Review article

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Changes in livestock farming systems in the Moroccan Atlas Mountains

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Abstract: This paper aims to characterize small ruminant farming systems in the Moroccan mountain regions and to assess undergoing socio-economic and ecological changes. Livestock farming systems in these regions are extensive with large flock sizes, especially sheep and goats raised mainly for meat production. Sheep producers utilized the inherent genetic diversity of their stock and developed adaptations to cope with seasonal availability of the mountain pastures and the need to diversify their own activities. Nowadays, farming systems in mountainous regions are undergoing socio-economic and ecological transformations that impact directly or indirectly on natural resources. Reduction and/or disappearance of herd transhumance, where flocks were moved seasonally from one climatic zone/vegetation type to another, was an important feature of the Middle Atlas sixty years ago. Along with this reduced contribution from natural rangelands, other external resources and agricultural by-products (straw, stubble) are offered which make the system heavily dependent on agriculture. Intensification of feeding systems is associated with a choice for more productive but less hardy breeds from lowland areas. As a consequence of the reduction in mobility and the sedentarization of herds, there is an increase in the grazing pressure causing new and significant degradation of rangeland resources. Other profound institutional modifications concern the management and the utilization of the mountainous pasture. Indeed, the power of the group and the institutions for managing the resources is being replaced by the individual initiatives.

Keywords: Mediterranean mountains, Morocco Mountains, Livestock farming systems, socio-economic and ecological changes

1 Introduction

Mountain systems represent 20% of the world land area and are home of 570 million people (Montanari 2013). Morocco possesses the most extensive mountainous area in North Africa, The Atlas Mountains, which comprise three blocks, the High-, Middle- and Anti-Atlas. As is the case with other mountain systems, the Atlas Mountains sustain a large population by providing economic resources and ecosystems services (Bernuès et al. 2011; Montanari 2013). These mountains are areas in which Berber communities settled and were engaged in agriculture and livestock activities for many centuries (Auclair et al. 2011; Benchrif and Johnson 1991). The system developed by these communities in the High Atlas is a mixture of subsistence agriculture with the cultivation of land built into terraces in the lower valley, irrigated by river water. This is combined with pastoralism practiced on the extensive rangelands of the watershed (Montanari 2013; Bourbouze 1999). In the lower flatter parts of the valleys, agro-pastoralists practice irrigated crops, mainly cereals (barley and wheat) and horticulture combined with the raising of crossbreed cattle. The upper parts of the valleys resemble extensive rangelands mainly composed of spiny xerophytic vegetation and coarse dry grasslands (Auclair et al. 2011). Livestock farming, mainly goats and sheep, represents a key element of the farming system since it is an opportunistic way to valorise the scattered resources of the extensive rangelands (Auclair et al. 2011). The Middle Atlas is an area of forests and pastures historically utilized by semi-Nomads (Naciri 1988). Pastoral communities of the Middle Atlas used to base their subsistence on lowland highland migration in search of complementary (in space and time) natural pastures (Benchrif and Johnson 1991). Income for these mountainous communities comes from seasonal cereal, vegetable, and horticulture supplemented with livestock. The forests provide the firewood, part of the forage, and the timber.

The sustainability of the Livestock Farming System (LFS) in relation to climate change, population dynamics

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and the environment is a matter of public concern and scientific debate (Bernès et al. 2011). During the last century, important changes occurred in the Northern part of the Mediterranean basin in response to the intensification of agriculture and industrial development. These changes resulted in depopulation and the reduction or the disappearance of livestock farming in rural areas (Bernuès et al. 2005; Strijker, 2005). In the Southern part of the Mediterranean basin, the situation is totally different with an overuse of the rangeland resources as is the case in the Moroccan mountains. This paper aims to characterize livestock farming systems in the Atlas mountain regions and to assess the socio-economic and ecological changes that these systems are undergoing.

