goats*	*Sheep*	*Camels*	*Horses*	*Mules*	*Total*
	%	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Algeria	+46		+81	+64	+223	-25	-78	+65
Egypt	+57	+17	+12	+14		+96	+277	+23
Libya	+57		+112	+44	-35	+30		+57
Mauritania	+74		+101	+98	+34	251		+96
Morocco	+42		+35	+49	+62	+18	-27	+45
Tunisia	-5		-11	+2	+2	+2	+2	-1
Total	+49	+17	+55	+50	+30	+30	-29	+50

Source: FAOSTAT

Herd size is highly variable, with a prevalence of smallholder livestock growers practicing traditional rearing systems (tens of heads), larger technicised producers of variable size and some intensive mega-dairy farms (thousands of heads) in irrigated areas. Sedentary livestock growing for milk production concerns cattle, buffaloes in the Nile valley and small ruminants and camels, especially in Argelia and Mauritania. The intensive dairy production systems rely on fodder and concentrates, the semi-intensive on crops residues and nearby grazing lands with minor quantity of concentrates, while the extensive systems are fully dependent on the steppe pastures. Due to the insufficient biomass production of the North African arid lands, concentrates are mostly produced by compounding imported feed ingredients - grains, milling by-products, added vitamins, minerals, fats/oils, and other nutritional supplements -. Milk produced by non-cattle species (i.e., small ruminants and camels) is seasonal and, concentrated in remote areas and almost not integrated in industrial processing chains, except a few cases in Algeria and Mauritania.

Figure 2 Livestock million heads, 2017-2019. FAOSTAT



The viability of dairy production requires the existence of a surplus of water and forages that limits its viability to best water endowed areas and whose trade is important in densely populated regions. Thus, it is concentrated in the mixed farms and mega-dairy farms exploiting surface water sources and constitutes a small part of the rainfed livestock production systems that depend on the extensive steppe pastures and are often affected by drought, their milk production being enough for the consumption of the herders' household and small trade with the host communities. Investment in dairy production is justified by the supply of domestic consumption rather than by the subsistence dynamics of pastoralism whose tradable livestock output is meat and leather. Furthermore, North African sheep breeds are of low milk productivity and the milk self-consumed by the pastoralist households. Cultural habits also play an important role in the consumers' preference. Goat milk represents only 5% of the total milk production in Morocco. Most of it is self-consumed by rural households. The milk market is not developed because fresh milk is never consumed fresh and the 'goat taste' of cheese is not appreciated by the consumers. But as the demand is evolving, this sector offers great potentialities. Buffalo milk plays an important role in Egypt, where its higher fat content, favors the production of derivate products as cheese, butter and ghee.

The higher milk yield (over hg/year 17,000) explains the preference for bovine cows specialization in this production. For example, Morocco has imported around 400,000 cows of dairy strains (initially Friesian and more recently Holstein-Friesian high-genetic breeds mainly from European countries (Holland, France, Germany, etc.) since the early 1970s. Many of them are culled rapidly (less than 2 years after imports) due insufficient feed and hygiene.

Camels milk yield is superior to that of the other species (over hg/year 2,000 per head) but the limited size of their herds and remoteness from highly populated areas discourages their exploitation for this production. Small ruminants score the minimum values of milk yield, under hg/year 1,000, only goats in Algeria overcoming such value (about hg/year 1,800). As a result, cattle represent quite the quite exclusive source of milk in Egypt, Tunisia and Morocco (over 97% of the total milk) while Mauritania (51%), Libya (35%) and Algeria (22%). Mauritania is also the only North African country with a significant camel milk production (7%).

Bovine livestock provide the about 90% of produced in the North African region, with goat milk being significant in Mauritania (30%) and goat milk in Libya and Mauritania (over 20%), followed by small ruminant milk in Algeria (about 10%). Camel milk is marginal, representing 7% or the whole production in Mauritania, the best scoring country.

Table 3. Milk production (%) by livestock species, 2017-2019

Country	*Cow*	*buffalo*	*Goat*	*sheep*	*Camel*	*Country*	*Regional share*
	%	%	%	%	%		%
Algeria	78	0	9	13	0	Algeria	25
Egypt	54	44	0	2	0	Egypt	39
Libya	63	0	8	27	1	Libya	2
Mauritania	42	0	30	21	7	Mauritania	3
Morocco	97	0	2	1	0	Morocco	20
Tunisia	98	0	1	1	0	Tunisia	11
Total	73	17	4	5	0	Total	100

An assessment of the economic, social environmental importance of the DLVCs in Egypt showed that DLVCs using buffalo milk had highest scores in both Upper Egypt and Delta, followed by cattle in Upper Egypt and Delta. Sheep and Camels had the highest ranks in the Desert region. DVLCs using buffalo and dairy cattle dominate milk production and milk derivatives. Enhancing these both types of DLVCs in the future will have a great impact for their sustainability and the improvement of farmers' incomes.

The proportion of milk producing animals on the total heads is quite variable, with the bovine species recording the highest rates and the camels the lowest. The highest cattle specialization in dairy production is recorded in Tunisia (70% of the animals) and the lowest in Mauritania (22%), the other countries scoring from half (Libya, Algeria, Morocco) to one third (Egypt). Buffaloes milk producing animals in Egypt are about half of the total heads, slightly more that the cattle in the same country. Small ruminants record the highest rate in Algeria, around 60%, and the lowest (goats) in Morocco and Tunisia (around 5%). The highest rate of milk producing camels is recorded in Morocco, around 50%, the lowest in Tunisia and Egypt (about 0%).

Table 4. Milk producing animals (%) over total heads, 2017-2019

Country	*cow*	*Buffalo*	*goat*	*sheep*	*camel*
	%	*%*	*%*	*%*	*%*
Algeria	54		59	63	23
Egypt	36	46	32	37	0
Libya	59		23	28	18
Mauritania	22		21	20	7
Morocco	52		27	5	54
Tunisia	70		34	4	2
Total	43	46	32	32	11

From 1994-1995 to 2017-2019, the cow, goat and sheep number size has increased about 50%, the camel one by 17% and the buffalo one by 17%. The greater changes are recorded in Mauritania (goat, sheep and cattle) and Algeria (camel and goat), only Tunisia presenting a substantially stable number of animals of each species. In the same period, dairy livestock have experienced an increase in size of 78%, their milk yield of 25%, for a total increase of production of 122%. All the countries have experienced variable increase in cow and buffalo herds size (15%-60%) and Mauritania and

Libya substantial increase of goat and sheep (50%-60%). Algeria has experienced an increase of 156% of milk livestock herds, with a peak of 188% in the case of sheep.
The countries that have recorded the highest increase of milk production are Algeria, Morocco and Tunisia (150%-200%). Cows milk production have increased by 200% in Algeria and Morocco, between 100% and 200% in Tunisia and Egypt and about 150% in Libya and Mauritania, and buffalos of 150% in Egypt. Algeria has also experienced the increase of over 100% of milk production by goat, sheep and camels, while the other countries have recorded values of increase between 10% and 50%.

Figure 3 Cow and buffalo milk production 2017-2019 (million MT). FAOSTAT

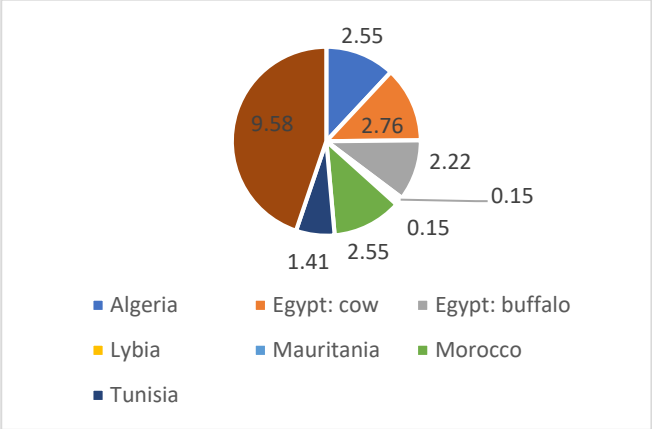
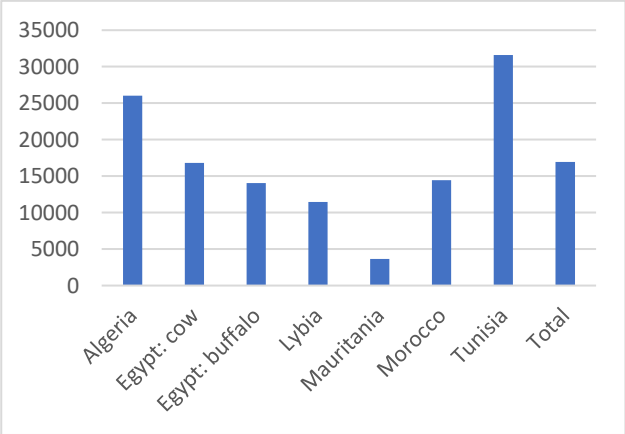


Figure 4 Cow and buffalo milk yield 2017-2019 (kg/animal). FAOSTAT



The increase in milk yield of over 100% have been recorded in Tunisia and Morocco while Libya and Mauritania have recorded a decrease in milk yield of about 10%. Specifically, all countries have recorded increase in milk cow herd yield, with Morocco, Egypt and Tunisia recording increases of 130%-140%. Buffalo yield have increased by 30% and Algeria and Egypt and Tunisia have recorded an increase in goat milk yield of about 15%-20%, Tunisia also a similar increase of sheep milk yield.

Table 5. Change (%) in milk production from 1994-1997 to 2017-2019

Country	*Cow Milk*	*Yield*	*Production*	*Buffalo milk*	*Yield*	*Production*

	Heads *%*	*kg/animal* *%*	*tons* *%*	*heads* *%*	*kg/animal* *%*	*tons* *%*
Algeria	+32	+137	+213			
Egypt	+34	+66	+121	+17	+30	+52
Libya	+60	-5	+52			
Mauritania	+38	+5	+45			
Morocco	+23	+141	+197			
Tunisia	+14	+129	+161			
Total	+29	+103	+161	+17	+30	+52

Country	*Goat milk heads* *%*	*Yield kg/animal* *%*	*Production tons* *%*	*Sheep Milk Heads* *%*	*Yield kg/animal* *%*	*Production Tons* *%*
Algeria	+80	+22	+119	+188	-24	+119
Egypt	+4	+16	+21	+7	-2	+5
Libya	+48	-8	+36	+66	-11	+47
Mauritania	+69	-11	+50	+62	-11	+44
Morocco	+28	-4	+23	+37	-8	+26
Tunisia	-8	+14	+5	+15	+21	+38
Total	+43	+23	+76	+120	-23	+69

Country	*Camel Milk Heads*	*Yield kg/animal*	*Production tons*	*Total Milk Heads*	*Yield kg/animal*	*Production tons*
Algeria	+174	-12	+141	+155	+12	+186
Egypt				+15	+58	+81
Libya	+20	+3	+24	+61	-8	+49
Mauritania	+26	-3	+22	+61	-10	+44
Morocco	+56	-6	+47	+28	+122	+84
Tunisia	+8	+2	+9	+5	+142	+155
Total	+62	-10	+45	+78	+25	+122

Source: FAOSTAT

Figure 5 Goat milk production 2017-2019 (MT). FAOSTAT

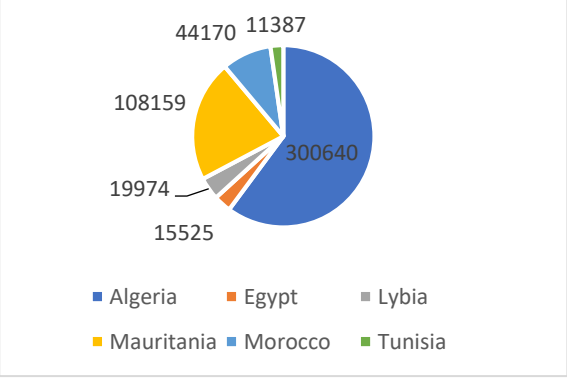


Figure 6 Sheep milk production 2017-2019 (MT) FAOSTAT

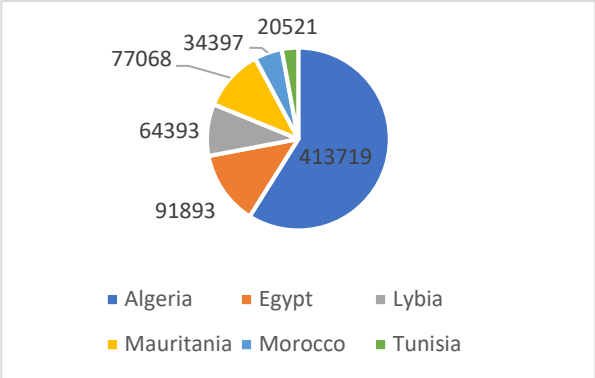
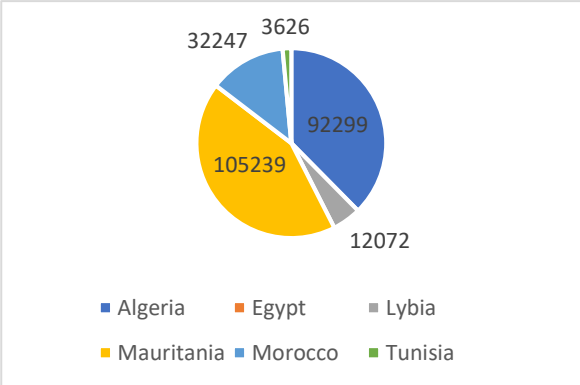


Figure 7 Camel milk production 2017-2019 (MT) FAOSTAT



According OECD FAO Agricultural Outlook 2018-2027, milk products consumption grew yearly by 1.8% in North Africa in the recent decades and will continue to expand as products diversify in source (large and small ruminants) and elaboration (fermented products). The prevalence of processed products is connected to cultural changes induced by the raising standards of life and exposure to other cultures. On the other side, the less affluent sectors of the population – but also the production of industrially processed foods - are recording an increased demand for imported milk powders, often subsidized in the country of origin. The availability of locally produced milk has raised 50% more than the population, doubling in Morocco, Tunisia and Algeria, increasing a bit more than 10% in Egypt and Libya and decreasing in Mauritania by more than 20%.

Table 6. Milk production and consumption per capita, 2017-2019

Country	Production		Change	Consumption	Domestic production / consumption
	1994-1996 L/person	2017-2019 L/person	%	2017-2019 L/person	2017-1019 %
Algeria	40	79	+97	130	60
Egypt	45	52	+16	50	89
Lybia	32	36	+11	75	48
Mauritania	109	84	-23	160	52
Morocco	34	74	+114	55	134
Tunisia	62	126	+102	110	114
Total	44	66	+151	70	84

Source: FAOSTAT, National reports

A comparison between the local production and the consumption of milk per capita shows a regional deficit in the production of milk, although Morocco and Tunisia are net exporters and Mauritania, Libya and Algeria are net importers. It should be noted that the available data do not allow to calculate the quantity of milk used for other uses than the human consumption. These may represent 10%-20% of the total consumption, consisting in the feeding of livestock and some non-edible industrial products.

Figure 8 Milk production 2017-2019 (L/capite). FAOSTAT

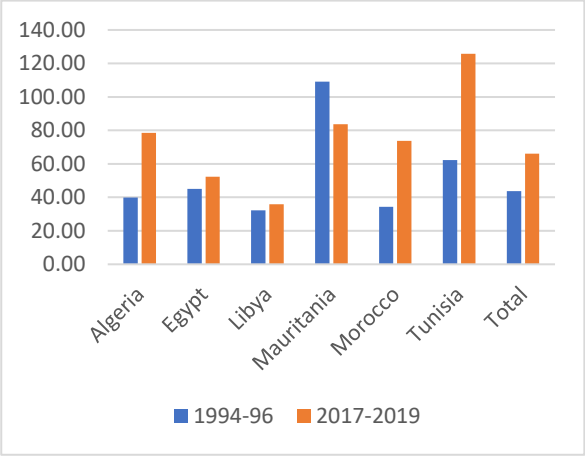
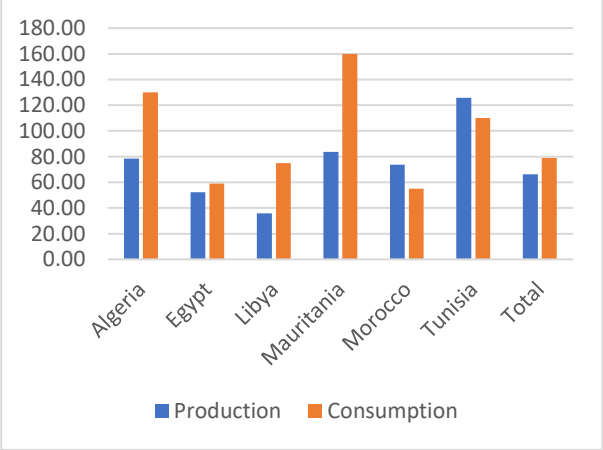


Figure 9 Production vs consumption 2017-2019 (L/capite). FAOSTAT/National reports



The dairy products demand, both per capita and overall, is steadily growing, although the starting point of each North Africa country is different and some depend hugely on import. This analysis shows that during the last decades, dairy production systems have consistently been moving towards intensification. The main factors that have pushed in such direction are the needs of the growing population and rising standard of living, the degradation of rangelands for overstocking and consequent need for concentrating livestock herds in the restricted areas where water is available and the availability of new technologies (high breeds cows, pumping systems, concentrates, mechanic dairying equipment, etc.).

