Pastoral systems and their interaction with spatio-temporal vegetation dynamics in the Atlas Mountains, Southern Morocco

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To whom it may concern

PhD thesis: "Pastoral systems and their interaction with spatio-temporal vegetation dynamics in the Atlas Mountains, Southern Morocco".

I declare that I have reviewed the language of the 'research report' part of the PhD thesis (title above) written by Zakia Akasbi (University of Hamburg) and, as a native speaker, can certify that it is in proper English.

Sincerely

W. Simonson

Will Simonson
Cambridge

I dedicate this thesis to the memory of my father

And to my wonderful mother

أهدي هذا البحث إلى روح والدي العزيز رحمه الله و إلى والدتي الغالية

Contents

Abstract

Rangeland degradation is an important issue in ecology and rangeland management, especially in the context of global change. Degradation is particularly severe in arid and semi-arid regions and is caused increasingly by livestock overgrazing. In these fragile ecosystems, rangelands are the main fodder resource for livestock. However, rangeland management strategies are still not sufficiently focused on the prevention of rangeland degradation. Therefore, this research has been conducted in semi-arid southern Morocco to study the two grazing systems occurring in this region – the sedentary and the transhumant – and their interaction with the environment and rangeland productivity.

In the first paper, a study in browsed and unbrowsed permanent plots in a sagebrush steppe was conducted. The interannual variability in standing biomass of the three most dominant dwarf shrubs (*Artemisia herba-alba*, *Artemisia mesatlantica* and *Teucrium mideltense*) was assessed in order to study the effect of browsing on biomass changes. Length, width and height of ten plant individuals from each species were measured to calculate their volumes in each treatment. Power-law regression functions of dry biomass on volume were used to estimate the interannual standing biomass variation from 2004 to 2009. Browsing affected the architecture of the dwarf shrubs and thus different functions for the browsed and unbrowsed plots were found. Moreover, browsing affected the three species differently. While browsing had a negative effect on biomass change of *Artemisia herba-alba*, it had no significant effect on *Artemisia mesatlantica*. *Teucrium mideltense* reacted inconsistently to browsing between the years. The fact that the later two species were only marginally benefited from browsing exclusion could be due to the increased competition of the most dominant species *Artemisia herba-alba*. Interestingly, the standing biomass increased whether or not browsing was excluded, but the increase without browsing was almost double that with browsing. This increase might be due to the recovery of the studied species after a preceding long drought. To generalise the findings of this study, I recommend carrying out others studies on the same species at a larger scale.

In the second paper, the general framework of transhumant migration movements was studied, in addition to the drivers and constraints affecting migration decisions by transhumant pastoralists. For this purpose, the three neighbouring tribes of Ait Mgoun, Ait Toumert and Ait Zekri were selected to conduct an ARGOS tracking study and an interview study. One goat herd within each tribe was tracked for a year, and structured interviews were used to describe the transhumance trajectories of the herders. Four

transhumance types were defined in order to describe migration trajectory length: semi-sedentary (less than 20 km), short-distance transhumance (20–40 km), medium-distance transhumance (40–100 km), and long-distance transhumance (more than 100 km). In all the tribes, different types of transhumance occur and the type of transhumance practised could vary between years within the same tribe and even by the same herder. Ecological and socio-economic factors were influencing transhumant migration. The most important factors that drive migration direction were firstly fodder availability and secondly the harsh climate, which forces the pastoralists to leave the cold high mountains in winter and the hot lowlands in summer. Other factors were herd-specific risk and cost assessment as well as personal constraints of the herdsmen. To conclude, this study provided important knowledge on transhumance in southern Morocco and therefore contributes to a better planning of development and management strategies.

In the third paper, which considers sedentary herds, the seasonal variation of the grazing patterns and intensities of tended goat herds were studied as well as their daily trajectories. For this purpose, one herd from each of the villages Ameskar, Taoujgalt and Bou Skour was selected. A GPS collar was fixed on one goat from each herd to track the movement of its herd for a period of a year. Two different recording intervals, 2 hours and 15 minutes, were used to assess the effect of each on the measured daily walking distance. Grazing intensities were calculated within 4-ha grid cells using ArcGIS. The highest grazing intensities were found in the first 250 m from the stable, while they were very low between 2,000 and 4,000 m from the stable. The seasonal mean daily walking distance varied between 3,480 and 4,460 m. It was longest in summer in Ameskar and Taoujgalt while in Bou Skour it was longest in spring. The shortest distances were in winter and autumn. This variation is mainly driven by fodder availability, climatic conditions, and day length. The relationship between GPS recording interval and the daily distance was explained well by the exponential function. This function allows the extrapolation from longer interval data to the actual walking distances. The decay of grazing intensity with increasing distance was described better with power functions and showed that grazing was concentrated around the stables. According to the results of this study, the area within the first 500 m from the village is the most affected by overgrazing and therefore requires specific management strategies.