2 Characterisation of traditional mountain livestock farming systems

Pastoralism, agriculture and silviculture are the pillars of the traditional land use system in Mediterranean mountain environments. Livestock farming systems (LFS) are extensive since they are based on pastoral resources which make LFS highly relevant in both environmental and social terms (Bernès et al. 2011; Gibon 2005). Pastoralists developed a number of strategies to attempt to cope with the specific pattern of animal production and availability of resources in mountainous regions (El Aich and Waterhouse 1999). These strategies concerned feeding systems that relied on sylvo-pastoral resources, matching of herd requirements to seasonal availability of pastures; using high animal genetic diversity geared more toward environmental hardiness rather than production; the use of the fragmented landscape resources to define seasonal movements of herds dictated a constantly present shepherd. The systems developed in these regions indicate a low input and output and great diversification in activities associated to livestock.

2.1 Traditional livestock husbandry

Livestock farming systems differ between the High and the Middle Atlas. Until the beginning of this century, the regions of the Middle Atlas were occupied by pastors exploiting an extensive semi-nomadic type of farming on the rangelands and the forest. To satisfy their domestic consumption needs, these pastoralists practiced subsistence agriculture mainly cereals in the most favorable locations (Beaudet 1969; Mahdi 2012). LFS

are extensive and based on grazing collective grasslands and woodlands by large flocks mainly of sheep with a few goats (Table 1). This LFS was characterized by the exploitation of the available resources by a low-density population and a livestock load allowing a reasonable use of the pastoral and forest resources. The movements and the practice of the “agdals” constituted the principal characteristics of this system and allowed a complementary exploitation of rangelands according to a double transhumance, summer in the mountains and winter in the azaghar (low lands). In the High Atlas, farming systems are composed of two compartments, the irrigated one in the bottom of the valley and the extensive one practiced with grazing small ruminants herds (Table 1) of the higher parts of the watershed. Established systems fit well this diversity in territories and resources. Crossbreed cattle depend on the irrigated compartment by using resources produced in the terraced production systems and the byproducts of the agriculture. Small ruminants better utilized the watersheds according to seasonal flock movements.

In both situations, small ruminants were never confined in the same pasture year-round. They were kept in a tight flock by a shepherd constantly present. The shepherd had a major role in determining the grazing and browsing pattern of his stock as well as defining their spatial behavior (El Aich and Waterhouse 1999). Full scale transhumance as described for mountain regions is less common in foothill systems, but most systems involved movements of livestock from higher lands to lower ones for winter grazing, or even into housing for part of the winter. Conversely in spring, after parturition, the stocks tended to move upwards through a range of pastures. This pattern is well described for Spain and Greece by Beaufoy et al. (1994) and for Morocco by Bourbouze (1982). Animal movements to use mountainous rangeland resources in these regions used to be highly regulated for conservation of standing forage such as “Agdal” in the Atlas Mountains of Morocco (Bourbouze 1982, Auclair et al. 2011). These movements of animals permitted the spatial variation of forage resources which ensured their sustainability. Many authors indicated that in such mountain environments, mobility of herds made them and their pastures more productive and better able to resist disease and drought than sedentary animals in the same conditions (Bremen and de Wit 1983) while at the same time causing less environmental degradation (Strijker 2005). In these mountainous regions livestock holders tend to raise large sheep flocks for meat production (El Aich and Chiche 2005).

2.2 Extensive feeding systems with low input and output

It is well established that small ruminants in mountainous areas rely on sylvo-pastoral feeding resources. The extent to which rangeland fodder resources cover livestock requirements varies from year to year and from one region to the next. Investigations in the High Atlas of Morocco have indicated the predominance of range and forest resources in small ruminant diets. The full dietary contribution of sylvo-pastoral resources represents an average 94% for both sheep and goats (El Aich and Bourbouze 1992; El Aich and Chiche 2005).