Annex 2 presents the data on milk production in 1994-1996 and 2017-2019 used in this analysis.

1.5 Milk market and investments

1.5.1 Egypt

Milk production and consumption is subject to seasonality, organizational constraints in the value chain. Smallholders account for nearly 75% of the milk is produced in Egypt. The fragmentation of production and multiple collection tiers negatively impact on the characteristics of this product. The farm-gate price of milk varies from US$/liter 0.30-0.35, the lower price in winter and spring that account for two thirds of the annual production due to availability of green fodder. The final farm gate price of milk depends on the financial agreements between the farmer and the collector rather than on its characteristics. Customers purchase loose milk traded by informal milk collectors US$/liter 0,50-070 and milk packaged by industrial diaries US$/liter 0.90-1.00. Domestic production meets only 72% of Egypt's demand. In order to fill the gap between the demand and supply, dairy processors and retail channels imports milk powder and other dairy products. In recent years Egypt has imported about MT 150,000 and exported MT 50,000 of milk and products per year.

Egypt's dairy sector comprises of both formal and informal market channels. The formal market is served mainly by medium to large-scale dairy farms that pass over their milk production to large dairy processors using chilling facilities. Informal or traditional milk market in Egypt often provide the main outlet for smallholder dairy producers and constitute the major source of fresh milk supply for consumers. Informal market channels may involve small to medium-scale producers, mobile middle traders, large-scale wholesalers and retailers (milk shops). Milk collection centers act as the link between the informal market and the formal dairy supply chain by adding value through chilling, transport and some quality control.

Dairy industry in Egypt has evolved as a commercial scale through public and private investments. The economic openness policy and encouraging domestic private and foreign investments since the 1970' have triggered the expansion of dairy processing factories. The Agriculture development program of the Ministry of Agriculture and Land Reclamation is the main instruments for public investment in dairy production. Credit is awarded through national banks (Egyptian Agriculture Bank, National Bank of Egypt, Misr Bank, National social Fund, and Egyptian Commercial bank).
The dairy packaging market is moderately competitive and comprises a significant number of regional as well as global players. The vendors account for a considerable share and are focusing on expanding their customer base across the country. They are introducing new products and packaging solutions, strategic partnerships, and other organic and inorganic growth strategies. The dairy production companies are expanding their volume of sales in packaged milk and fermented products. The European Bank for Reconstruction and Development is promoting investments in such sector. Large-scale private-sector companies (Juhayna, Almarai, Lamar, Obourland and Danone) have invested in industrial processing and packaging of dairy products, having the capacity to control prices of different sorts of dairy products.

1.5.2 Morocco

The dairy production is driven by:
- a high value products' niche for consumers with enough incomes to afford buying expensive products (i.e., Ultra High Temperature [UHT] drink milk, cheese, butter, etc.), and

- a general demand for drink milk by the majority of households. Consumers with a limited income access the informal circuit where prices of traditional dairy preparations are lower than those of the industrial products.

The mega dairy farms represent less than 1.2% of the cows stock and produce 13.3% of the processed milk in Morocco. These cows produce about 8,000 liters per year and consume 17.5% of the concentrates and less than 0.1% of the straw. Smallholders produce about 1,000 liters per cow per year which are not totally processed. The *Farm gate price* (i.e., the price paid by collection co-operatives to farmers) is US$/ 0.32 to 0.35 for smallholders and up to US$ 0.45 US for mega diaries. Collection center sell milk to dairy processors at US$/liter 0.38. Consumers pay drink pasteurized US%/liter 0.71 up to 0.78. During the rainy season, from February 15thand August 14th, the farm gate milk price decreases by 10%, raising again during the dry season. The formal milk processing chains represent almost 70% of the processed milk, 20% is collected and distributed by the informal dairy chain (*mahlaba*) and 10% is consumed on-farms (i.e., drunk by calves or consumed by the farmer's family). Dairy production is increasing along with the diversification of the milk products market.

The government promotes investments in the DLVC with the aim of achieving self-sufficiency and to add value to the assets of the rural areas. The Green Morocco Plan is providing credit for the purchase of dairy heifers, milking machinery. The Ministry of agriculture and its agencies advertise projects and the Agricultural Development Fund subsidies investments in dairy production. investments in dairy production. Local and international financial groups have invested in the creation of mega dairy farms on state lands rented for 99 years, integrating milk production and dairy processing. There are a dozen dairy farms, almost wholly located in the North of the country and belonging to private investors with strong ties with the dairy processors and 2,700 collection centers, in majority managed by the farmers' co-operatives. Downstream the chain, there are 82 dairy processors. Current investments are shifting from yield gain to climate smart dairy business through the production of water saving fodder crops, introduction of reasoning irrigation and proper feeding systems distributing sufficient and balanced diets according to the productive statuses of the cows. Transnational dairy companies as Danone, Bel, Nestlé are investing in the Moroccan DLVC introducing good management practices in dairy factories and the diversification of the dairy products whose consumption is steadily growing in urban areas. Milk processing requires the import of dairy preparations and ingredients (whey protein) as well as butter and milk powder, used by dairy processors to improve the local milk for certain preparations.

Morocco imports about MT 85,000 of milk and dairy products from the international market while exports are minimal. Some spread cheese is exported along with other fermented products (mainly yogurts and drink milk) that are sold in the Sub-Saharan countries (Mauritania, Senegal, Mali, etc.).

1.5.3 Mauritania

In Mauritania livestock farming represents 25% of Gross domestic product, 30% if we take into account the value added generated by the processing/ distribution sector. The milk sold account for 85% of the production while the other 15% are consumed by the producers' family and livestock offspring. The 79% of the value added is at the producer's level. Income-generating activities upstream or downstream of production account for 12% of the added value. The import of milk and its products (UHT liquid milk, powdered milk, sweetened condensed milk, butter and butter oil, cheese and yogurt) has been about MT 86,000 in 2014. At the end of the dry season, local milk becomes scarce and is substituted by that obtained from milk powder. During the drought years, the government often subsidizes the livestock feed through the Livestock Input Supply Centre.

Milk is traditionally a matter of women that process it (curdling, skimming, churning) to increase its conservation and added value. Curdled milk and butter oil or *sirmé* (liquid butter) have a higher price than raw milk. In the North milk is also conserved by pouring curdled milk onto levelled fine sand, drying and storing in bags. For use, it is dissolved in a calabash containing water.
Milk distribution can be performed along different circuits:
- the traditional direct circuit where the producer direct sells milk to consumers especially in rural areas
- the integrated circuit in which the producer sells milk to a dairy factory or collection and refrigeration center that prevails in peri-urban areas
- the semi-integrated circuit in which a collector, usually a woman, purchases the milk from the producer and resell it to market kiosks or shop.
The farm gate price of milk grows from US$/liter 0.42 in the rainy season to USS/liter 0.56 in the dry one and milk collectors resell It at US$/liter 0.57 and US$/lite 0.70 per liter, respectively.
Herds of transhumant cattle and camels have been divided into dairy units (*ateliers laitiers)* and transhumant units. The formers are the result of investments by traders and officers and supply a network of raw milk markets as well as milk collection/packaging centers in the main cities.
Dairy production is developing on the periphery of major cities to supply milk-packaging plants in Nouakchott. The industrial dairy production and processing sector in Mauritania has experienced significant expansion since the 2000s. Five industrial actors, four private (Tiviski, Top Lait, El Watanya, Irijy) and one public (Société Mauritanienne des produits laitiers). The collection is organized around collection centers located in the Trarza, the Brakna and the Hodh El Chargui (Rosso, Boghé, Aleg, Néma) and major road routes in these Wilayas. Tiviski group in partnership with Candia, a French dairy company, has established a modern milk processing factory in Nouakchott that purchase and distributes milk across the country. They produce fresh pasteurized milk, Ultra high temperature milk, yoghurt, fresh cream and goat's cheese.
The government imports large quantities of feed to support the livestock during the lean period, that have reached MT 88,000 in 2020.

1.5.4 Milk price

The coexistence of intensive dairy farms and semi-intensive production by smallholders and commercial producers characterize the DLVC in North Africa. The smallholders sell their product to intermediaries that aggregate the offer and sell it to the consumers or to large mill collectors and dairy factories. As a consequence of the multiple levels of intermediation the consumers pay milk also twice the farm gate price.

Table 7. Milk price, 2017-2019 (US$/L)

Country	*Farm gate*	*Local sellers*	*Dairy industry*	Local seller / farm gate	Dairy industry/farm gate
	US$/L	*US$/L*	*US$/L*	% increase	% increase
Egypt	0,30-0,35	0,50-0,70	0,90-1,00	82	188
Morocco					
- Smallholder	0,32-0,35		0,71-0,78		134
- Mega dairy	0,45		0,71-0,78		67
Mauritania	0,42-0,56	0,57-0,70		26	

Source: National reports

The producers have a comparative advantage when they directly sell milk locally, as in Mauritania rural areas, or are mega diaries directly selling the dairy industries as in Morocco. Where there are multiple layers of intermediaries between the producers and the dairy industry the difference of price from farm gate to the consumer is greater, as in Egypt. The aggregation of the producers and improvement of milk production practices improve the characteristics of the milk and make possible for the smallholders to directly sell their products to the large milk collectors and dairy factories, thus getting a larger share of the price paid by the final consumers.

1.6 The dairy livestock value chain

Livestock rearing contributes to the subsistence of the rural population in the drier areas prevailing in North Africa and has become a business in those more endowed with water that produce a regular supply feed. The application of advanced breeding and feeding technology has spurred significant productivity growth in dairy production although it increasingly faces natural-resource constraints and growing competition in the use of resources as water and feed. Large and small livestock exploits in a versatile way the potential of the territory and through dairy production boosts the diet and health of the population. The environmental adaptability of dairy livestock makes it apt for intensification and alleviation of poverty and ensuring food security in the arid and semi-arid regions that characterize North Africa. Since its impact on ecosystems can be disproportional with its output, innovation has to be careful adapted to the environmental constraints. The trade of fresh milk from producers to processors and from these to consumers generates extra income for the farmers and transfers innovation to the farmers. Commercial farmers and mega-dairy farms can negotiate milk price directly with the processors while smallholders' fragmentation multiplies the number of milk intermediators.

1.6.1 Actors of the DLVC

Most *milk producers* are mixed farmer that include subsistence micro-farmers who contribute with the largest share of milk relying on traditional practices, traditional commercial small and medium producers with partly technicised practices and a limited number of specialized and modern dairy farms that import foreign breeds of cattle as the Holstein one. In fact, micro-farmers production is mainly geared towards domestic consumption (subsistence production systems) while the other systems (under the commercial and modern production systems) are directly oriented to supply the market. The subsistence and commercial livestock production system are mostly using indigenous livestock breeds although incorporating a growing share of imported blood breeds. Mega dairy farms (over 1,000 cows), mostly privately funded, have strong ties with the dairy processors. However, the supply of raw milk remains largely dependent on collection centers which themselves rely on smallholder farms' deliveries. Smallholder units daily deliver milk to middlemen or collection centers.

Milk collection, cooling, and transport are usually done through a long chain of intermediaries, namely: milk collecting and wholesaler middlemen and milk collection centers. Most milk transporters are young men although there are also women that carry milk either directly by using donkeys and carts, or indirectly by hiring young men to operate their vehicles. A specific category of milk collectors exists in Mauritania where trader women that supply fresh milk to sellers in the market or shops or final customers for daily consumption in the cities and in the villages.

Middlemen have small daily collection capacity of 300-500 kg and no treatment facilities. They live in villages, often being also smallholder milk producers, and supply milk wholesalers. Milk collectors

have important functions in milk marketing and logistics, such as bulking the milk for commercial handling, averaging milk price and milk quality as different qualities have different prices, transferring milk out of the villages. Due to their dispersion on the territory, many producers still depend on middlemen to supply milk processors. These petty traders are often commercial milk producers trading also their neighbors' produce and often provide subsidiary services to farmers as transport and storage of milk or advance money for the purchase of production inputs. They play several roles as intermediators in the purchase of farming inputs and sale of farm products at once. Usually, milk collectors provide payments to the farmers for milk on a weekly basis or longer period. Dairy farmers receive a marginal price for their milk, with middlemen controlling the increase in their margins and reduction of their costs.

Artisanal milk processors consist of traditional dairy workshops (mainly active in suburbs and in popular areas of large cities that supply consumers with traditional preparations such as buttermilk, yogurts and ghee. They informally purchase milk from producers or middlemen / petty traders, and process, transform and distribute it through the small shops, food outlets or consumers without storing reserves of product. Their market is limited to the village or small residential areas of the cities.

Milk collection centers are growing and have slowly substituted the government-run and producers' cooperatives and larger technicised plant that treat and conserve milk. They supply fresh milk to consumers of the nearest town or to other dairy processing plants for further processing.

Industrial milk processors are capital intensive businesses, sometimes using foreign capitals that purchase milk from dairy farms, commercial producers and cooperatives of smallholder farmers and that serve wholesalers and food distribution chains. Their supplier farmers are in direct competition with the importers of powder milk and other dairy products. A few industrial processors serve the national market. They are often joint ventures with foreign investors and rely on local production of imported powder milk.

The *dairy products traders* assure the distribution of the milk products and constitute with the middlemen and processors the milk cold chain i.e., use electric-powered storage and transport facilities. They are active in the distribution of local and imported milk products and include wholesalers, supermarkets and retailer food shops.

The *consumers*' sensitiveness to price, taste and presentation depends on their traditions and are increasingly differentiated due to the influence of imported dairy products and change of diet in the urban areas.

The *feed mills*, fertilizers and drugs providers not only supply farmers but they also play a role in technology transfer along with the extension services and veterinarians. They ensure the access to imported concentrate feed, animal drugs and electro-mechanic dairy equipment often through oligopolies due to the bottlenecks in the trade. They promote and broker innovation, as formulas of feed, advise farmers on the use of their products, as part of their commercial services. The farmers purchase (mostly small and medium farms) their concentrate feed through retailers or via farmers cooperatives either in cash or in credit. Big farms mostly buy their feed directly from feed mills or produce their own feed.

Financial institutions play a major role in the commercial dairy production where intensive use of inputs and large size require the access to loans to anticipate running expenses. In the case of small producers, livestock itself is the capital that is sold to pay for the family expenses in case of crisis. This explain the existence of large herds of little yield that farmers keep also when their exploitation is not economically viable.

Public agencies running *irrigation services* sell the water derived from large dams or rivers, as in the case of the Nile, (water not for sale in Egypt, it offers free from the state only pumped aquifers in the desert) to farmers. The irrigations are scheduled primarily according to water availability in

dams. Whenever there is a long drought period, the irrigation can be suspended. In the large-scale irrigation schemes, irrigation is generally done by furrow means, implying significant losses that however contribute to the refilling of groundwater reserves. The shift from furrow to drip irrigation that accelerate the rhythm of groundwater depletion.
Governmental agencies (Ministry of Agriculture, Universities, Agricultural research centers, Veterinarian and Extension services) and *non-governmental organizations* (cooperatives, veterinarians, NGOs, dairy producers' organizations) act as brokers of technical and economic services to the livestock growers. Public authorities are encouraging the establishment of inter-professional governing bodies gathering the stakeholders of the DLVC, as organizations representing smallholders, milk collection operators as co-operatives of farmers, and dairy processors. Producers have been grouping in cooperatives, as in Morocco, Algeria and Egypt, to improve their negotiation strength.

1.6.2 DLVC governance and consumption changes

The running of the DLVC governance – the way actors discuss, negotiate and solve production and commercial problems - faces great hurdles in North Africa, starting with the small size of milk production units, the bottlenecks in the access to inputs and technology and the variability of price. The fragmented offer (trading numerous batches of limited quantity) adds logistic costs and delays milk collection. The rainy season is generally characterized by a decreased consumption of dairy products, which forces processors to make stockpiles of powder milk in advance to the summer season when dairy yield decreases and consumption grows Finally, another source of losses is represented by the limited share of fermented products (i.e., yogurts and cheese) that is a minor component of local dairy products. As a comparison, in Europe, fermented dairy products represent 80% of raw milk, allowing processors to significantly increase the value of their activities. In fact the growing urban consumption of fermented dairy products consists mostly of imported cheese (common and specialty types).
The governance of the milk value chain is centered in the action of *producers' organizations*, service providers and the dairy industries along with the Ministries of agriculture. The most influencing are the agricultural institutions that cumulate the regulatory and supervisory role with the supply of specific services as research, planning and monitoring, extension and veterinary surveillance and, less extensively, control. The emergence of the smallholder producers' cooperatives and associations has faced several challenges that are rooted in limited financial capacity of their members, their weak governance and dependence on government subsidies. notwithstanding such setbacks, these organizations are slowly growing and improving the market positioning (negotiation capacity) of the member farmers. *Private services* play a greater role in assisting the mega-diary and commercial producers that invest in technology and have to comply with strict product standards. *Milk factories* growing role depends on the expansion of the urban markets that require scale economies thus displacing *artisanal processors*.
The dairy chain is regulated through public policies in which the voice of the producers is increasingly heard. This public private alliance to govern the DLVC faces several hurdles. Producers' organizations often fail to add value to their members and face internal struggles that weaken their representation power in dealing with the other DLVC actors. These setbacks are particularly important as they also delay the access to innovation. For example, the research devoted to dairy production is rather limited as the livestock growers are little effective in presenting their exigencies to researchers. Their contribution in establishing research priorities and in testing innovation

requires an active role of their organizations in analyzing and advocating for investments in adaptive research.

The DLVC is undergoing a slow transition from traditional patterns of production and consumption, that depends on the locally available resources and products, to a more dynamic and diversified thread of interactions among dairy actors that intensifies production in response to the diversification of consumers' preferences on the basis of the composition, taste, presentation, price of milk products. Consequently, the share of fermented products is growing in the formal dairy market and their supply is driven by the imported products. The factors limiting the transition from traditional to technicised dairy production and processing practices are several. Dairy production economies of scale are small because of its high labor needs. Smallholder producers' costs are often comparable with those of large dairy farms because the former employ non remunerated family workforce. This situation explains the prevalence of small herds also in the sub-urban areas of North Africa, satisfying the growing demand of milk products. Livestock diet improvement and mechanization often overcome the financial capacities of the smallholder farmers, also when they operate associated in cooperatives. Not uniform lots of milk require extra treatment and may be inadequate to the production of fermented products homogeneous and constant in the time. Transaction costs little impact on profit efficiency at the production level, as feed is largely forage-based, not requiring access to credit while they are an important factor in the trade and processing where costs are higher for the collection of milk from smallholders, a situation that discourages dairy factories to procure it from them. The plurality of the limiting factors discourages change, starting with the recurrent droughts that result in milk composition and quantity variability and stimulate the continuation of subsistence livestock rearing practices. Thus, only the larger producers can afford the access to innovation and supply milk with predictable characteristics to the factories of fermented products while the smallholder dairy systems mix traditional and modern and supply formal and informal traders and milk collection centers, in practice the milk consumed as a drink.

The Milk factories commitment to the growth of the fermented products market is checked by dietary customs as the preference for the daily glass of milk drunk also in the urban areas of pastoral regions that is rooted in the local culture and conjugate with informal trade of the surplus milk produced by subsistence farmers. The supply of the glass of drink doesn't require extra investments as the cold chain and is preferred also if it is more expensive than the powder milk.

The new dairy products penetration in the market faces the concurrence of the traditional ones that leverage cultural patterns shared by producers, traders and consumers – as in the case of buffalo milk in Egypt and sheep milk in Algeria –. The petty traders' relations with rural dwellers play an important role in this respect as they are thread along the family and social networks that link the rural and recently urbanized population. Consumers' choices continue the dietary preferences of the social groups of origin. On the contrary, where local competition is weak – as in the case of fermented products -, the change of dietary patterns can be swifter as imported cultural model don't have to fight against customary habits. Of course, milk factories can analyze these hurdles to the introduction of new products to identify market niches and modalities to modify consumers' preferences, although not to change the structural patterns of the local diet.

The COVID-19 pandemic has shown the limits of the food systems based on a linear model of globalization without limits. The food systems relying on local commodities rather than on unbounded imports have to be promoted although they have carbon footprint is higher. Dairy systems may appear indicated, as they add value to locally grown forage resources, as well as weeds, in comparison to poultry production which relies entirely on imported maize and soybeans meals.

The COVID-19 pandemic has also impacted on the pastoral systems by reducing the mobility of herds across pastoral areas due to the scarcity of feed there, increase of the cost of concentrates, the access to drugs and vaccines and the closure of borders.

1.7 Knowledge management systems

Local breeds of dairy livestock are adapted to the climatic conditions, tolerate endemic diseases and produce and reproduce under less than optimum feeding conditions. Knowledge management can be formal through university curricula and informal through peer-to-peer learning. The first one is now relying on academic courses and practical on farm training. The analysis of the persistence of traditional production and consumption practices in remote and urbanized areas alike reveals that, the inertia of traditional knowledge management systems explains the slow pace of change recorded in North Africa. The role of formal education systems in promoting the substitution of traditional knowledge has little influenced the popular modalities of knowledge elaboration and transmission. The emotional basis of the learning processes (motivation and feelings) acts as a filter of ideas and information whose justification resides in their rationality. These are appraised on the basis of their compatibility with the feelings, preferences and orientation of the learner' social group. In the case of the dairy livestock growers', their experience and convenience pre-exists to their exposure to innovation. They can integrate individual inputs in their rearing practices. However, it is unlikely that these modify the complex of their habits that constitute the core of their production systems. This is the case of feed additives whose harnessing in the diet of the livestock little impacts on the other livestock rearing practices, as exploitation of the farm residues or on the transhumant herds size. Herders use them to cope with a temporary shortage without transforming them in a structural feature of a new dairy production system. Thus, their more likely impact of their adoption is not the substitution of the traditional practices but their juxtaposition. They become part of a set of alternatives managed along the principles of the traditional production systems. The same happens with vaccination campaigns that for their promoters should orientate pastoral herders to adopt improved hygienic practices that these systematically elude.

Dependence on imported technology competes with and limits the exploitation of the results of local research also if this is more adapted to the dryland conditions of North Africa. These have little buy in among the mega diary (foreign technology dependent) and lack proper ways of divulgation among the traditional producers (weakness of the extension services). Rare works have tried to characterize the nutritive value of local feedstuffs, and there have been some partnerships with large farms to analyze some of their practices (milking, culling, etc.) and the effects on their performances. These studies are far from the actual constraints faced by smallholder producers. Some leading dairy processors have established ties with research centers to think for a roadmap of good practices to be defined to decrease the vulnerability of the sector to reduced renewable water availability. This encompasses on-farm good practices from the irrigation of fodder crops to the design of dietary rations adapted to the herds genetic value and finally to the ways of increasing milk valorization through the promotion of its chemical and hygienic quality. Exceptionally, a club of mega dairy farms was created in Morocco in 2015 where their managers meet yearly to exchange experiences on cattle breeding, heifers' rearing practices, dietary rations adapted to Holstein cows, heat stress and effects on reproduction, etc. Exchanges of experiences between smallholder farmers, usually brokered by development projects with the assistance of agricultural authorities, are also organized. They include training sessions animated by experts in aspects related to the topics covered by dairy breeding: milk quality components, profitability of a dairy herd, mastitis management and health, etc.

2. Environmental challenges to dairy production

Dairy livestock production faces many challenges. They range from resources use efficiency to the valorization of products where several options exist to improve the dairy production outputs and profitability. For example, dairy products growing and diversifying consumption shows that there is room for improvement in quality, in quantity and in processing. A huge variability exists in the dairy products sale that means that many people cannot afford buying milk regularly. This is directly in relationship to dairy products' prices, which is seen by many families as expensive commodities. This can explain the success of the dairy boycott movement in Morocco (2018) that has left significant scars in the DLVC actors. There is a need to reconsider water use and feed production according to the worsening balance of these resource. A crucial point is to stop assuming that a homogenous dairy development model fits the conditions, exigencies and perspectives of all the dairy livestock growers. The efficiency of the use of production inputs varies from region to region and doesn't allow to use the same coefficient of milk yield or economic rentability. Livestock rearing practices combine and exploit them on the basis of the local constraints. In some areas annual rainfall overcome mm 400 (regardless of inter-annual variability) or surface water allows irrigation whereas in steppe and desert areas, where groundwater reserves are being depleted, herds depend on erratic rainfalls of less than mm 100 per year. Here there is a need for regulations that implies a stronger role of public authorities and their collaboration with all the partners of water management. As grazing lands are dry and arable land is 3% of the North Africa total land, the growth of dairy production in the recent decades has resulted in the shortage of water and fodder. This gap has prompted the import of the ingredients of the concentrates that have made possible the intensification of dairy production.

2.1 The water and feed balance

The DLVC links the natural resources management, to livestock rearing systems and food trade and processing. Dairy production shares inputs and practices with the meat, food processing and trade value chains. Its specificity depends on the greater intensity of inputs and technology it requires vis-à-vis the more differentiated patterns of meat production that encompass extensive to intensive rearing. Economic dairy production needs extra water to produce fodder and more intensive health surveillance and control. Thus, it concentrates in the water endowed and more densely populated areas of North Africa – and consummates more concentrates -. Milk storage and processing to serve the urban market also requires extra investments and results in the concentration of these tasks in large scale facilities.

Water consumption if made of direct use (service and drinking water) and indirect use (production of feed, fertilizer, pesticides and other inputs). Arid grazing lands are not convertible to cropland and livestock can be the only option for producing edible biomass. The water deficit is measured in the loss of yield and in the import of the ingredients for the concentrate feed alike. As the need of livestock drinking water is less than 2% of the feed requirements, the latter – made of forage, straw and concentrate ingredients) determine the cost and success of milk production. The water and feed balance in Egypt, Morocco and Mauritania shows that their insufficient availability is a common challenge notwithstanding the different livestock rearing practices and intensity in the use of resources. Water productivity depends also on its seasonal distribution. Dry summer and autumn make drop the green fodder availability in North Africa. Milk yield are of more stable under irrigation systems and by recurring to imported feed inputs. The import of the ingredients for the production

of concentrates and the import of milk (powder or fermented products) fills in the gap in water resource that limits dairy production.
In drought-prone areas, where average rainfall levels are below mm 400, extensive systems based on pastures, transhuman or nomadic herds are obliged. Where rain is over this amount, semi-intensive systems prevail with forage and straws used as feed. Intensive systems are possible only where irrigated crops provide adequate nutrients that are usually associated to concentrates. Forages and silage maize are cropped in the irrigated dairy farms and contribute with straw and concentrates to the nutrition of dairy livestock. The cattle rearing systems are designed to add value to rainfall stored in the ground in favorable rain-fed agricultural zone. Hence can thrive along seme-intensive and extensive rearing practices. In irrigation schemes livestock production has to be intensified to pay for the higher cost of water harvesting, thus prompting the DLVC.

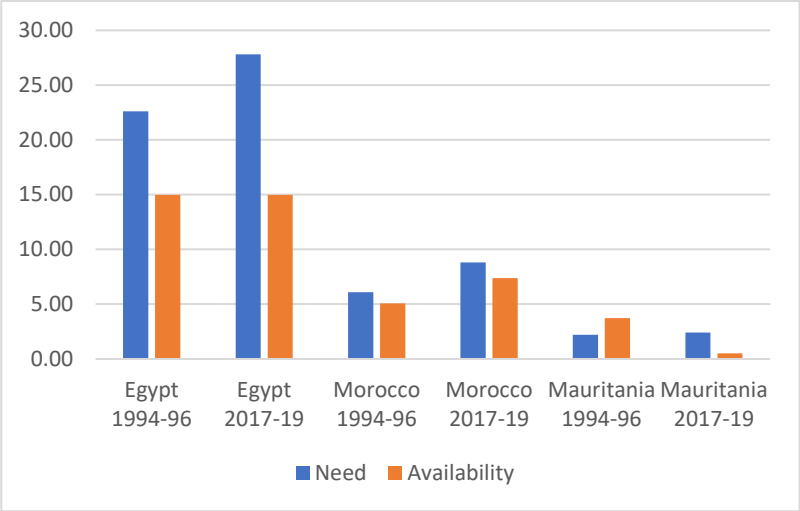
Factors influencing water efficiency in dairy production include the fitness and yield of livestock species and breeds and the moisture content and production of feed. Diverse production systems are adapted to exploit the mix of inputs that are used in dairy production. The limited resources of the available animal feed are the most hindering factors of dairy production. Poor feeding conditions, a heteroclite genetic structure of the herd (in smallholder farms, cattle of local breeds, as well as several crosses between local and imported breeds, and of course purebred Holstein cows) and also numerous production setbacks like health disorders (mastitis, tuberculosis, etc.), reproduction failures, are the main constraints to milk yield by smallholder farmers. The *feed gap* is about half the requirements of dairy livestock. On the other hand, potential of using crop residues as an alternative source of animal feeds is limited due to poor nutritive value, low digestibility and low palatability. Crop residues are mainly fibrous materials that are by-products of crop cultivation which form high percentage of the total feeds.

Table 8. Water and feed balance in Egypt, Morocco, Mauritania, 2017-2019

Country	*Milk animals*	*Milk*	*Water*			*Feed dry matter*			*Year*
			Needs	*Availability*	*Balance*	*Need*	*Consumption*	*Balance*	
	Heads milion	*MT milion*	*Billion m^3*	*Billion m^3*	*Billion m^3*	*Million MT*	*Million MT*	*Million MT*	
Egypt	6,26	5,09	27,80	14,99	-12,81	38,19	20,79	-17,40	
- forage, straw			11,86	8,20	-3,66	24,82	17,18	-7,64	
- concentrates			15,94	6,79	-9,15	13,36	3,61	-9,75	
Morocco	3,38	0,93	8,81	7,37	-1,45	10,84	7,08	-3,76	2018
- forages, straw			7, 37	*7,37*	0,00	8,43	6,58	-1,85	
- concentrates			1,45	0,00	-1,45	2,41	0,5	-1,91	
Mauritania, pastures	4,33	2,64	4,32	3,74	-0,58	15,82	7,10	-8,71	2017-1919
Total	14.96	8,09	40,93	26,10	-11,94	64,85	34,97	-29,87	

Source: FAOSTAT (heads, milk) National reports (water, feed)

Figure 10 Water balance 2017-2019 (billion m3). National reports



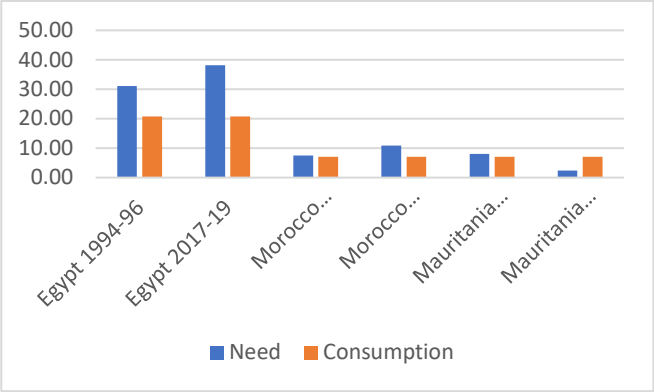
The increase of the livestock herds and of milk production from 1994-1996 to 2017-2019 has augmented the water and feed requirements. The shortage of milk in all the countries, including Mauritania where there was a surplus of water and in Morocco and Mauritania where the feed unbalance was quite limited. The cumulative effects of climate change (greater variation of extreme weather conditions and natural disasters), increased livestock load and the progressive depletion of the groundwater negatively impact on the conservation of natural resources and the sustainability of dairy production in North Africa.

Table 9. Change in water and feed balance, 1994-1996 - 2017-2019

Country	*Water balance*			*Feed balance*		
	1994-1996 Billion m³	*2017-1019 Billion m³*	*Change Billion m³*	*1994-1996 Million MT*	*2017-1019 Million MT*	*Change Million MT*
Egypt	-7,61	-12,81	-5,20	-10,25	-17,39	-7,14
- forage, straw	-1,44	-3,66	-2,22	-3,00	-7,64	-4,64
- concentrates	-6,17	-9,15	-2,98	-7,25	-9,75	-2,50
Morocco	-1,00	-1,45	-0,45	-0,40	-3,76	-3,36
- forages, straw	0,00	0,00	0,00	0,77	-1,85	-2,62
- concentrates	-1,00	-1,45	-0,45	-1,16	-1,91	-0,75
Mauritania, pastures	1,54	-0,58	-2,12	-0,97	-8,72	-7,75
Total	-7,08	-14,84	-7,76	-11,62	-29,87	-18,25

Source: FAOSTAT (heads, milk) National reports (water, feed)

Figure 11 Feed balance 2017-2019 (million MT). National reports



2.2 Forages, straw and concentrates

In Egypt, irrigated lands are used to produce the forage (clover, alfalfa) and straw that feed dairy livestock. An extensive network of irrigation canals crosses the Nile valley and delta. Clover is the main fodder crop grown in winter, followed by alfalfa, green maize, sorghum, elephant grass, cow pea, etc. The natural pastures cover a limited extension in Egypt being scattered across the desert and near the Mediterranean coast. Their fodder production is quite low and used for feeding some desert animal like camels, sheep and goats raised by transhumant and nomadic herders in these areas. Due to the relatively low consumption rate and adequate milk production level, this product is quite entirely supplied by domestic production.

In Morocco irrigated farms account for 70% of the milk output. The price of the irrigation water is around US$/m^3 0.05. The irrigations are scheduled primarily according to water availability in dams. Whenever there is a long drought period, the irrigation can be suspended. In the large-scale irrigation schemes, irrigation is generally done by furrow means, implying significant losses. However, such losses may help maintaining the levels of the groundwater reserves steady. Irrigation ensures a steady supply of feed to dairy animals, particularly cows and buffaloes that are the most important dairy species and also the most sensitive to scarcity of feed and drinking water. Dairy production is almost entirely based on cultivated fodder crops, as well as spontaneous fibrous resources (weeds in cultivated plots, grasses from fallow, natural grasslands, etc.) and of course on concentrates (a vast share of them being imported and considered previously as virtual water). Large dairies farms rely on maize silage, concentrate feeds and little straw and stubble. Smallholder cattle growing consume green fodder, straw and little concentrates. Fodder crops include irrigated fodder, and it is mainly alfalfa, followed by clover and silage maize and rain-fed fodder crops, led by barley, oats and vetch melted to other cereal grains. Due to the good milk production level, consumption is largely assured by domestic production.

In Mauritania, local feed is quite exclusively coming from pastures and straw. The grazable land, hosts about 4 million units of tropical livestock, i.e., 80% of the potential load. The bulk of their diet is represented by natural pasture, whose potential varies according to the ecological zone. The most important pastoral potentialities are found in the East of the country, where two thirds of the exploitable areas are concentrated, the rest being distributed between the center and south where runs the Senegal river. Under-exploitation of pasture is the result of poor distribution of water points, leading to over-exploitation of resources in the less dry areas where dairy livestock concentrates. The milk producers are obliged to recur to the import of concentrates: rice bran, peanut meal, concentrates combining imported ingredients. Due to the huge milk production deficit, consumption is largely dependent on the import of powder milk.