The low yields of livestock flocks can be explained by their poor reproductive performance. Within mountainous regions, lambing is linked to seasonal availability of pastures. Mating and pregnancy typically coincide with the period of poorest growth and often the most difficult climatic conditions. Lambing starts during winter before the beginning of the grass-growing season, with lactation occurring through the period of lowest grass growth. In the Atlas Mountains, high lamb mortality is recorded

and explained by the low availability of rangelands and the inadequate supplementation (Table 1). Moreover, poorer lands cannot sustain higher levels of performances and there are physical difficulties in providing high levels of inputs in many mountainous systems (El Aich and Waterhouse 1999). Therefore, reproduction and production performances are usually poor, lowering small ruminant herd productivity. The fertility rates recorded among these herds are also in fact quite low (Table 1). This low rate is due to the lack of a timetable for breeding which would match feeding requirements to forage available of pasture. Livestock owners do not organize breeding so that lambing will take place at the best time of the year when pasture resources are relatively abundant. Feed supplementation during the phases of the breeding cycle is not a widespread practice. Breeding therefore hinges upon climatic factors, with very little intervention from the livestock owner. Other causes of lower breeding performances include the rarity of good stud bucks and rams, a fact that induces livestock owners to use young studs from neighbouring farms or bought from weekly livestock markets. Selection criteria vary from region to

Table 1: Main characteristics of small ruminant flocks in Mountainous regions

	Middle Atlas	High Atlas
Flocks size and composition		
Flocks composition	Mainly sheep	Sheep and goats
Flock size		
Average flock size	60 to 150	10 to 14
Extremes	20 to 1500	0 to 50
Breed raised	Timahdit: one of the 5 Moroccan breeds	Heterogeneous populations of mountains: small with white wool
Reproduction		
Ram breeder	Ram permanently with the herd	Ram permanently with the herd
Lambing period	One lambing per year, from October to May	One lambing per year, from December to February
Reproductive Effectiveness	80 to 95 lambs weaned per 100 ewes	80 to 95 lambs weaned per 100 ewes
Mortality		
Before weaning	5 to 20%	10 to 35%
Adults	Less than 5%	5 to 15%
Production		
Milk (kg/lactation)	50 to 55; no milking	Estimated at 33; no milking
Meat		
Weight at birth (kg)	3 to 4	1.6 to 1.8
Daily gain (0 to 5 months)	100 to 150 g/day	55 to 70 g/day
Adult weight (kg)	35 to 50 for males and 30 to 35 for females	30 to 35 for males and 24 to 28 for females
Winter weight lost for adults (kg)	1 to 2	2 to 5
Sale		
Lambs	80% sold at 6 months end of April	Year long
Old ewes (7 to 8 years)	20% of ewes at summer	Year long
Ewes with lambs	During winter	Year long

region. Sheep Livestock Unit (S.L.U.) and Goat Livestock Unit (G.L.U.) productivity expressed as the live weight gain in kg per G.L.U. is usually quite low in the High Atlas and never exceeds 12 and 7 kg for sheep and goats respectively, while in the Middle Atlas they might average 20 kg per S.L.U. Feed conversion ratios, expressed as the requirements in fodder units “FU” (one french fodder unit contains the energy equivalent of one kg DM of barley) per kilo of live weight meat, are high and underlined the extensive character of the system. In the High Atlas, Chraïbi (1985) suggests an index of 28 FU/kg for goats and 31 FU/kg for sheep. In the Middle Atlas rangelands, El Khamkhami (1988) found a ratio of 21 FU/kg of live weight gain for sheep. These figures show the low efficiency of conversion of the grazing resources in these regions.

2.3 Great diversification in activities associated to livestock

Diversification may take many forms such as the mix of species, herd composition, subsistence cropping and the practice of non-agricultural activities. A diverse mix of species managed by the same household fully valorizes the diverse environment resources; better serves the subsistence needs of the household and reduces risk from external shocks. For instance, in the High Atlas of Morocco, herds are composed of cattle, sheep and goats. Cattle are directly linked to the irrigated part of the watershed while sheep and goats are associated to the extensive part of the watershed (El Aich and Bourbouze 1992). Diversification concerns herd constitution. Producers prefer having many animals (especially females) of different kinds and also a mixture of animal species in their herds. The diversity of kinds of animals and having large proportion of females insures rapid recovery from stressful situations such as droughts. Diversification of subsistence activities between agriculture and livestock is a way to cope with climatic risk (Montanari 2013). Indeed, animals may survive even when grain yield is low. In addition, diversification of crops grown is usually considered to overcome the risk of crop failure (El Aich and Bourbouze 1992). Other forms of diversification are taking place in mountains regions such as tourist accommodation. This activity has developed well in the High Atlas, where the number of houses, “gits”, offered to host tourists has been increasing during the last years. This form of diversification is generating income that can then be invested in horticulture to plant apple trees and plant potatoes or in livestock to buy dairy cattle (Stitou 1994).

3 Changes in Moroccan Mountain Livestock farming systems

Mountain systems are changing more rapidly. Pastoralism that is the dominant farming systems in mountains is under stress. According to Msuya (2015), some pressure originates from the system itself, its economics and policy changes, and other pressures come from the climate and environment. There is no doubt that Moroccan Mountain systems are undergoing transformations of a socio-economic and ecological nature that impact on livestock, primarily small ruminants as well as natural resources (Auclair et al. 2011; Mahdi 2012).

3.1 Socio-ecological changes

There is no doubt that these transformations are widening the gap between the utilization of natural resources and the carrying capacity of these mountainous systems, especially in the Middle Atlas. Pastoral territories have been reduced by the expansion of the cultivated areas as result of pressure for land from an increasing sedentary population. Lands suited for cropping are often among the best pastures. Such restrictions reduce the diversity of ecosystems available to herders. In the Middle Atlas, the transhumance between the mountain pastures and the lowlands disappeared with the extent of cultivation of the low land territories (Bourbouze 1999). The break down in this mobility resulted in an increased duration of grazing of mountainous rangelands. In addition to decline of rangelands areas, livestock numbers increased leading to an overgrazing of the remaining fragile rangelands. Reductions in herd mobility have also taken place in some European mountainous regions, for example in Greece and Spain, where transhumance systems were long-established (Beaufoy et al. 1994). It is well established that low-input agricultural systems are often also of great value to biodiversity (Strijker, 2005) and losses of such natural and semi-natural grassland in the last century range from 11% in the UK to 82% in Spain (Strijker 2005).

Other transformations are taking place in mountainous areas with the introduction of herd movements by motorization thus changing completely the traditional mobility in these regions allowing outlying areas to be grazed (El Aich 2000). Motorization has made the feed resources and water reach the animals rather than the animals move to feed and water as it used to be. In the Middle Atlas, delivery of water to animals is now easy and only constrained by the financial capacity of the livestock owners (Mouahidi 1999). Many social changes have also been occurring. Herd

Table 2: Species Richness, diversity index and evenness index in grazing areas stocked differently in the Middle Atlas

Grazing areas	Touna	Hebri	Chdifat	Bouanguar
Stoking rates (ewe/ha)	1	3.73	4.57	5.44
Species Richness	39	23	26	17.33
Shanon Index (H')	3.37	2.26	2.36	2.71
Evenness Index	0.64	0.63	0.50	0.67

mobility on mountainous collective rangeland was managed by institutions concerned for conservation of standing forage as “Agdal” in the Atlas Mountains (El Aich 2000). The decline of these traditional institutions resulted in the conversion of delicate ecosystems to open access systems. As consequence of the decline in the power of these institutions, movements are not decided collectively, but rather by individuals or small groups of relatives. Therefore, movements are influenced by individuals according to their financial means and social status to decide where and when to move and how long to stay. Recently herdsman are having trouble finding herders to take care of flocks in the Middle Atlas which emphasizes the considerable lack of new young shepherds willing to graze their flocks using traditional methods, even though payments to herders has been increased. Herders have become more demanding which constitutes a real constraint for grazing livestock. Other social transformations were reported elsewhere. Indeed, what is happening in the Middle Atlas of Morocco was reported by Beaufof et al. (1994) in Greece. They indicated that for a typical Greek mountain village during the late 1980s average age of the shepherds increased from 57 to 63 years of age. The number of shepherds dropped by 16% while the number of animals moving by transhumance decreased by 25% and the ageing population associated with sheep and goat keeping was a common theme.