In addition to cultivated fodder (whether rain-fed or irrigated), weed from cultivated plots and natural rangelands, which output is highly dependent on rainfall levels and monthly distribution, the dairy herd consumes significant amounts crop-byproducts. The most important one is of course cereal straw, as cereals represent the core of the agriculture in the region. The annual output of straw is highly variable as they depend on the erratic rainfalls. Straw is especially important for small ruminants and equines.
Cereal crops by-products such as straw and stubble as well as other industrial crops by-products (sugar beet pulps) are also source of ingredients for the formulation of concentrates, particularly in smallholder units. Their nutrients content is limited but they are essential for dairy production during drought periods when green fodder is scarce. A large part of the straw, fallow land in rainfed areas provides grazing and weeds from orchards contribute to the livestock diet. Whenever, the beginning of the rainy season is late, straws become crucial to ensure the maintenance of the herd and its price increases sharply. It should be noted that the upgrading in the nutritive value of crops residues requires technology advances in their mechanical, chemical and biological treatments. Treatment of crop residues by ammonia and by urea to improve their nutrient value are practices that have proved successful in large produces but failed with smallholders due to loss of dry matter and the cost of the import of these chemical substances.

Livestock growers usually purchase concentrates directly feed mills, particularly for large herds. However, for most smallholder producers, no purchases of concentrate feed occur, since they prefer to rely primarily on on-farm feed resources (fodder, straw, etc.) and on individual ingredients (wheat bran mixed with sugar beet pulps). In some irrigation schemes of Morocco, where the extension services are active, there has been recently the promotion of collective purchases of concentrate feed through dairy collection co-operatives to uniformly enhance the milk production. Payments of such purchases of concentrate feed is generally ensured by the milk volumes delivered by farmers to the collection co-operative, although such an operation implies additional management costs for the dairy collection co-operative. In Mauritania, dairy production dependent on semi-intensive and extensive agro-pastoral systems. The concentrates production is highly dependent on imported ingredients, maize, soyabean meal, additives, industrial crops byproducts. Dairy cows concentrate feed prices are generally steady, being mainly impacted by the volatility of their ingredients in global markets. As dairy cattle require bulky fibrous feed, the herds are raised close to the source of feed also when part of their diet is made of concentrates. Concentrates make possible the filling of the gap in water resources. In practice, they have increased the dairy livestock production potential by increasing the availability of water, known a virtual water, that is used abroad to produce the components of the concentrates -.
The negative balance among the needs and availability of forages in Egypt and Morocco is about 80%, a value that the import of concentrates reduces to 57%, the rest being accounted by the loss of potential yield. In Mauritania, where concentrates are not a resource as dairy livestock production is semi-intensive, the deficit of feed accounts for 55% of the needs, also this value representing a substantial loss in milk yield. The instability of the price of the feed available in the market affects the quality and price of the milk and discourages farmers from purchasing high-quality feed. The competition of low-quality feed and the insufficient awareness of farmers on the importance of feed quality to improve milk production are the main challenges to invert this negative trend.

2.3 Natural resources and environmental constraints

2.3.1 Water challenges

North African countries are under the water scarcity limits of 1,000 m^3/capita/year of renewable water resources to cover domestic, agricultural, industrial and other water needs. Water scarcity has repercussions on all the phases of the DLVC in North Africa. This constraint limits the dairy production to the more favorable areas of the region. Droughts have multiplied the use of off-farm practices, as the purchase of feed concentrates, have increased production fees and in some areas have depleted groundwater, putting at risk the survival of the herds themselves. Another consequence of the water scarcity is the decrease of soil fertility. This is particularly true in farming systems where crops production and livestock rearing are not associated. Some of the largest dairy farms rely on entirely purchased feedstuff (even fodder) a situation that has created problems of manure management and loss of fertility of the cropped land.

Governments have made huge efforts to improve the access to this vital resource. Nowadays, the expansion of drip irrigation has developed a lot with the help of public subsidies. This has increased the depletion of groundwater reservoirs. Boreholes' digging technologies (often used in the oil industry) have allowed reaching water at depths at more than 300 meters, but this is now jeopardizing the supply of this resource. Pressure on water resources has gone so far, that unconventional water resources as desalination whose cost (US$/ m^3 7-8) is not affordable for dairy production.

In North Africa, the high value of water makes possible dairy production only in the best endowed and market integrated areas, where the price / cost ratio is more favorable. Otherwise, water scarcity reduces the efficiency of the production inputs and results in dairying only the minimum needed to satisfy the exigencies of the herder's family (diet integrator and in some cases community trade commodity). In Morocco, the recurrent drought has limited dairy production to the irrigated areas. In arid and semi-arid rangelands of Mauritania, water harvesting infrastructures have been built to reduce the concentration of livestock during the dry season in the few well-endowed water points. Also here, the dairy production concentrates around the most populated areas where fodder is available and import of concentrates affordable. The Egypt dependence on Nile water concentrates farming activities along the two sides river and in the delta region that are dissected by a dense network of water ways. About km 50,000 of canals branch from the Nile and convey water to 2 million farmers. Alongside are km 18,000 of drains where, water is partially re-used by farmers pumped back to higher delivery canals bound from coastal lagoons and the Mediterranean sea. Of all sectors in Egypt, agriculture is the largest consumer of water representing about 85% of the total water demand. Because of recent population growth and climate change, the country as a whole is experiencing, severe water scarcity. With the continuously increasing population the share of renewable water resources in Egypt has been decreasing from about 2500 m^3/capita/year in 1950's to about 700 m^3/capita/year in 2015 and is expected to reach 250 m^3/capita/year in 2050. The increasing gap between the available renewable water resources for Egypt and the water needs reflected has been fulfilled by water reuse, use of non-renewable groundwater, desalination and imports of virtual water embedded in a lot of food products such as, wheat, maize, table oils, meat and others. It should be noted that the import of concentrates makes possible the exploitation of the other dairy production inputs whose efficiency is limited by the scarcity of water. It also contains the increase of the nitrate levels in surface water that is often recorded in in mega dairy farms intensively cropping forages and silage maize.

Until now, prevention and mitigation of water shortage has been marginal in intensive dairy livestock rearing based on irrigated forage production. Most of the corrective actions have been

directed to the expansion of the irrigation area to produce more fodder, as a response to water scarcity. As all the available water resources have been mobilized, the building of new large dams is not going to solve the problems linked to water scarcity in the long term. The recourse to alternative dairy systems, based on efficient water uses, entails the mobilization of resources to invest innovation in the production practices and to sensitize consumers on the environmental impact– carbon and water footprint – of their diets.

2.3.2 Feed challenges

The most noticeable evolution of the livestock diet of recent years has been the expansion of the irrigated land sown with maize silage, particularly in large dairy herds as well as by private entrepreneurs who aim to sell it to farmers. In fact, the average yield of this fodder crop has been steadily increasing, reaching nowadays peaks of MT/ha 80. This trend has also increased the pressure on groundwater, given that maize vegetative cycle does not coincide with the rainy season. In addition, fodder systems based entirely on maize silage have ignored its collateral environmental consequences: the exhaustion of soils' fertility, as maize is followed by maize indefinitely, a total dependence on imported protein sources feed (like soybean meals) given that maize contains almost no protein, and the continuity in crops' pests given that the cycle of grasses species is not broken. Recently, there have been spectacular outbreaks of viral diseases on maize crops, meaning that the expected biomass yields were not achieved, and therefore the pressure on off-farm feed resources surged, implying huge losses for breeders.

Some other fodder crops have experienced significant setbacks. They are rarely studied by academics, as both agronomists and livestock scientists consider that it is a group of crops that interests the other one. On the ground, the average yields remain very far from their potential, as water shortages and erratic availability (particularly in totally rain-fed systems) has an important impact. In addition, fertilization and crops' pests are seldom well managed.

Another source of setbacks in feed management in North Africa is the scarce use of balanced diets. Given the large diversity of animals present (as farms, particularly smallholder units, are rarely specialized in dairy), the breeders generally feed the animals a similar diet, without considering their specific needs (for example cows in the beginning of their lactation cycle and cows near to the dry period). On-farm experience shows that it is possible to increase the milk yield through a continuous monitoring of herds' productive status, implying the knowledge of the structural composition of the herd (i.e., the genetic merit of the cows) and the evolution of their physiological status (i.e., dates of calving and drying). However, such interventions require proximity with the breeders' day-to-day practices as well as their available feedstuffs on-farm (whether roughages and concentrates), and this means support efforts not affordable currently.

The organization of concentrate feed mills has reached a high level of professionalism. This sector relies entirely on imported feedstuffs. It is progressively gaining momentum, since many farmers have acknowledged the need to find concentrate feeds with all the requested criteria (i.e., net energy, protein content, minerals, etc.) available all year long at affordable prices, avoiding the long search for ingredients which nutritive value is not always guaranteed.

Management of pastures shows that biomass production is low in North Africa and that the environmental conditions are deteriorating even if some areas record a surplus. The pasture lands continue to shrink. The desertification advance associated with the development of agriculture due to hydro-agricultural developments, creates sources of potential conflicts between farmers and herders and between herders themselves. Likewise, massive sedentarisation accentuates the

pressure on resources because of the search for the satisfaction of domestic needs (food, construction, heating, etc.).
The management of the pastures is a challenge to the compatibility of tradition and innovation in North Africa. Grazing lands are the encounter point not only of livestock production but also of the cultures of different sectors of the society. The droughts, the movements of populations and livestock have led to disorderly exploitation of the rangelands. This traditional pastoral system in an already very fragile (Saharo-Sahelian) ecosystem has been profoundly destabilized (herbaceous biomass made up of annual grasses with a very short vegetative cycle and perennial grasses which are in the process of reduction).
The management of pastoral resources is based on customary rules referring to Sharia or Islamic law. Pastoral lands exploitation is shared with other uses and it is linked to the society components interaction. Traditional herding practices make reference to the mobility of the herds and knowledge of the environment. Pastoral techniques, based on mobility and knowledge of the environment, have allowed for a long time, in normal periods of rainfall, the use of the rangelands without destroying them. However, the extensive exploitation strategies that characterized traditional pastoral systems were mainly aimed at securing animal production. Public achievements in pastoral water supply have been unevenly distributed in space. Often, the improvements carried out did not provide for any accompanying measure at the level of water points created anarchically (measure relating to the rational management of water and surrounding pastures). Despite great achievements over several decades of creation of new wells and boreholes, the accompanying measures are only rarely or not applied. Also, several pastoral areas have few or no water points. This poor distribution of water points further complicates the management of natural resources, particularly during the lean season and / or during intra- or inter-annual rainfall deficits on the national territory.

2.3.3 Climate change impacts

Analyses of climatic trends in North Africa reveal a warming trend in recent decades to the increase of mean temperatures whose extrapolation to 2050 and 2100 is expected to be in the range of +1.4° C and +2.5° C, respectively. Higher temperatures in the arid regions with resulting evaporative losses coupled with increasing water demands will likely result in decreasing water availability. There is also some possibility of significant decline in rivers stream flow under climate change as a result of changes in precipitation in the highlands. The impact on the coastal zone of the Nile delta in Egypt have also serious implications for livestock production. Sea level rise will adversely impact prime agricultural land through inundation and salinization, while the intensive irrigated agriculture upstream would suffer from any reductions in irrigation water availability. Some climate change studies predict a reduction in the productivity of two major crops that will further increase the gap between feed production and demand, competition between food and feed and could be considered as an important indirect impact on milk production as maize is the main energy source in the rations of dairy livestock. The multipronged and long-lasting consequences of climate change impact include the deterioration of animal health, outbreaks of disease or destruction of irrigation systems and other infrastructure. Such impacts can be particularly detrimental in smallholders' dairy production that lack the resources for improving their technology. Inefficient use of resources produces economic losses for farmers that cascade along the DLVC, affecting the overall growth of the sector or national economies at large.
In the other North African countries, more than 80% of the arable land is rain-fed, and even in irrigation systems, crops' yields are still affected by drought, this implies that the effects of climate change are expected to be very worrying. For example, mean temperature in Morocco is expected

to rise by almost 2°C and rainfall to decline by 15% by 2050. As a result, activities with an important water footprint, such as the dairy production, might suffer a lot from decreased water availability.
Heavily reliant on weather, climate and water for its ability to prosper, agriculture is particularly vulnerable to disasters, weather extremes and climate change. In Mauritania, dairy production remains largely rain-fed and uninsured against the large fluctuations caused by weather and climatic variability. Extreme climatic events and climate variability have far-reaching repercussions on agricultural and food production systems. The most direct impact is reduced production, which cascades along the entire value chain, affecting rural livelihoods and placing security and nutrition security at risk.
Pastoralists in arid and semi-arid regions have always been confronted with natural hazards. To resist the impacts of climate variation, they have had to implement climate risk management mechanisms, which may concern the individual or collective level. Among the mechanisms implemented, we can mention:
- Self-insurance. Among pastoralists, self-insurance often takes the form of building up a large herd of small or large livestock, which represents capital that can be cashed in to buy food if necessary.
- The distribution of risks. It consists of mechanisms tending to make the best use of the spatial and temporal diversity of the surrounding environment. Successive exploitation of rangelands located in different agro-climatic zones by herds of nomadic or transhumant herders.
- The promotion of complementarity. It can be sought between agricultural activities in the broad sense (plant and animal production) leading to the association of different speculations within production units. It can also take the form of complementarity between different social groups, as is the case between farmers and breeders in the context of animal housing contracts in the fields at the end of the cropping period.
The adaptation to climate change has led livestock growers to seek practical solutions to the situations encountered. Their responses are often short-term; in the face of a crisis situation which is on its own, and do not necessarily constitute a lasting response to the problem encountered. They include:
Alternative productions. In the livestock sector, sheep tend to be replaced by goats because the latter are less demanding with regard to the quality of fodder, they make better use of aerial pastures and they tolerate heat better.
Change of grazing areas. The shift is taking place towards areas that retain exploitation potential, such as large-scale transhumance to areas further south (for example from Mauritania to Mali) for pastoralists in Sahelian areas.
Producers' fragmentation is one of the most important opportunities for the DLVC resilience to the impact climate change. The numerous smallholder farms bring real resilience to the supply of milk. In fact, whenever one farm disappears because of technical or economic problems, there several hundreds of thousands staying in activity and still ensuring regular deliveries. This might continue for a very long period due to the numerous roles ensured by the dairy activity (steady incomes, valorization of weeds, creating employment opportunities within households, etc.). However, most of the mega dairy farms, which are brokering the import of innovation in milk production, heavily rely on Holstein cows, maize silage, drip irrigation whose water footprint (particularly groundwater depletion) and contribution to environmental pollution (nitrates, pesticides' residues in soil, water and even in milk) are checked by the growing water shortage.
Responses to climate change include adaptation, to reduce the vulnerability of people and ecosystems to climatic changes, and mitigation, to reduce the magnitude of climate change impact in the long term. However, neither adaptation nor mitigation alone can offset all climate change impacts. To respond to this threat, it will be necessary to focus on mitigation, to reduce the level of

emission of gases contributing to global warming, and on adaptation, to support local communities in dealing with the impacts.
The extreme heterogeneity of the DLVC needs to be considered when defining the overall sustainability of a mitigation strategy, which can vary across different livestock systems, species, and climates. No isolated measures encompass the full emission reduction potential, while a combination selected from the full range of existing options will be required to reach the best result. It is also important to consider the *pollution swapping* effect when evaluating the effectiveness of a mitigation strategy. Reduction of methane emissions during enteric fermentation might be counteracted by increased greenhouse gas emissions in applied manure. Reduction of direct nitrous oxide emissions during storage might result in higher nitrate leaching and ammonia volatilization during field application. Mitigation may occur directly by reducing the amount of greenhouse gases emitted, or indirectly through the improvement of production efficiency.

2.3.4 Livestock diseases

The main diseases affecting dairy livestock in North Africa are: Foot and mouth disease (FMD), Rift valley fever (RVF), Lumpy skin disease (LSD), Peste des petits ruminants (PPR) or goat plague and Sheep pox (SP). Death of young animals, reduced productivity through loss of milk and meat has negative socio, economic impact. FMD and LSD are common bovine viral diseases that affect cattle, with severe impact on the animal's production, health, and immune status. FMD is an endemic disease despite the mandatory vaccination routine, and focal outbreaks still occur in many parts of the region, as the 2012–2013 outbreaks at different localities of Egypt. LSD is also an endemic viral disease of cattle in North Africa. Climate change is impacting on livestock health. The Rift valley fever outbreaks follow strong rains after a drought. These diseases impact on public health, livestock health, milk production and the smallholder producers' food security.
High mastitis occurrence implies poor milk hygienic quality and increase processing costs that decreases the profitability of dairy production. As a result, milk yield per cow remains weak, even for the imported Holstein breed, as it often does not exceed 2,500 liters per year, particularly in smallholder farms. Reproduction failures are also frequent, given the scarce nutrients' availability in dry seasons as well as the limited hygiene in many farms. This implies frequent rapid culling of cows, sometimes newly imported as heifers, amplifying losses for growers.
Veterinary services and clinical investigation are embedded in public services usually run by the Ministry of agriculture. With the development of the One Health concept, the collaboration with the Ministry of health is providing extra expertise for livestock diseases surveillance and control (e.g., access to laboratory facilities). The livestock disease surveillance and control consist of large-scale operations concerning generally all the national territory, and realized yearly, mostly funded by public budget. The access to veterinarians remains too expensive for the majority of smallholder farmers. However, veterinarians are available in all the intensive livestock rearing areas, particularly large-scale irrigation schemes, where cattle concentrates. The interventions of veterinarians are highly appreciated with regard of dystocia, milk fever, mastitis treatments, etc. However, given that milk is seldom paid on the basis of hygienic parameters, veterinarians almost do not contribute to the prevention of mastitis as they are seldom requested to treat it.