Consequences of a reduction in herd movement in a mountain ecosystem are overgrazing and increased grazing season duration which reduces the carrying capacity of these mountainous pastures and increases their dependence on external feed resources. For instance, in the Middle Atlas, Benelkhou and Azzouzi (2002) studied the settlement of herdsman on mountainous grassland as result of the break down in the transhumance. They found an increase in the grazing pressure that ranged from 2 to 4 sheep/ha. The rise in the number of settlements enlarged the grazing pressure which affected vegetation cover as reported in Table 2. Indeed, species richness declined as grazing pressure increased, e.g., eighty species were found in the lightly grazed area (Benelkhou and Azzouzi 2002). Richness¹ in palatable species followed the same

trend of that reported for total species. In the meantime, Shanon index (H')², that measure of the complexity of the vegetation cover, distribution and frequency distribution of the plant communities, decreased as grazing pressure increased, inducing less stability of the system (Table 2). The uniformity of the vegetation measured by the Evenness³ index decreased with the sedentarization of the sheep holders on the high altitudes grazing areas year-round.

3.2 Husbandry feeding system changes

The degradation of rangelands has reduced their value as food resource, which made livestock owners use large amount of external feed resources as illustrated by Table 3. In the Middle Atlas of Morocco, distribution of large amount of concentrate and coarse feedstuff (hay and straw) is becoming common especially during the period November to April (El Aich 2000; Barhdadi and Ouariche 2011). November through April was the period when the tribes of the Middle Atlas used to move to the lowland winter grazing areas. The break of the transhumance to the winter pastures for the tribes of the Middle Atlas was compensated by the use of the external feedstuff (concentrates and coarse) from late fall to early spring which changed the feeding calendar and increased the costs for meat production in these regions. Indeed, Barhdadi and Ouariche (2011) found that the contribution of sylvo-pastoral resources to cover an animal's requirements did not exceed 50%. External feed either bought or produced at the farm has had to be brought in to cover remaining animal dietary requirements increased these last 20 years. For some farmers, the costs of the external feed represent annual expense of 45 to 50 euros per ewe, which increase drastically the cost of production.

Madih (2016) reported the operating expenses per ewe for different farming systems for the Ait Arfa du Guigou Tribe in the Middle Atlas. In calculating the operating expenses, Madih (2016) included the costs of external

² Diversity is calculated by using the Shannon information index (Shannon and Weaver 1949) $H' = -\sum p_i \ln p_i$

³ The Evenness index (Pielou 1975), $J' = H'/H'_{\max}$, describes the evenness of the plant community

¹ Richness is the number of vegetation species encountered

Table 3: Typical feeding calendar of small ruminants raised in mountains

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Middle Atlas												
Rangelands	Low	Low	Low	Low	High	High	High	High	High	High	Low	Low
Forest	High	High	High								High	High
Straw	Low	Low	Low	Low							Low	Low
Hay	High	High	Low	Low							Low	High
Concentrate	High	High	Low	Low						Low	High	High
High Atlas												
Rangelands	High	High	High	High	High	High	High	High	High	High	High	High
Forest	High	High	High	High							High	High
Hay	Low	Low	Low	Low								Low
Concentrate	Low	Low	Low	Low								Low

feedstuff (concentrates and hay and straw) with 39%, the cost of watering animals (10%), those relative to veterinary expenses (2%) and the expenses of herding and labor for maintenance of sheep pens (44%). As the size of the flock increase, the expenses per ewe decrease. The operating costs averaged 82.2, 60 and 40 euros per ewe for flock sizes less than 100, 101 to 500 and more than 500 ewes, respectively. To overcome this, small farmers who own less than 100 ewes, make agreements with other farmers or city investors to increase the size of their herds and use primarily family labor that usually does not need to be costed. The increase in the costs of production as result of the use of external feeds and the decrease in the availability of rangeland resources can explain the maintenance if not the reduction of the numbers of sheep kept and the timid shift towards agriculture.