2.3.5 Extension services

Ministries of agriculture across North Africa promote genetic improvement of farm animals, characterization, conservation and dissemination of genetically improved breeds, improve quality

of animal products and economics of the productive process, maximize the use of agricultural and non-agricultural inputs for animal production under different farming systems, develop and improve the dairy industry, technical advices and training on modern techniques and cooperate with other research institutes to develop animal wealth. The use of mechanic tools (dairy equipment) in animal rearing, high breed, artificial insemination, availability of feed and water in term of quantity and characteristics, veterinary services and mechanic dairy equipment are the most common innovation practices promoted by extension services to smallholder producers.

The traditional distinction between crop farmers and livestock keepers is gradually fading and information on production methods, animal health, and fodder is increasingly requested by livestock producers. In addition to enhancing skills and knowledge among livestock producers themselves, more qualified extension agents are urgently needed to deliver this much-needed advice and training. Currently, there are agricultural extension agents, but there are not extensions for livestock. Integration of livestock and agricultural extension services is the key while, information needs to be delivered at local levels and respond to local needs. Livestock services, and the ministries or departments that are responsible for them, often have a strong focus on animal health. Yet, livestock production extension could be managed in different ways. In addition to national or regional governments, extension services could be managed by NGOs, cooperatives, universities, or national agriculture research institutes as well as by the private sector.

Extension and veterinarian services are often hybrid suppliers of good and services, where the government agencies are leaving the place to supplier-driven advice. Of course, this transition is creating differential approaches that penalize the most remote producers. The access to innovative technologies as improved breeds and artificial insemination is still highly depending on public extension services.

The transfer of technology to smallholder farmers faces logistics, economic and cultural difficulties. Extension services alone are lacking targeted goals and instruments. Private dairy processors, to ensure an increase in milk deliveries, promote on-farm good practices, by their own extension staff (generally inseminators), but they have limited means and they have not always in a position to understand the smallholders' extra-technical constraints. The variable capacities of the producers' associations decree the success of the framework agreements signed with veterinarians and suppliers of equipment, materials and services. They are especially important in mediating the offer of training modules that require a strong customization of the teaching. Thus, the strengthening of the capacities and of the governance of the inter-professional organizations is critical for targeting the need of producers and guiding service providers. Farmers' co-operatives sometimes organize demonstrations o drip irrigation management, fodder crops' technical operations, dairy cows' feeding or milk collection co-operatives' management, with the assistance of public extensionists or trips to other regions to exchange experiences and learn from success stories. For this last aspect, the use of digital tools (i.e., personal computers, data storing, etc.) is spreading as the young assist the elders in managing the flow of data (milk deliveries by farmers to the collection center, purchases of feed by farmers from the collection center, etc.) generated by the interaction with the collection centers.

2.3.6 Research and development

Research programs on dairy production are rare. University curricula programs are based on courses, mainly theoretical, rarely treating the actual constraints of dairy development in an arid to semi-arid country, with a structure of production where most of the actors are smallholder farmers. Research was during many years devoted to just a disciplinary component (i.e., animal genetic, animal feeding, disease control, etc.), but rarely considering the whole system (i.e., farms and

territories) as such. Institutions in charge of research programs have only recently felt the necessity to consider the realities on the field, but it is taking time to change mentalities and to get sufficient budget for research funding. In addition to universities, training is also realized in institutes of agricultural technicians, getting a Bachelor degree at the end of their studies. There are three of these institutes devoted to herds' management. But they have not enough qualified professionals and the newly graduated students may find difficulties to get a job. However, with the launching of mega dairy facilities in the last decades, some of them have been employed successfully in such farms.

The Agricultural research centers in North Africa conduct applied research to develop all husbandry issues related to animal production (feeding and nutrition, genetic improvement, physiology and behavior). In Egypt, increases in milk production in the past have depended on the growth in herd and flock size rather than yield increases. In the last three decades, solutions combining scientific, technological, institutional, and social approaches, and encompassing a wide range of value chain actors such as research organizations, policymakers, feed and forage farmers, veterinarian services, local agro-dealers, and equipment providers, have strengthened the local veterinary drug production and research on indigenous knowledge on disease control improving the milk yield. Technical feeding packages have been elaborated on the basis of the results of research oriented by farmers' demand. These packages were design to address the issues of increasing productivity of fodder crops such as, fodder beets, clover, sorghum, mixing clover with barely, and clover with fodder beets. Others were design to address of improving and upgrading nutritive value of crop residues by mechanical, chemical and biological treatments. Also preserving of green fodders into hay or silage.

National and international research and development programs are usually addressing livestock production as such thus missing the specificities of the DLVC. For example, there are many formal extension programs in Egypt, but mainly for agriculture activity not for dairy livestock. In El-Fayoum governorates, the majority of the farmers (95%) have no extension services while 5% had extension services. On the other hand, 30% of extension services came from government sources, while 70% came from non-government sources like neighbors, friends and family members. Yet access to extension services increased the probability of adopting innovation that improves livestock production. This means that regular visits by an extension worker are necessary to enhance the adoption of interventions because extension services provide information, knowledge and skills which enable smallholders to apply innovation.

2.3.7 Transfer of technology

Several factors affect the productivity of livestock, including nutrition, feed availability, feed quality, diseases and parasites, access to inputs, genetic composition, animal health services, and access to markets, as well as extreme weather events and a changing climate. Livestock value chains represent all stages of value addition in animal-sourced foods-such as milk, meat, production through processing, distribution, and wholesaling/retailing to consumption. At each stage or transaction, the dairy animal or its product gains *value* either as its quality improves or as its delivery to the final consumer is made more efficient. The DLVCs comprise compound networks, relationships, and transactions. They also support a multitude of subsidiary value chains for services, inputs, and outputs. For instance, DLVC interacts with other livestock and agricultural value chains as they create demand for fodder crops and crop residues from farmers. Producers gain or lose monetary value at each stage, depending on their health and appearance and other market information. Dairy products gain value especially as they are transformed to processed products such as yoghurt. At each stage where value is added, actors along the value chain retain a share of

the additional value. Small and medium-scale DLVC producers and other value chain actors can engage by upgrading production processes and producing new upstream or downstream goods and services. Adopting a market-oriented value chain approach ensures that interventions are demand-driven and meet market requirements. This approach encourages greater productivity, improves supply linkages, strengthens relationships among suppliers and attracts investment across the whole the value chain, ultimately leading to increased value of the final product.

Often value chains are integrated within an enterprise to streamline the production and supply of inputs for the subsequent activities. Supporting a growing DLVC also requires investments in the critical phases of the production to pull the demand from subsidiary value chains like the production of feed, animal health and extension services and genetics.

3 Livestock production policies

3.1 Agricultural policies and programs

The management of the resources within the value chain (above all water and feed) has become a priority for the DLVC. This encompasses proximity follow-up of farmers, systematic training, negotiation opportunities involving all the stakeholders (from farmers to collection centers, dairy processors, public authorities, etc.) to discuss all the pending aspects of dairy development and value chain improvement: milk prices, quality monitoring and payment, water uses, etc. To ensure the achievement of such priority goals, new governance methods, truly based on inclusiveness and a bottom-up approach will certainly be mandatory. The needed programming and regulatory framework encompasses the environmental and economic topics analyzed above with those concerning human welfare and international relations. Their regional dimension is growing through consultations but still largely dominated by the internal demography, culture and history of each North African country. Therefore, they are presented independently and later linked in the analysis of the regional integration.

3.1.1 Egypt

Two agricultural policy reform programs were implemented in Egypt between 1987 and 2002. In 2010, the Agricultural Research & Development Council has elaborated the Sustainable Agricultural Development Strategy towards 2030 (SADS 2030). This strategy aims at increasing dairy milk productivity to achieve an annual consumption of kg 63 per capita and to reduce milk imports. its main components are:

- Encouraging the establishment of an institutional entity grouping milk producers and dairy processors.
- Linking farmers, particularly small and medium farmers with collection centers and markets, including development of marketing systems and channels and the provision of marketing information, is essential especially for the perishable products like milk.
- Establishing an integrated system for dairy livestock registration, for identifying the genetically appropriate animals and expanding their breeding.
- Liberalizing artificial insemination services from the monopoly of the Veterinary Services Authority, restricting its role to registration and performance supervision and encouraging the private sector and cooperatives to undertake this responsibility.
- Encouraging the establishment of small breeders associations and providing support to such associations.
- Developing a basic system for collecting, handling and processing milk at the level of small farmers.
- Improving the capabilities of the extension system of the animal sector.
- Establishing incentives for investing in dairy processing and handling.

The Ministry of agriculture and the Ministry of water resources and irrigation have issued new water policies in 2009 promoting improved methods of irrigation to avoid the misuse of water supply and to recycle the water used for certain crops for irrigation in others. The Law n. 53/1966 regulates livestock production, it is completed by the following acts on feed production:

- The Ministerial decrees n. 554/1986 and n. 1498/1996 that regulate the animal feed production and its control.
- The Ministerial decree n. 518/1989 that regulates the Central laboratory for feed and food.

- The Ministerial decree n. 119/1992 that regulates the process of checking and release feed shipment.

The main organizations representing the interests of the DLVC producers and processors are the Egyptian Milk Producers Association and the Dairy Industry Development Association.

3.1.2 Morocco

From the 1970s, with the launching of the 'Dairy Plan' until 2020, with the end of the 'Green Morocco Plan', the dairy sector has always been considered as one of the pillars of the agricultural policy. The aim was to reach self-sufficiency and to add value to the assets of the rural areas: labor, land, cattle, water, etc. By the beginning of 2008, when Morocco adopted a very ambitious agricultural strategy named the *Green Morocco Plan*, the dairy sector benefitted from important incentives: purchase of dairy heifers, milking machinery, etc. In addition, mega dairy farms were setup for the very first time, on state lands rented for 99 years with preferable prices to private investors, a majority of them being involved in the business of dairy processing or having privileged ties with this industry.

Public policies orientate the evolution of the DLVC through MAROC LAIT, an entity funded by the Ministry to promote milk production. Its goal is to ensure self-sufficiency in dairy products, and therefore avoid costly imports. Another aim is to add value to the rural world's asset: labor, land, water and herds. The government encourages the shift from furrow to drip irrigation, but this has mainly promoted water volumes used, accelerating the rhythm of groundwater depletion

The Fond de Développement Agricole subsidises farmers' investments in irrigation (wells and boreholes' digging, drip irrigation equipment, etc.), the purchase of milking devices and milking parlors and other farming and feeding equipment (tractors, feed mixers, straw grinders, etc.), as well as refrigerating devices within milk collection co-operatives, etc. (30% in advance and a maximum of 80% of the investment of 100% for smallholder farmers).

The Moroccan government has instituted the Animal health surveillance and control organization to take charge of herds health as well as the control of animal products' sanitary quality. This entity monitors the health status of dairy herds to ensure that there are no outbreaks of food borne diseases. In the LDVC, this organization controls the sanitary status of herds (particularly through campaigns of foot and mouth disease vaccination and the control of the outbreaks of tuberculosis and brucellosis in the farms) and issues the authorization of the milk collection centers requesting the control of cooling devices, procedures of milk reception, etc. Finally, ONSSA routinely controls processed dairy preparations compliance of national regulations.

In the last decades, research programs on water productivity in cattle have been intensified to cope with the exacerbation of groundwater depletion in the South. The new water policies consider the impact of dairy production on the conservation and use of the water resource.

The measures included in the *Green Morocco Plan* (2008) establish an ambitious target for the DLVC: increasing the national milk output from 1.8 to 4.5 billion tons from 2008 to 2020. This goal was not achieved due to numerous constraints on resources, particularly water scarcity. The 2020 assessment of the achievements of the plan has noted the insufficiencies of its top down approach and has pledged for a more inclusive one that implies farmers, particularly young to promote a more balanced approach to rural development.

3.1.3 Mauritania

The Ministry of agriculture and livestock has drawn up a sector strategy entitled the Letter of livestock policy (2004). Its implementation is underpinned by several projects implemented or in progress in the field of breeding and local development. The implementation of the Rural Sector Development Strategy (SDSR) and Accelerated Growth and Shared Prosperity Strategy (SCAPP) set the framework for the dairy production improvement. The liberalization of pharmacy and veterinary medicine has improved the livestock health status. The Ministry of trade and industry has adopted the Order 40/1988 setting the standards for compound feed for cattle. The private sector has established federative and inter-professional organizations in the field of livestock and dairy production. The government encourages the establishment of socio-professional organizations. Several federative and inter-professional organizations operate in the field of livestock and milk production:

- Fédération des Agriculteurs et Eleveurs de Mauritanie (FAEM)
- Fédération Nationale des Eleveurs de Mauritanie (FNEM)
- Groupement National des Associations Pastorales et Coopérative (GNAPC)
- Association des Producteurs de Lait Traditionnels (APLT)
- Fédération des Eleveurs Indépendants et Transformateurs Laitiers de Mauritanie (FEITLM)
- Fédération Nationale des Acteurs de Lait en Mauritanie (FNALM)

The legal instruments regulating livestock production are:

- Decree 2016-139 Organizing the Genetic Improvement of Domestic Animal Species
- Order 012-2020 MDR establishing a National Committee for Genetic Improvement of Domestic Animal Species (CNAGEAD)
- Law 024-2013 on the Law of Agropastoral Orientation
- Law 024-2004 on the Livestock Code
- Law 2000-045 of 26 July 2000 establishing an environmental framework
- Law 2000-044 of 26 July 2000 on the Pastoral Code
- Decree No 040 of 12 March 1988 laying down standards for compound feeding stuffs for livestock and poultry

The National Livestock Development Plan 2018-2025 has fixed the following dairy production objectives:

- Installation of modern specialized milk farms.
- Installation of collection centers and processing unit of transformation.
- Construction and equipment of local village mini-dairies.
- Strengthening refrigerated transportation infrastructure for dairy production.

3.2 Natural resources management

3.2.1 Egypt

In Egypt, rainfall is minimal at 18 mm per year, occurring mainly during autumn and winter. The vast majority of the territory is desert. Agriculture and population are confined to the narrow Nile River Valley and Delta, about 4% of the land area. Under current water management and agricultural practices, up to 60% of agricultural lands can be irrigated but significant amounts are being lost through degradation (salinization and desertification) and urbanization. About 35% of the agricultural lands may suffer from salinity. The rising groundwater levels, unsound drainage practices, and encroaching sand dunes in the North delta is reducing agricultural land. The government is countering this trend with massive and expensive efforts to reclaim land from the desert.

The country depends for 97% of its water supply on the Nile. Water drainage returns water to the Nile for downstream use, increasing irrigation efficiency rating. Water quality in the Nile deteriorates along the course of the river due to organic loads discharged from some of the drains and industrial activities. Groundwater is contaminated from nitrogen and fertilizers and the impact of pesticide and herbicide use, the latter being used to control weeds in canals. Shallow aquifers, in particular in the Nile Delta, are often heavily contaminated. The total area equipped for irrigation was 3.4 million hectares in 2002, 85% of this area is in the Nile Valley and Delta. Climate change is likely to affect water availability to Egypt, although the direction of change is uncertain. Water savings in agriculture are an important objective of Egypt's water strategy. Investment includes the creation of water and drainage users' associations and the performance of irrigation projects. The Nile Basin Initiative provides a forum for regional cooperation on the river water resource management. The government has launched mega-projects promoting investment in irrigation on new lands outside the Nile River Valley in the 1990' (Toshka area of New Valley), on the fringe of the Western Nile Delta, and in the Northern Sinai). These projects require large amounts of irrigation water sourced through irrigation efficiency on already irrigated old lands and the reuse of drainage water and treated wastewater.
Land access is a significant issue, particularly in Upper Egypt. Agricultural land per capita is low, and rural landlessness is high. The government plays a critical role in managing the Nile-based water supply for agricultural and non- agricultural uses by regulating the conversion of agricultural land to urban uses; developing new lands in upper Egypt and the Sinai to reduce pressures on both urban and agricultural resources. Water distribution and management systems have been decentralized; much water could be conserved through improved irrigation management and a focus on water efficiency in crop selection and agricultural production techniques. Many external investors and donors support Egypt's efforts to make optimal use of its land and water resources. Water use efficiency is slow by regional standards. The centralized system of water irrigation and use is becoming more decentralized, primarily through Water users' associations.

The *Integrated Water Resources Management Plan (2005)* promotes institutional strengthening, policies and legislation, physical interventions, capacity building, technological and information systems, water quality, economic and financial framework, research, raising awareness, monitoring and evaluation and transboundary cooperation. The United States, European countries and the World Bank provided major investment financing irrigation and drainage investments as well the water users' associations. The Gulf countries finance mega-projects to develop new lands for irrigation. USAID provided substantial support to improve irrigation infrastructure and to support water user associations. A Joint Integrated Sector Approach based on the National Water Resources Plan to better coordinate the efforts from various donors, particularly in irrigation, has been put in place. The government is offering desert land to recent university graduates in the form of a long-term lease whose cost corresponds to providing irrigation.
Development agencies have invested in providing credit to small farmers, improving irrigation systems and water-use efficiency, and increasing productivity and farmer incomes.
The West Delta Water Conservation and Irrigation Rehabilitation Project funded by World bank improves the livelihood and increases the income of population through the mitigating further environmental degradation caused by drawdown of the groundwater resources and establishing a framework for financial sustainability of irrigation infrastructure in the use of water resources. Other Work bank projects support water users' associations.

3.2.2 Morocco

Most of Morocco has an arid and semiarid climate and is fighting desertification and a trend of reduced rainfall attributed to climate change. Morocco's rainfall in the desert and dry zones is less than mm 250 per year and in the semiarid zone mm 250-500 a value surpassed in the mountain ranges and some coastal areas. The 93% of the country land is arid or semiarid. Pastureland have been reduced by settlement and cultivation, extending now over approximately 50 million hectares. The 2% of total land is permanent cropland. Eighty percent of farm households keep some livestock; only about 18% depend solely on animal husbandry for their livelihoods. Water availability per capita is less than m^3 1000 per year. The river water is used primarily for irrigation. Drainage and urban development are shrinking agricultural land that is also subject to pollution from fertilizers and urban sewage.

Most cultivation is on rainfed land, and productivity suffers from lack of inputs. Livestock allow households to diversify, but rangeland is increasingly pressured by expanding cultivation and degraded by overuse. In years of good rainfall, Morocco's agricultural productivity is high, and farmers are able to feed the country, but when rainfall is scarce, the country relies on food imports. A significant aspect of transforming agriculture is developing more effective policies and programs to make better use of the country's land, water, forests and the rural labor force.

The harsh climatic conditions, including erratic rainfall and recurrent drought; soil degradation due to erosion and salinization; degradation of forests and rangeland resulting from overgrazing, cultivation of marginal lands, and harvesting of wood for fuel; inadequate water resources and infrastructure; and inadequate herd management. Key challenges in the management of natural resource include the lack of comprehensive policies governing land, water and the other natural resources and the limited water available. Specifically, the water-sector challenges include the need to manage scarce water resources, weaknesses of the legal framework, inefficient agricultural water use. The government is strengthening Water users' associations.

The government is performing large programs to address these issues, including improving agricultural productivity through expansion of irrigated land and development of water-delivery infrastructure. The Plan Maroc Vert boosts agriculture by funding innovation and supporting investments. Government is investing in the watershed management, to conserve rangeland ecosystems, which reduce flooding and runoff and support groundwater renewal due to inappropriately located cultivation and overgrazing. It supports natural resources conservation also by establishing national parks and protected areas.

The Moroccan High Commission for Water, Forests and Combating Desertification Plan, which includes a variety of strategies to combat desertification, including afforestation and reforestation campaigns, the establishment of protected areas, and the conservation of forest resources.

Development agencies are funding projects improving rangeland management including the infrastructure to support improved management of rangeland. These initiatives include credit for improving irrigation infrastructure, water management governance and the strengthening of traditional land management practices. Water projects tackle watershed management through agroforestry and soil-erosion control and the reclamation of semiarid land for irrigation and in the East to increase grazing land for pastoral people.

The government is revising the institutional and legal framework and developing strategies for coordination among relevant ministries on topics such as financing the sustainable use of resources and the development of ecotourism, environmental education and participative resource management. World bank/ GEF project seeks to reverse the effects of overgrazing and degradation of forest and rangeland through the development of co-management systems in the Middle Atlas. The European Union is supporting the government Moroccan High Commission for Water, Forests

and Combating Desertification plan in reversing land degradation due to excessive exploitation of natural resources.

3.2.3 Mauritania

Mauritania is divided into two climatic zones: the Saharan-Sahel region to the North and the Sahel region to the South. Limited rainfall and recurrent drought and desertification limit the arable land to less than 1% of the total land, mostly situated near the Senegal river flood plain. Nearly 70% of freshwater withdrawals in are dedicated to agriculture. Water access and supply, water harvesting, water use efficiency and productivity are limited. Climate changes include a shift in seasonal patterns and a reduction in wet periods and rainfall.

The average annual rainfall shifts between 100 mm in the North and 600 mm in the South. The Sahara desert is moving southwards absorbing some of the country more productive landscapes, due to over-exploitation of grazing lands. Increase in floods, later rains, shorter rainy seasons and periods of prolonged drought are affecting the patterns of livestock production, concentrating the herds and thus further depleting the available natural resources. The pasture available for nomadic livestock producers is being reduced. Their spatial and temporal movements is being reduced and livestock production is becoming sedentary. A shift from from camels and sheep to less-mobile livestock such as cattle that have higher water and fodder demands is taking place. Groundwater availability is also declining. Longer periods of fodder shortage are causing malnutrition. Rising temperatures and reduction in rainfall affects the nutritional value of the feed and the health of livestock, reducing herd fitness and vitality.

Traditional pastoralist systems in the Sahel are under threat due to climate change, instability, and large-scale development projects. Transboundary animal diseases, shared rangelands and water resources, cross-border trade, market information, and pastoral risks (which include droughts and conflicts) cut across national borders and have regional dimensions.

The COVID-19 pandemic has also had an impact on pastoralism. Border closures have disrupted the return of transhumant animals to their territories of origin and presented risks to animal health, given the high concentration of livestock at border crossings. The risk of conflicts has also increased between farmers ready to plant and herders unable to move. Restrictions on mobility have led to sharp increases in livestock prices in the cities, and pastoralists' livelihoods have been undermined by markets closures.

The Management of Natural Resources in Eastern Mauritania project and two Associations of milk and meat producers (APLVT and APLVB) have set up micro-credit systems through livestock food shops. Germany has funded the Natural Resources Management Programed promoting decentralization in natural resources management supporting the establishment of Associations of Local Collective Management that are in charge of pastoral woodlands, wetlands and their surroundings.

The World bank funds the Regional Support Project for Pastoralism in the Sahel (PRAPS, 2015-2021) that improves the access to essential means and production services and to markets for pastoralists and agro-pastoralists in six Sahelian countries including Mauritania and their capacities to respond to pastoral crises. In Mauritania, this project has improved the performance of veterinary services (epidemiological monitoring and vaccination campaigns). The PRAPS has also contributed to improving the management of natural resources through the establishment of hydraulic infrastructures for pastoral and agro-pastoral populations and the prevention of conflicts, and the access to markets through the creation infrastructures (mini-dairies, cattle markets, rest and slaughter areas). These activities are aimed at promoting and securing the national and cross-border mobility of transhumant herders and to open / develop in a sustainable way pastures under-

exploited for lack of points. of water. These infrastructures reduce the average distance between functional water points accessible to transhumant (agro)-pastoralists in targeted areas and reduce the animal load in the more concurred grazing lands.
World bank / GEF project strengthens the resilience of vulnerable rural populations by improving agriculture and livestock sector planning and the application of innovative practices at the catchment level. It supports agriculture and livestock producers in managing shared natural resources by developing consultation modalities and their participation to land planning. This initiative promotes technical assistance in establishing community-based land governance and provides credit to access to innovation.
The International Fund for Agricultural Development (IFAD), the European Union (EU), the Government of Mauritania and private partners have funded the Inclusive Sectors Development Project (2016-2024) that improves the income and food and nutritional security of poor rural populations relaying on goat milk production and other sources of revenue.
Three European Union has funded the following food and nutritional security and sustainable agriculture projects supporting the population of the agro-pastoral zone:
- the Institutional Strengthening Project in Mauritania towards Agricultural and Pastoral Resilience (RIMRAP, 2016-2020) that strengthens the resilience of populations vulnerable to food and nutrition insecurity through the enhancement of the governance in equitable access and sustainable management of resources in the context of climate change;
- the Institutional Strengthening Project in Mauritania for the Development of Rural Infrastructure (RIMDIR, 2018-2023) that promotes small and medium rural and energy infrastructure;
- the Institutional Strengthening Project in Mauritania for the Development of Sectors (RIMFIL, 2018-2023) that invests in agricultural and pastoral sectors.
Mauritania has experienced an innovative cooperative approach to dairy production and marketing, thanks to TIVISKI dairy industry. This company links the pastoralists and agro-pastoralists to urban consumers by purchasing, processing and supplying fresh milk to food shops. The factory started in 1989 by processing exclusively fresh milk produced by dromedaries at the start, then by cows milk and recently by goats. An Association of TIVISKI dairy producers was established in partnership with the company that directly purchases milk from the nomadic herders. The company provides several services to the suppliers: veterinary care, vaccinations, feed (the amount of which is recovered from the price of milk), technical assistance and training. The producers are in charge of the transport to the collection centres. The company produce livestock feed and supplements that sells to the producers as advances on the sale of milk and supports women through advances for the purchase of goats.

3.2.4 Regional initiatives

The African Union Livestock Development Strategy for Africa (LiDeSA) provides a framework for the mainstreaming of livestock into national and regional agricultural investment plans through coordinated action and synergies of the African countries. It identifies climate change negative impact on grassland and rangeland productivity as a limitation to dairy production and advocates for sector specific initiatives, as the creation of a dairy development fund and emergency disease control fund to tackle this emergency.
The Nouakchott declaration of October 2013 has identified the main pillars and fields of action for the sustainable development of pastoralism in the Sahel. Among these pillars, significant investments in pastoral water supply are still considered today as an important lever for the development of pastoral breeding.

A network of North African (Mauritania, Morocco, Algeria and Tunisia) federations of cattle breeders' associations has been created and become effective in 2017. This network exchanges experiences and promotes synergies in solving shared constraints as water stress, fragmented offer, quality controls, etc. Notwithstanding its official recognition, this network is almost at a standstill because of insufficient funds. The member countries have locked their national space thus stopping meetings and exchanges between its members in response to the COVID-19 pandemic.

North Africa has vast areas of steppe and desert favorable to pastoralism, including high-altitude mountains, coastal Mediterranean and the Sahara desert. The increasing imbalance between water demand and limited supply is the main challenge to the conservation of natural resources in North Africa. Pastoral communities and rural households keep livestock. Traditional rotational rangeland management practices regulate the access to grazing lands. Intensification of agricultural production and the privatization of common lands is reducing pastoral mobility and customary organizations. Rangelands are fast degrading due to growth of population in the more fertile areas along with urbanization and the effects of climate change have become visible with rainfall becoming more erratic and extreme weather events such as severe droughts and floods becoming more common. Northern Africa has begun to increase forest cover over the last decade, primarily through tree-planting projects, with Egypt having the highest average increase of afforestation.

Regional consultations have been performed at through the Arab Land Conference and FAO-CIHEAM meeting on Mediterranean Pastoralism. The Arab Pastoral Network has been established to advocate for the recognition of traditional pasture management. The Germany funded Regional cooperation in the water sector in the Maghreb project since 2016 has developed regional cooperation between stakeholders in the water sector in Algeria, Morocco and Tunisia, exchanging information on the management of common water resources and identifying successful approaches and projects.

The Billital Maroobè Network (RBM) is a regional network breeders and pastoralists of nine Sahelian countries, including Mauritania that advocates for their interests at the economic, political, social and cultural level. It has started an Information watch in the member countries in 2013 to observe the pastoral dynamics and the methods of circulation of information in the cross-border area; exchanging information on the situation of pastoralists; and provide inputs to develop operational cross-border strategies for the access to pastoral resources. The Information watch monitors the pastoral situation and the threats to pastoral families, also alerting the authorities to alleviate crises and strengthen pastoral systems. This network has also been monitoring the economic impacts of COVID-19 pandemic on pastoral populations.

4. The way forwards: best practices for dairy livestock production systems

Water scarcity is at the root of the slow growth of dairy livestock productivity in North Africa. An integrated approach is needed to reduce the impact of drought and to improve water productivity, involving a broad set of measures and not only the management of water. Reducing the amount of irrigated feed and animal water consumption are the two main strategies to reduce livestock impact on water scarcity in drylands. Other measures include disease control and animal health, livestock feeding management, mobility and stratification of production to reduce grazing pressure on drylands. Research and experience combined provide insights on best practices and opportunities to combine the yield increase with its sustainability.

Priority areas for intervention include:

Basin based irrigation water management. Strengthen water basin management by involving representatives of the different categories of users in their management. Establish public private boards to run such bodies.

Improving feed production efficiency. Develop, test and divulgate formulas of feed diets on the basis of the research results (grass and legumes associations, selection of adapted varieties, promotion of forage seed production), by rotating crops, selecting water saver forages, using additives to improve their nutritional value. Establish farm field events to compare the fitness of different formulas.

Improving crop residues management. The recycling of farm products is a core feature of most agricultural systems. The use of livestock manure, liquid excretes and by product is not always efficiently exploited by the farmers. Practices for improving their contribution to soil fertility should be analyzed in relation to the multiple uses of by products, as biogas generation associated to the production of fertilizers. Scale economies are needed to produce economically sustainable results. Thus, the livestock growers' associations should be sensitized to broker innovation in this field.

Breeding dairy livestock for yield and adaptation. Carry out genetic improvement by crossing high dairy breeds with the local genetic pools through the establishment of reproduction pools to serve remote areas and artificial insemination in the more favoured ones in the frame of selection for dairy productivity and environmental fitness at once.

Improving dairy livestock diet. Develop a dairy livestock feeding strategies based on the rational use of feed and pastures by considering the evolution of the quantity and quality of biomass of cropped forages and pastures and the need for concentrates. In this context, fodder cropping, preparation and storage of hay and silage have to be associated in the mixed dairy farms. Cropping systems conserving soil fertility by rotation of crops are critical for sustainable dairy production in arid and semi-arid lands.

Training and information of milk producers. Reinforce the capacities of the associations of producers by training on administrative and financial management, access to and negotiation of professional services and good purchase, and of their members in technical fields ranging from dairy herds health, feeding, reproduction and processing and storage of milk and its products.

Promoting co-operative milk collection schemes. Promote partnerships between dairy factories, dairy producers and extension services to create scale economies in the aggregation of the milk offer, associate livestock growers in accessing to technology and supplying the product to milk collection centre. These initiatives can appeal to development agencies and investors due to their hybrid nature aiming at social and business development goals.

Organization of consultation meetings of the stakeholders of the dairy livestock value chain. Organize national and regional conferences of stakeholders of the LDVC to develop mutual understanding and identify common challenges and solutions. These events should include sector sessions and produce policy papers, roadmaps and strategies to feed advocacy actions supporting the identified priorities.

Strengthening the governance of the dairy livestock value chain. Enhance the DLVC governance to ensure inclusiveness and a bottom-up representation of the farmers' expectations. This should start with the strengthening of the producers' organizations, the establishment of inter-professional associations and be supported by the systemic follow-up of farmers, training and assistance in negotiation with other DLVC actors on dairy development and value chain improvement: milk prices, quality monitoring and payment, water uses, etc. in pastoral areas, the producers' associations have to strengthen their capacities of monitoring the water and pastures and oversee the use of production infrastructure.

Improving soil fertility. Develop integrated packages of farming and livestock production practices that address the reduction of soil fertility due to salinization, pollution, soil degradation and erosion. The integration of soil fertility conservation in the livestock and agricultural production systems is linked to the performance of the priority areas as their success is dependent on the natural and human environment.

Integrating imported concentrates inputs in forage and straw based diets. The dependence on imported input poses a structural hurdle to the DLVC. High genetic value cattle, feed concentrates, machinery (milking devices, refrigerators, etc.) and other vital inputs used in the dairy business are imported. This creates a situation of vulnerability, given the supply bottlenecks and price variability due to the increased global demand of key inputs (like heifers for instance).

Enhancing knowledge management systems. Carry out studies on the pastoral ecosystem (plant biomass, pastoral hydraulics), the inventory of the herd (actual numbers and dynamic parameters of herds), traditional knowledge and livestock rearing practices. Often, strategies and programs are identified, carried out, evaluated without really knowing the basic data of dairy production as they are based on estimates.

Ecological surveillance of pasturelands. Oversee and monitor the environment to plan the access to natural resources in collaboration with communities and pastoralists. This function should be associated to interventions that limits the natural hazards as the establishment of firewall barriers, establishment of natural forage reserve areas, rationalization of water points, etc.

Stabilizing the agro-sylvo-pastoral systems. Consider the complementarity between the different production systems in the management of the rangelands. The agricultural areas as river valleys should ultimately be used to sustain the intensive milk production system. They also produce large

quantities of fodder and agricultural or agro-industrial by-products to ensure complementary food for the herds of breeders who are in extensive breeding.

Sustainable management of drylands natural resources. Improve the management and use of resources within the DLVC starting with the soil, water and feed. Participatory approaches to the sustainable conservation and use of natural resources have to be devised to commit stakeholders to their surveillance. This approach requires studies and strengthening of community based organizations to improve their buy in of technology and networking to deal with regional challenges. These associations should contribute to the monitoring the evolution of pastoral resources and on the development of firewalls and water and soil conservation works in sylvo-pastoral areas. Forage reserves should be established – endowed with water sources - for drought years with the participation of the communities in their surveillance.

The interventions for improving the DLVC are prioritized on the basis of their relevance for the DLVC development for the whole North Africa region, irrigated or rainfed areas, respectively.