Transformations of mountainous livestock farming systems concerned the kind of breeds raised. Indeed, the intensification of the traditional pastoral systems and its evolution toward an agro-pastoral one did generate forages or grain or other by-products. Livestock holders opt for better and more efficient breeds that better utilise the resources available to them. Therefore, more productive breeds and/or species are preferred as insurance against loss of hardiness. This is happening in the Middle Atlas where sheep-producers are mainly concerned with production characters rather than rusticity ones. In the High Atlas, sheep more adapted to mountains are replaced by more productive breeds coming from the plains or from the Middle Atlas (for example Timahdit breed). For cattle, cross breeding native cows is common practice in the valleys of the High Atlas (Stitou 1994).

4 Conclusion

Mountain livestock farming systems are evolving. During the last 60 years, farming systems in the Middle Atlas have seen tribes put away their tents and stop their transhumance practices. With the development of motorization, mobility has been reversed, so that feed and water are brought to animals rather than the other way around. External feedstuff has replaced the winter grazing in low level rangelands that are now cropped. The evolution that these systems are going through is widening the gap between the utilization of natural resources and the ecological reality of the mountain farming systems. Settlements of sheep holders had increased the grazing pressure on the highland grazing areas which resulted in decline in availability and degradation of these rangelands. This promoted the use of external feedstuff leading to an increase in the cost of meat production. Additionally, farmers are diversifying their sources of income by switching to agriculture to grow crops with high added value such as potatoes and onion and horticulture and in the meantime developing tourist-related activities.

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References

- Auclair L., Baudot P., Genin D., Romagny B., Simentel R., Patrimony for resilience: Evidence from the Forest Agdal in the Moroccan High Atlas Mountains. *Ecology and Society*, 2011, 16(4), 24
- Barhdadi A., Ouarriche O., Contribution à l'étude de la dégradation des parcours du Moyen Atlas: Cas de la fraction des Ait Beni