Table 12. Region-wide priorities for dairy production

Priority	*Practice*	*Explanation*
1	*Organization of consultation meetings of the dairy production value chain*	The top-down approaches have shown great limits in agriculture. Involving the producers, and above all the numerous smallholders in development policies is vital to increase milk output.
2	*Strengthening the governance of the dairy production value chain*	More negotiation spaces are required to discuss critical topics, such as value distribution (prices along the chain), milk characteristics monitoring and grading for payment, management of milk surplus in the rainy seasons, etc.
3	*Improving feed production efficiency*	Many setbacks hamper feed production of fodder crops. The adoption of good management procedures includes the economy of water in irrigation and rainfed fields, fertilization and sanitary and phytosanitary practices, as well as adaptation to the environment (harvest time, conservation means, etc.).
4	*Training and information of milk producers*	The average milk yield per cow, even for high genetic imported Holstein, is still far from its genetic potential. Training has to encompass all the aspects of modern dairy production, from fodder cultivation, to hygiene, reproduction management and balanced diets formulation.
5	*Breeding dairy livestock for yield and adaptation*	Imports of heifers and artificial insemination straws challenges the adaptation of cows to the environment. The breeding programs have to include local breeds and crossbred cows (local breeds x imported Holstein).
6	*Promoting co-operative milk collection schemes*	Milk collection centers source and grade raw milk. Their hygiene and management have to be upgraded to international standards through interventions encompassing producers in the collaboration schemes adoption of good management practices.
7	*Enhancing knowledge*	Knowledge management covers all the DLVC elements. The development of knowledge management capacities to ensure the

	management systems	generation, access to and dissemination of information is conductive to rationalize and enhance the DLVC.
8	*Improving dairy livestock diet*	Regular monitoring of farms, especially the smallholder units is needed to ensure the adoption of adequate (enough dry matter) and balanced diets (no energy or protein wastes) in line with the cows genetic potential and physiological conditions.

13. Additional priorities specific of irrigated dairy production areas

Priority	*Practice*	*Explanation*
1	*Basin based irrigation water management*	The direct link between water and milk production requires the improvement of the water productivity, as its efficiency is low due to losses, especially where distribution canals are made of sandy soil.
2	*Improving crop residues management*	Enhance crop residues management as a feed resource for the dairy cows, especially cereal crops straws, may be upgraded through proper urea treatment and sound complementation. Comparative on-farm trials have to be done to ensure the fitness of these techniques to the environment.
3	*Improving soil fertility*	Recent agricultural policies sideline the loss of soil fertility. Its rehabilitation and conservation is needed for the sustainable agricultural production in which livestock and crops are associated.
4	*Integrating imported concentrates inputs in forage and straw based diets*	Comparative on-farm trials have to present the optimal mix of forage, straws and concentrates in each agro-ecological area. These trials have to explain the milk production and economic rentability effects of different combinations of feeds.

Table 14. Priorities specific of rainfed dairy production areas

Priority	*Practice*	*Explanation*
1	*Ecological surveillance of pasturelands*	This practice has to be associated to the following ones
2	*Sustainable management of drylands natural resources*	This is an important element in drylands where dairy production is semi-intensive and extensive. Public private partnerships can be established with communities to run water-endowed forage reserves for drought years.
3	*Stabilising the agro-sylvo-pastoral systems*	The participation of livestock producers in the comparative testing and adaptation of dairy livestock rearing practices creates mutually reinforcing effects among different production systems.

5. North Africa natural resources management for DLVC support action

1. General objective

To support productivity, resilience and sustainability of Dairy livestock vale chain (DLVC) in North Africa

2. Specific objective

To strengthen the knowledge management and exchange of information on natural resources management between researchers, service providers and dairy livestock producers in North Africa.

3. Context

The limited availability of water and feed, fragmentation of dairy herds and dependence on external technology challenge the sustainability of the growth of milk production and to keep the pace with the consumption growth in North Africa. The consequent overexploitation of natural resources reduces the options available for the expansion and intensification of dairy livestock rearing practices, augmenting the dependence on the import of concentrates and opposing the interests of livestock growers to those of other sectors of the population. Research and the dissemination of innovation by service providers (extension services, professionals, traders, etc.) have produced some notable success story in the intensification of dairy production as well as in the joint management of natural resources although it has not impacted at the national and regional level. The adoption of new technologies, the organization and collaboration of milk producers with collection centres and factories, the integration of imported concentrates in the livestock diet, as well the national policies assisting medium- and small-holders face many hurdles in reorientating the livestock rearing systems to mainstream resilience and sustainability in productivity gains.

The national support programmes, sector collaborations and business agreements are achieving short term results, also when they improve water economy, intensify livestock feeding and raise milk production have little impact on the income of many medium- and most small-holders that are negatively affected by the degradation of the natural resources their livelihoods are based on. Research and import of innovation are seldom adapted to the dairy producers' exigencies and hence when they solve some specific problem often end in creating diseconomies and further degradation of the environment. The small and micro dairy producers face substantial difficulties to access to innovation and the market due to their weak capacities to represent their needs and to aggregate their offer. Their contribution to the governance of the value chain is also minimal, making difficult to negotiate the removal of the macro-economic barriers to the direct interaction among producers and processors. They miss the benefits of the growth of the urban market of dairy product also in

presence of favourable decisions and support by the public sector (polices, research, development and education, extension and animal health surveillance) as they lack the organization skills needed to transform dairy production from subsistence to business. Some initiatives empowering women and strengthening the relations between their aggregation and partnership with dairy collectors have shown the viability of the improvement of practices and increase of the share of the final price.

The exchange of knowledge on natural resources management between research, service providers and dairy livestock. Access to innovation and the aggregation of the North Africa dairy livestock growers has to be enhanced to facilitate their access to innovation, the transition from subsistence to market oriented production and the access to best practices to reverse the progressive depletion of water and feed sources. Initiatives in this field have been limited in dairy production notwithstanding the growing trend experienced by this sector in the last decades. Success stories have been mostly confined to the mega dairy farms and some collaborations of dairy producers' associations with collectors often with the support of investors and development programmes. Innovation in large scale production is confined there and often negatively impacting the access to natural resources by smallholder mixed farmers and agro-pastoralists. A balanced approach is also needed the aggregation and representation of the smallholders and their participation to the governance of the physical and biological resources of the water basins and grazing lands. New knowledge management modalities have been tested at the national and sub-regional level but not focused on the opportunities and peculiarities of dairy production. Their positive results have remained confined to the direct participants without upscaling or triggering multiplicatory effects, due to the lack of a unifying vision and approach to deal with the peculiarities of each context and capacities of the medium- and small-holder producers of milk.

4. Strategy

This initiative is going to strengthen the innovation value chain for dairy production in the field of the sustainability of the conservation and use of natural resources to ensure:

- the inclusion of the producers' needs and expectation in framing research programmes,

- the transfer, adaptation and adoption of technology by medium and smallholder dairy producers,

- the exchange of experience and collaboration at the national and North Africa level.

This intervention is framed around the opportunities that well-structured and integrated knowledge management systems offer for the conservation and sustainable use of natural resources to support the expansion and intensification of dairy production. In fact, a dairy production specific approach to knowledge management can contribute to solve the following gaps in national and regional programmes:

- exploiting the economic opportunities offered by the growing consumption of milk and its fermented product due to the growing population and way of life.

- building on the capacities of the dairy producers whose practices are knowledge intensive,

- targeting a specific sector of the agricultural production characterized by a strong market orientation and dependence on the access to external inputs,

- exploiting the potential of the DLVC as a modality of collaboration, exchange of experience, transfer of technology,

- ensuring inclusion of women and vulnerable groups to the governance of the SLVC,

- supporting the transition from subsistence to marker oriented milk production and improving the share of milk price obtained by smallholder livestock growers.

The improvement of the knowledge management modalities in dairy production is expected to exploit and share success stories and best practices across North Africa and strengthen the aggregation of medium- and small-holder producers. This achievement is going to enhance regional collaborations in the frame of a well-defined value chain that has a strong potential of expansion and improvement of the share of the added value for the mixed farmers and agro-pastoralists whose fragmentation has until now limited such progresses.

This project exploits the results of the studies and ongoing projects of AU-IBAR to boost the livestock production in North Africa in the frame of the Livestock Development Strategy for Africa (LiDeSA) 2015-2035. Its knowledge based approach is cross-cutting the four LiDeSA strategic objectives[1] and creates the conditions for interventions improving specific components of the DLVC (water management, feed production and diet management, breeding for resilience, landscape management, extension and veterinary services delivery, producers' organization, etc.).

The performance of this action is expected to make knowledge management in the strategic feature of the programmes and initiatives in the field of dairy production, by focusing on its peculiarities and potentialities, distinctively from the livestock production as a whole. It strengthens their relations across North Africa by focusing on the natural resources management for DLVC. Its results are expected to provide inputs for the integration of these topics in national policies and development programmes and to ensure their concrete alignment to resilience and sustainability criteria as well as for the undertaking of initiatives by the private sector that contribute to the strengthening of the collaborations among the actors of the DLVC in this field.

The execution of the project is made of the following activities:

1. Establishment of the project coordination by AU-IBAR in collaboration with the agricultural authorities of the North Africa countries that acts as coordinator of programmes and initiatives supported by this action.

This phase consists in consultations of AU-IBAR Project coordinator with the national authorities, to define the coordination modality and develop the planning and coordination of the project implementation. AU-IBAR contacts the Ministries of agriculture of the North Africa countries that

[1] 1. To attract public and private investments along the different livestock values chains
2. To enhance animal health and increase the production, productivity and resilience of livestock production systems
3. To enhance innovation, generation and utilization of technologies, capacities and entrepreneurship skills of livestock value chain actors
4. To enhance access to markets, services and value addition

identify their focal point in charge of coordinating the national contribution to the project. The Project coordinator along with the focal points designed by the national authorities constitute the Project coordination committee that advises the AU-IBAR project coordinator in steering this action. This activity is expected to produce the project work plan along with its monitoring and communication strategy.

2. Identification of regional and national programmes, initiatives and actors active in the field of natural resources management and of dairy production.

The AU-IBAR and national coordinators revise the documentation, identify and consult representatives of the DLVC to identify organisations, initiatives and actors and map the national and regional priorities and modalities of generation and dissemination of innovation and information on the management of the natural resources for dairy production. This activity is expected to produce the Map of programmes, initiatives and actors.

3. Elaboration of the road map for regional collaboration in managing knowledge and sharing information and experiences in natural resources management for dairy production with emphasis on water and feed.

The regional collaboration is axed on the creation of a consultation network of key public and private actors representing the interests of dairy production stakeholders in relation to research, access to information, creation of capacities. This activity connects the national and regional level of the consultation of and exchange of experience among the stakeholders of the management of knowledge on natural resources the DLVC. This activity produces the road map to the establishment of this consultation network that is expected to become effective by the end of the project and ensure its exit strategy. In practice, it creates the operational modality for enhancing the regional collaborations on the management (creation, dissemination, use) of the knowledge on natural resources for DLVC.

4. Organisation of national and regional consultation meetings of the dairy production value chain to discuss the opportunities and challenges of the DLVC.

The project in collaboration with the national authorities organises one national consultation (discussion meeting of conference) in each country and one regional one to identify and discuss success stories and best practices in knowledge management, participatory research and transfer of innovation to medium- and smallholder dairy producers. This activity produces the (6) national and the regional Strategy papers on the opportunities and challenges of natural resources conservation and sustainable use for the DLVC. The proposed consultation meetings should be associated to communication actions to boost the dissemination of their results. In practice, it collects and systematises the options and best practices and formulates the priorities for improving natural resources management at the national and regional level.

5. Selection of and support to regional and national programmes and initiatives adopting the identified best practices in knowledge management, participatory research and transfer of innovation on natural resource management to medium- and smallholder dairy producers.

This activity is aimed at strengthening the knowledge management on natural resources for DLVC by funding 2-4 Pilot actions that combine the project technical assistance with the execution of grants by national and / or regional actors. It includes the following steps:

- establishment of the selection committees, that could be made of the members of the project coordination committee or be nominated by it,

- definition of the criteria for the delivery of the support, as regional consortia or initiatives, etc. that ensure the enhancement, dissemination and replication of knowledge management best practices across the region,

- launching of the Call for proposal or of an equivalent mechanism for awarding the grants funding the Pilot actions,

- awareness raising, capacity building events to increase the understanding of the topics at stake and innovative modalities to manage knowledge to improve dairy production,

- selection of the initiatives to be supported,

- awarding of the grants / delivery of the assistance services,

- mobilization of AU-IBAR and external technical expertise to backstop and follow up the selected initiatives,

- monitoring and systematization of the lessons learnt of the pilot actions to provide inputs for networking, communication and advocacy of the project initiatives and to produce multiplicatory effects.

The project strengthens ongoing and new actions the strengthen the management of knowledge on natural resources for the DLVC. This activity takes in consideration the output of the previous ones to define and implement actions (by supporting ongoing initiatives and funding new ones) that strengthen the modalities of management of information on natural resources conservation and sustainable use for DLVC. Each action should include at least 3 North Africa country and can concern water, forage, biodiversity, in relation to one or more aspects of the DLVC (breeding, production, education, extension, information management, etc.).

The performance of this activity includes the definition of the support / intervention modalities (grants, technical assistance, coordination, etc.) and the execution of 2-4 pilot actions contributing to improve the communication between researchers, services providers and dairy producers in the creation and exchange of information conductive to the conservation and sustainable use of natural resources for DLVC (water, soil, biodiversity, landscape management, etc.). For instance, these actions can support ongoing initiatives or develop new ones of a regional reach, e.g. by networking national actors across the region, promoting the exchange of experiences, strengthening the communities of interests (e.g., producers organisations) in relation to their participation to the innovation value chain (interaction with researchers, services providers).

6. Networking, communication and advocacy of the programmes, initiatives and actors participating to this action.

The establishment of Regional / national consultation mechanism - linked to the DLVC governance mechanisms - that facilitates the dialogue of researchers, service providers and dairy producers on the management of natural resources for dairy production. The networking and communication among key actors in the North Africa region is intended to be the immediate consequence of the project execution.

This activity puts in place the Regional / national consultation mechanism designed in the Road map for regional consultation. The shaping of this mechanism sums the experience acquired through the execution of the 2-4 pilot actions and of the knowledge developed by the project on the modalities of regional consultation and exchange of experiences on the management of natural resources for the DLVC. The features of the Regional / national consultation mechanism – independently from the fact that it be or not be institutionalised – are being defined on the basis of the experience developed by the project and of the results achieved by the 2-4 pilot actions. Specifically, the result of this activity is the elaboration of the project exit strategy to capitalise on its results and to exploit its results for undertaking further actions at the national and regional level. A regional project closing meeting is organised to validate the project exit strategy.

7. Project administration

The AU-IBAR supports the execution of the project by providing the relevant administrative, financial, monitoring, reporting and auxiliary services (e.g., institutional communication with the national authorities). The AU-IBAR project coordinator is the liaise between the project activities and the AU-IBAR backstopping services. This activity produces the annual technical and financial reports of the project.

5. Modality of execution

AU-IBAR coordinates this action through its collaboration with the national agricultural authorities. The elaboration of the modalities of support to regional programmes, initiatives, actors is defined at the time of the elaboration of the work plan of the action. The action is framed in the Live2Africa strategy. Thus, its implementation is expected to benefit from the collaboration with the other interventions promoted under Live2Africa. A Steering committee supervises the implementation of the action and coordinates the selection of the 2-4 pilot actions.

6. Timeline and resources

The duration of the action is 5 years. Activities, resources, timeline and results are presented in the following table.

Table 15. Timeline and resources of the regional action

N	*Activity*	*Resources*	*USD*	*Timeline (months)*	*Results*

1	Establishment of the project coordination	AU-IBAR staff	20,000	6	Project work plan
2	Identification of regional and national programmes, initiatives and actors	Project unit	30,000		Map of programmes, initiatives and actors
3	Elaboration of the road map for regional collaborations	AU-IBAR and national agricultural authorities	50,000		Technical road map for regional collaboration
4	Organisation of national and regional consultation meetings	Project unit and national agricultural authorities	150,000	6	Strategy papers on the opportunities and challenges of natural resources conservation and sustainable use for the DLVC
5	Selection of and support to regional and national programmes and initiatives	Project unit and Steering committee			
5.1	Preliminary phase	Project unit, Service providers (organization of events) and Steering committee	100,000	6	Creation of capacities on innovative modalities to manage knowledge Guidelines for the support implementation guidelines / Tender documents
5.2	Implementation of support	Project unit, Implementing partners, Service providers (external expertise)	500,000	36	Improved communication between researchers, services providers and dairy producers
6	Networking, communication and advocacy	Project unit, National agricultural authorities, Implementing partners	50,000	6	Regional / national consultation mechanism
7	Project administration	Administrative and financial support to the project	100,000	60	Annual technical and financial reports
Total			*1,000,000*	*60*	

The resources needed for the project implementation consist in the establishment of a coordination mechanism (AU-IBAR and national focal points) and the mobilization of expertise to support the implementation of the planned activities. The preliminary breakdown of the project cost is indicative. Each of the 2-4 pilot actions funded under item 5.2 includes:

- the delivery of services by the project (coordination, technical assistance, studies, etc.), and

- the execution of the grant by the supported organisations.

The Project coordination is in charge of the validation of the reports of the beneficiaries of the grants.