- Yakoub des Ait Arfa du Guigou, Mémoire de 3^{ème} cycle d'Agronomie, I.A.V. Hassan II, Rabat, 2011, 115 (in French)
- Beaudet G., Les Béni M'Guild du Nord. Etude géographique de l'évolution récente d'une confédération semi-nomade. *Revue Géographie du Maroc*, 1969, 16, 3-80 (in French)
- Beaufoy G., Baldock D., Clark J., The nature of farming: Low intensity farming systems in nine European countries, IEEP, WWF, JNCC, 1994
- Benchirfa A., Johnson J.D., Changing resources management strategies and their environmental impacts in the Middle Atlas Mountains of Morocco, *Mountain Research and Development*, 1991, 11(3), 183-194
- Bernués A., Ruiz R., Olaizola A., Villalba D., Casasús I., Sustainability of pasture-based livestock farming systems in the European Mediterranean context: synergies and trade-offs. *Livest. Sci.*, 2011, 139, 44-57
- Bernués A., Riedel J.L., Asensio M.A., Blanco M., Sanz A., Revilla R., Casasús I., An integrated approach to studying the role of grazing livestock systems in the conservation of rangelands in a protected natural park (Sierra de Guara, Spain). *Livest. Prod. Sci.*, 2005, 96, 75-85
- Benelkhou H. et Azzouzi M., Etude de l'Utilisation des parcours dans la Fraction des Ait Beni Yacoub (Moyen Atlas). Mémoire de 3^{ème} cycle d'Agronomie, I.A.V. Hassan II, Rabat, 2002, pp. 230 (in French)
- Breman H., de Wit C.T., Rangeland productivity and exploitation in the Sahel. *Science*, 1983, 221(1), 1341-1342
- Bourbouze A., Gestion de la mobilité et résistance des organisations pastorales des éleveurs du Haut Atlas marocain face aux transformations du contexte maghrébin, In *Managing Mobility in African Rangelands: The legitimization of transhumance* pp. 236 - 265, Edited by Maryam Niamir – Fuller, FAO and Beijer International Institute of Ecological Economics, IT Publication, 1999
- Bourbouze A., L'élevage dans la montagne marocaine, Organisation de l'espace et utilisation des parcours par les éleveurs. Thèse de Doctorat Ingénieur de l'INA Paris-Grignon, 1982, pp. 345 (in French)
- Chraïbi E., Productions Animales en zones de montagne, étude comparée de la vallée de l'Azzaden entre 1975 et 1985. Mémoire de 3^{ème} cycle d'Agronomie, I.A.V. Hassan II, Rabat, 195, pp. 153 (in French)
- El Aich A., Chiche J., Les systèmes de l'élevage de l'Atlas marocain, pp. 174-182, In *Manuel de zootechnie comparée Nord-Sud*, eds, Théwis A., Bourbouze A., Compère R., Duplan J.-M. and Hardouin J. INRA Editions INRA et Agence Universitaire de la Francophonie, 2005, pp. 606 (in French)
- El Aich A., Management of range resources in Africa: goals, constraints and policies. 3rd All Africa Conference on Animal Agriculture and 11th Conference of Egyptian Society of Animal Production, Alexandria, Egypt, 6-9 November, 2000
- El Aich A., Waterhouse A., Small Ruminants in Environment Conservation. *Small Ruminants Research*, 1999, 34, 271-287
- El Aich A., et Bourbouze A., Quinze années après : Innovations et Transformations des systèmes d'Elevage dans la Vallée de l'Azzaden (High Atlas, Morocco), *Symposium on Farming Systems*, Saragosse, Septembre 1992 (in French)
- El Khamkhami, Etude de la charge et des systèmes de production des ovins dans la commune de Timahdit. Mémoire de 3^{ème} cycle d'Agronomie, I.A.V. Hassan II, Rabat, 1988, pp. 153 (in French)
- Gibon A., Managing grassland for production, the environment and the landscape. Challenges at the farm and the landscape level, *Livestock Production Science*, 2005, 11- 31
- Madih I., Transformation des systèmes de production dans le Moyen Atlas entre les années 1970 et 2015, Cas de la commune rurale de Timahdit. Mémoire de 3^{ème} cycle d'Agronomie, I.A.V. Hassan II, Rabat, 2016, pp. 201 (in French)
- Mahdi M., Transhumance chez les Ait Arfa du Moyen Atlas: Ruptures et continuité, In *Seminar: "L'actualité de la transhumance dans le Haut et Moyen Atlas"* 10 mars 2012, Ecole Nationale de l'Agriculture de Meknès, Morocco, 2012 (in French)
- Montanari B., The Future of Agriculture in the High Atlas Mountains of Morocco: The Need to Integrate Traditional Ecological Knowledge, In *the Future of Mountain Agriculture*, (ed.), Springer Geography, 2013, pp. 51-72
- Mouahidi M., Effet de la fréquence d'abreuvement sur les performances de croissance, la digestibilité et les caractéristiques des carcasses d'antennais Timahdit. Mémoire de 3^{ème} cycle d'Agronomie, I.A.V. Hassan II, Rabat, 1999, pp. 77 (in French)
- Msuya D.G., Pastoralism Beyond Ranching: A Farming System in Severe Stress in Semi-Arid Tropics Especially in Africa, *Journal of Agriculture and Ecology Research International*, 2015, 4(3), 128-139
- Naciri M., L'aménagement et le développement des montagnes au Maroc ; population/Environnement. *Projet MOR/88/PO9*. UNESCO, 1988, pp. 115 (in French)
- Pielou E.C., *Ecological diversity*. Wiley, New York, 1975
- Stitou H., Recherche sur une stratégie de développement de l'élevage adaptée aux structures sociales de la montagne marocaine. Mémoire de fin d'études du Centre National d'Etudes Agronomiques des Régions Chaudes (C.N.E.A.R.C.), 1994, pp. 94 (in French)
- Shannon C.E., Weaver W., *The mathematical theory of communication*. University of Illinois Press, Urbana, 1949
- Strijker D., Marginal lands in Europe: causes of decline. *Basic and Applied Ecology*, 2005, 6, 99-106