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2021 FAOSTAT database

2. Statistics

1. Population 1994-1996, 2017-2019

Country	1994-1996 '000	2017-2019 '000	1994-1996 %	2017-2019 %
Algeria	28.746	41.809	21	21
Egypt	62.344	97.433	46	49
Lybia	4.947	6.630	4	3
Mauritania	2.314	4.343	2	2
Morocco	26.987	35.805	20	18
Tunisia	9.120	11.499	7	6
Total	134.458	197.519	100	100
%	100	147	100	100

Source: FAOSTAT

2. Land usage 2016-2018

Country	Land area '000 Ha	Agricultural land '000 Ha	Arable land '000 Ha	Agricultural /total land %	Arable/total land %
Algeria	238174	41351	7460	17	3
Egypt	99545	3802	2870	4	3
Lybia	175954	15350	1720	9	1
Mauretania	103070	39661	400	38	0
Morocco	44630	30079	7495	67	17
Tunisia	15536	9730	2593	63	17
Total	676909	139973	22537	21	3

Source: FAOSTAT

3. Livestock Head, 1994-1996

Country	cattle Heads	Buffaloes Heads	goats Heads	sheep Heads	camels Heads	horses Heads	mules Heads	Total Heads	%
Algeria	1.254.563		2.739.450	17.569.600	125.490	62.890	79.007	21.563.613	27

Egypt	2.898.000	2.948.256	3.272.000	4.470.530	131.474	41.000	800	13.588.786	17
Lybia	143.333		1.253.333	5.200.000	100.333	35.000	0	6.596.667	8
Mauritania	1.111.000		3.726.133	5.589.067	1.109.333	19.007	0	10.426.200	13
Morocco	2.374.133		4.194.033	13.744.533	37.000	160.800	529.833	20.312.700	25
Tunisia	670.767		1.341.400	6.392.200	232.000	56.200	81.000	8.404.367	10
Total	8.451.797	2.948.256	16.526.350	52.965.930	1.735.631	374.897	690.640	80.892.332	100
%	1.224	427	2.393	7.669	251	54	100	11.713	

Source: FAOSTAT

4. Livestock Head, 2017-2019

Country	Cattle Heads	Buffaloes Heads	Goats Heads	Sheep Heads	Camel Heads	Horses Heads	Mules Heads	Total Heads	%
Algeria	1.830.666		4.967.498	28.848.842	405.241	47.276	17.317	35.647.006	44
Egypt	4.560.092	3.451.385	3.669.477	5.089.148	\	80.176	3.018	16.770.102	21
Lybia	225.140		2.652.152	7.489.982	65.347	45.667	0	10.367.274	13
Mauritania	1.930.542		7.476.703	11.047.724	1.490.341	66.653	0	20.454.969	25
Morocco	3.377.667		5.643.000	20.444.667	59.841	189.667	389.000	29.465.333	36
Tunisia	639.177		1.188.129	6.489.761	237.358	57.270	82.683	8.317.067	10
Total	12.563.283	3.451.385	25.596.960	79.410.123	2.258.128	486.710	492.018	121.021.750	150
%	2.553	701	5.202	16.140	459	99	100	24.597	

Source: FAOSTAT

5. Milk livestock / total heads, 2017-2019

Country	Cattle	buffalo	goat	sheep	camel
Algeria	0,54		0,59	0,63	0,23
Egypt	0,36	0,46	0,32	0,37	
Lybia	0,59		0,23	0,28	0,18
Mauritania	0,22		0,21	0,20	0,07
Morocco	0,52		0,27	0,05	0,54
Tunisia	0,70		0,34	0,04	0,02
Total	0,43		0,32	0,32	0,11

%

Source: FAOSTAT

6. Milk livestock, production, yield, 1994-1996

Country	Cow			buffalo			goat		
	Heads	hg/head	MT	heads	hg/head	MT	heads	hg/head	MT
Algeria	744.000	10.968	816.000				1.616.980	849	137.333
Egypt	1.227.460	10.161	1.247.246	1.358.878	10.791	1.466.331	1.115.344	115	12.871
Libya	82.667	12.016	99.333				415.000	355	14.730
Mauritania	301.667	3.498	105.533				945.000	762	72.032
Morocco	1.435.938	5.978	858.333				1.196.245	300	35.882
Tunisia	392.833	13.772	541.000				440.631	246	10.833
Total	4.184.565	8.764	3.667.446	1.358.878	10.791	1.466.331	5.729.200	495	283.682
%									

Country	sheep			camel			Total		
	heads	hg/head	MT	heads	hg/head	MT	heads	hg/head	MT
Algeria	6.275.333	301	189.000	33.732	1.784	6.016	8.670.046	1.325	1.148.350
Egypt	1.754.035	500	87.702				5.455.717	5.158	2.814.150
Libya	1.250.000	350	43.750	10.033	2.000	2.007	1.757.700	909	159.820
Mauritania	1.390.000	386	53.614	83.644	2.541	21.250	2.720.311	928	252.430
Morocco	730.658	374	27.357	20.733	2.886	5.983	3.383.574	2.741	927.555
Tunisia	242.258	612	14.833	3.368	2.969	1.000	1.079.090	5.261	567.667
Total	11.642.284	358	416.256	151.511	2.393	36.256	23.066.437	2.545	5.869.971
%									

Source: FAOSTAT

7. Milk livestock, production, yield, 2017-2019

Country	Cow			Buffalo			Goat		
	Milk Animals Heads	Yield kg/animal	Production MT	Milk Animals heads	Yield kg/animal	Production MT	Milk Animals heads	Yield kg/animal	Production MT
Algeria	981.339	26.030	2.554.379				2.908.568	1.034	300.640

Egypt	1.638.710	16.827	2.757.377	1.585.125	14.034	2.223.961	1.157.907	134	15.525
Lybia	131.975	11.437	150.937				613.698	325	19.974
Mauritania	416.939	3.662	152.681				1.598.146	677	108.159
Morocco	1.767.624	14.426	2.550.000				1.526.180	289	44.170
Tunisia	447.299	31.575	1.412.333				406.237	280	11.387
Total	5.383.885	17.790	9.577.708	1.585.125	14.030	2.223.961	8.210.736	609	499.854
%									

Country	Sheep Milk Animals heads	Yield kg/animal	Production MT	Camel Milk Animals heads	Yield kg/animal	Production MT	Total Milk Animals heads	Yield kg/animal	Production MT
Algeria	18.092.624	229	413.719	92.299	1.571	14.503	22.074.830	1.487	3.283.241
Egypt	1.874.195	490	91.893				6.255.937	8.134	5.088.755
Lybia	2.073.557	311	64.393	12.072	2.061	2.488	2.831.303	840	237.792
Mauritania	2.246.666	343	77.068	105.239	2.457	25.854	4.366.990	833	363.763
Morocco	1.003.938	343	34.397	32.247	2.723	8.782	4.329.989	6.091	2.637.349
Tunisia	277.399	740	20.521	3.626	3.017	1.094	1.134.561	12.739	1.445.335
Total	25.568.380	275	701.991	245.483	2.148	52.721	40.993.610	3.185	13.056.235
%									

Source: FAOSTAT

8. Milk, whole fresh value, 2017-2019. Thousands of US dollars

Country	camel	Buffalo	cow	goat	sheep	Total
Algeria	9.316		1.063.009	138.322	252.349	1.462.995
Egypt		1.189.249	1.147.486	7.143	56.050	2.399.928
Lybia	1.598		62.813	9.190	39.276	112.877
Mauritania	16.608		63.538	49.763	47.008	176.917
Morocco	5.642		1.061.186	20.322	20.980	1.108.130
Tunisia	703		587.745	5.239	12.517	606.204
Total	33.867	1.189.249	3.985.777	229.979	428.180	5.867.052
%	8	278	931	54	100	1.370

Source: FAOSTAT

9. Milk production and consumption per capita

Country	Production		Change	Consumption	Domestic production / consumption
	1994-1996 L/person	2017-2019 L/person	%	2017-2019 L/person	%
Algeria	40	79	197	130	60
Egypt	45	52	116	50	89
Lybia	32	36	111	75	48
Mauritania	109	84	77	160	52
Morocco	34	74	214	55	134
Tunisia	62	126	202	110	114
Total	44	66	151	70	84

Source: FAOSTAT, National reports

10. Egypt water balance

Category	*Livestock size*	*Dairy production*	*Needs*	*Availability*		*Consumption*	*Balance (surplus / gap)*	*Total*
	0	*000 MT*	*DM billion m^3*	*Sources*	*Quantity*		*DM billion m3*	
Cattle (e.g., cow, mixed farming)	3.071	2.930						
1. Forages			4,35	3,01			-1,34	
2. Concentrates, additive , etc.			5,85	2,49			-3,36	
Buffalo	2.746	2.500						
1. Forages			3,89	2,69			-1,20	
2. Concentrates, additive etc.			5,23	2,23			-3,00	
Sheep	1.071	0						
1. Forages			1,52	1,05			-0,47	
2. Concentrates, additive etc.			2,04	,869			-1,17	
3. Additives								
Goats	636	125						

1. Forages 2. Concentrates, additive, etc. 3. Additives			,900 1,21	,624 ,516			-0,28 -0,69	
Dromedaries 1. Forages 2. Sub-products, concentrates, etc. 3. Additives	153	0	,217 ,291	,150 ,124			-0,07 -0,17	
Equine	692	0						
1. Forages 2. Concentrates, additice, etc. 3. Additives			,980 1,32	,678 ,561			-0,30 -0,76	
Total	8369	5.555	27,80	14,99			-12,81	

Source: National report

11. Egypt feed balance

Category	*Livestock size* *000 heads*	*Dairy production* *000 MT*	*Needs* *000 MT*	*Availability* *Production systems*	*000 MT*	*Storage / processing*	*Trade*	*Consumption*	*Balance (surplus / gap)* *000 MT*	*Total*
Cattle (e.g., cow, mixed farming)	3.071	2.930		mix farming						
1. Forages			9.109		6.304				-2.805	
2. oncentrates, etc.			4.904		2,091				-4.902	
3. Additives										
Buaffalo	2.746	2.500								
1. Forages			8.145		5.638				-2.507	
2. Sub-products, concentrates, etc.			4.385		1.870				-2.515	
3. Additives										
Sheep	1.071	0								
1. Forages			3.177		2.199				-978	
2. Sub-products, concentrates, etc.			1.710		729				-981	
3. Additives										
Goats	636	125								

1. Forages 2. Sub-products, concentrates, etc. 3. Additives			1.886 1.016	1.306 433	-580 -583
Dromerdaries 1. Forages 2. Sub-products, concentrates, etc. 3. Additives	153	0	454 244	314 104	-140 -140
Eqauine 1. Forages 2. Sub-products, concentrates, etc. 3. Additives	692	0	2.053 1105	1421 471	-632 -634
Total	8.369	5.555	38.188	20.791	-17.397

*Source: National report

12. Morocco water balance

Category	*Livestock heads*	*Dairy production*	*Needs*	*Availability*		*Consumption*	*Balance (surplus / gap)*	*Total*	*Year*	*Source*
				Source	*Quantity*					
Cattle, mixed farming	3.3 million heads (meat and milk) of which 1.7 million cows	1.85 million tons of which 1.20 million processed by industrial factories Import of cheese: 24,200 tons Butter: 18,450 tons Milk powder: 11,300 tons		Livestock drinking water	0.06 billion m^3	All needs fulfilled			2018	Personal estimate
1. Forages	520,000 ha of fodder crops 55% rain-fed		Strong annual variation Rainfall 50%	Total Rainfall	5.88 billion m^3: 3.68 billion $m^3$of rainfall (green water)	Fully consumed (insufficient water availability)				Personal estimate

	45% irrigated	Irrigation 30%	Irrigation water	2.20 billion $m^3$of irrigation water (blue water)	A part of that is from groundwater. Many problems related to depletion	
2. Sub-products, concentrates, etc.		Virtual water 20%	Mostly virtual water Only crop by-products produced locally	1.45 billion cubic meters	A	Concentrate feed mills
3. Additives				0		
4. Total			7.37 billion m^3	8.82 billion m^3	-1.45 billion m^3	

Source: National report

13. Morocco feed balance

Category	*Livestock heads*	*Dairy production*	*Needs*	*Availability* *Category*	*Quantity*	*Storage / processing*	*Trade*	*Consumption*	*Balance (surplus / gap)*	*Total*	*Year*	*Source*
Cattle (e.g., cow,mixed farming)	3.3 million heads (meat and milk) of which 1.7 million cows. 1.6 million growing calves, heifers, steers, etc.	1.85 million tons of which 1.20 million processed by industrial factories Import of cheese: 24,200 tons Butter: 18,450 tons Milk powder: 11,300 tons		Smallholder units	(400,000 farms) 1.68 million cows 1.69 million tons of raw milk of which 1.04 million tons processed	Deliveries to milk collection centers	Milk sold at 0.32 to 0.35 US $/liter				2018	Official sources
				Mega dairy farms	10 farms 20,000 cows (all Holstein) 160,000 tons of raw milk. All processed	Direct sales to processors	Milk sold at 0.45 US $/liter					
1. Forages			8.43 million tons DM fodder (56 million fresh) Straw	Total Rainfed Irrigated Rainfed/irrigated	2,53 million tons DM fodder (16,90 fresh) 0.73 million tons DM (4.90 million fresh) 1,79 million tons DM (11.96 million fresh) 15.3 million tons DM* (17.0 million fresh)	Limited storage capacity (industrial farms)	Small fodder import in drought years only Estimate	All consumed	-3,46 million tons DM deficit Compensated by fallow, straw, stubble, etc. All rain-fed		2020	Official sources

		Fallow land	Grazing	N/A				
2. Sub-products, concentrates, etc.		2.41 million tons DM concentrates	Concentrates imported	0,5 million tons DM of which 0.35 million tons DM for cows 0, 15 million tons DM for calves	Imported	All consumed	-1,91 million tons DM deficit Compensated by local crops' byproducts (wheat bran, sugar beet pulps, citrus pulps, carob pulps, etc.)	
			Concentrates local	N/A	local			
3. Additives				0				
4. Total				10,84	7,08	-3,76		

Source: National report

14. Mauritania water balance

Category	*Livestock size*	*Dairy production*	*Needs*		*Availability*		*Storage / processing*	*Trade*	*Year*	*Source*
			UF	*MAD (kg)*	*Production systems*	*[1]Quantity(TonneMS)*				
Cattle	1.944.047	155.000	1.944.047.000	108.866.632	Pastoral system		NA	NA	2017	FAOSTAT
	1.914.874	155.000	1.914.874.000	107.232.944					2018	
	1.932.704	148.044	1.932.704.000	108.231.424					2019	
Camelids	1.474.657	25.000	1.474.657.000	82.580.792	Pastoral system		NA	NA	2017	FAOSTAT
	1.495.394	26.243	1.495.394.000	83.742.064					2018	
	1.500.973	26.318	1.500.973.000	84.054.488					2019	
Ovins	10.966.563	73.000	2.193.312.600	122.825.506	Pastoral system		NA	NA	2017	FAOSTAT
	11.023.085	78.786	2.204.617.000	123.458.552					2018	
	11.153.523	79.419	2.230.704.600	124.919.458					2019	

Caprins	7.421.444	100.000	1.236.907.333	69.266.811	Pastoral system		NA	NA	2017	FAOSTAT
	7.469.283	111.858	1.244.880.500	69.713.308					2018	
	7.539.383	112.620	1.256.563.833	70.367.575					2019	
Total	21.806.711	353.000	6.848.923.933	383.539.740	Pastoral system	7.102.044	NA	NA	2017	
	21.902.636	371.887	6.859.765.500	384.146.868		8.371.001			2018	
	22.126.583	366.401	6.920.945.433	387.572.944		5.833.086			2019	

Source: National report

15. Mauritania feed balance

Category	*Livestock size*	*Dairy production*	*Nombre UBT*	*Consumption[1] (Tonne MS)*	*Balance (surplus / gap)*	*Year*	*Source*
Cattle	1.944.047	155.000	1.944.047	4.471.308		2017	FAOSTAT
	1.914.874	155.000	1.914.874	4.404.210		2018	
	1.932.704	148.044	1.932.704	4.445.219		2019	
Camelids	1.474.657	25.000	1.474.657	3.391.711		2017	FAOSTAT
	1.495.394	26.243	1.495.394	3.439.406		2018	
	1.500.973	26.318	1.500.973	3.452.238		2019	
Ovins	10.966.563	73.000	2.193.313	5.044.619		2017	FAOSTAT
	11.023.085	78.786	2.204.617	5.070.619		2018	
	11.153.523	79.419	2.230.705	5.130.621		2019	
Caprins	7.421.444	100.000	1.236.907	2.844.887		2017	FAOSTAT
	7.469.283	111.858	1.244.881	2.863.225		2018	
	7.539.383	112.620	1.256.564	2.890.097		2019	
Total	21.806.711	353.000	6.848.924	15.752.525	-8.650.481	2017	
	21.902.636	371.887	6.859.766	15.777.461	-7.406.460	2018	
	22.126.583	366.401	6.920.945	15.918.174	-10.085.088	2019	

Source: National report

16. Water and feed balance in Egypt, Morocco and Mauritania, 1994-1996

Country	*Milk animals*	*Milk*	*Water*			*Feed*			*Year*
	Heads	*MT*	*Need*	*Abailability*	*Balance*	*Need*	*Consumption*	*Balance*	
	million	*million*	*Billion m³*	*Billion m³*	*Billion m³*	*Million MT*	*Million MT*	*Million MT*	
Egypt	5,46	2,81	22,60	14,99	-7,61	31,04	20,79	-10,25	1994-1996
- forage, straw			9,64	8,20	-1,44	20,18	17,18	-3,00	
- concentrates			12,96	6,79	-6,17	10,86	3,61	-7,25	
Morocco	3,38	0,93	6,08	5,08	-1,00	7,48	7,08	-0,40	1994-1996
- forages, straw			5,08	5,08	0,00	5,81	6,58	0,77	
- concentrates			1,00	0,00	-1,00	1,66	0,50	-1,16	
Mauritania, pastures	2,72	0,25	2,20	3,74	1,54	8,07	7,10	-0,97	1994-1996
Total	11,56	3,99	30,89	23,81	-7,08	46,59	34,97	-11,62	