In conclusion, the three studies provided insights into important issues related to rangeland management and sustainable land use; i.e. the assessment of rangeland productivity and grazing intensity as well as migration patterns of transhumant herds. Moreover, I estimated a range of carrying capacities in the sagebrush steppe of Taoujgalt:

between 0.34 SSU ha^{-1} in a dry year under continuous browsing and 2.32 SSU ha^{-1} in wet years within the exclosure. The carrying capacity within the exclosure was two to five times higher than outside the exclosure. The actual grazing intensity was nearly 13 times higher than the carrying capacity in the 250 m around the village, while the areas over 1000 m from the village were understocked by sedentary herds. The carrying capacity was strongly influenced by precipitation and rangeland conditions; therefore, it should be adjusted depending on precipitation and fodder availability. Consequently, I recommend doing similar studies within other villages and other tribes in order to complement this thesis and to generalize the findings to a larger scale. Additionally, rangeland managers should take into consideration the estimated carrying capacities in their conservation strategies.

Zusammenfassung

Die Degradierung von Weideland ist in der Ökologie und für nachhaltiges Weidemanagement ein wichtiges Thema, insbesondere im Kontext der Debatte über globalen Wandels. Degradierung ist in ariden und semi-ariden Regionen stärker, und überwiegend durch die Überweidung durch Nutztiere verursacht. In diesen empfindlichen Ökosystemen ist Weideland die wichtigste Quelle der Futterressourcen. Allerdings sind Management-Strategien derzeit noch nicht ausreichend auf die Verhinderung von Degradierung ausgerichtet. Deshalb wurde die hier vorgelegte Studie im südlichen Marokko durchgeführt, um die beiden auftretenden Weidesysteme in dieser Region – sedentär und transhumant – und ihre Auswirkungen auf die Umwelt und die Weideproduktivität in dieser Region zu untersuchen.

Im ersten Paper, wird eine Studie in beweideten und unbeweideten Plots in einer Beifuß-Steppe durchgeführt. Die interannuelle Variabilität der stehenden Biomasse von den drei häufigsten Zwergsträuchern *Artemisia herba-alba*, *Artemisia mesatlantica* und *Teucrium mideltense* wurde untersucht, um die Beweidungsauswirkung auf die Biomasse zu bewerten. Länge, Breite und Höhe von zehn Individuen der drei Arten wurden innerhalb und außerhalb des Zaunes gemessen, um ihre Volumina zu kalkulieren. Exponentielle Regressionsfunktionen von getrockneter Biomasse auf Volumina wurden gefunden. Diese Funktionen in der Folge benutzt für die Einschätzung der Biomassevariabilität von 2004 bis 2009. Die Beweidung hat die Zwergstraucharchitektur beeinflusst. Außerdem war der Beweidungseinfluss zwischen den Arten unterschiedlich. Während Beweidung einen negativen Einfluss auf die Biomasse von *Artemisia herba-alba* hatte, konnte kein signifikanter Einfluss auf *Artemisia mesatlantica* nachgewiesen werden. Der Einfluss auf *Teucrium mideltense* war von Jahr zu Jahr unterschiedlich. Die Tatsache, dass die letzten zwei Arten vom Beweidungsausschluss kaum profitieren ist wahrscheinlich der erhöhten Konkurrenz der dominanten Art *Artemisia herba-alba* geschuldet. Ein weiteres interessantes Ergebnis ist, dass die stehende Biomasse sich unter beiden Treatments (mit und ohne Beweidung) erhöht hat, der Anstieg ohne Beweidung aber fast doppelt so hoch war wie mit Beweidung. Dieser Anstieg könnte durch die Erholung der untersuchten Arten nach einer vorangegangenen langen Dürreperiode bedingt sein. Um die Ergebnisse meiner Studie zu verallgemeinern, empfehle ich die Durchführung vergleichbarer Studien in einer größeren Region.

Im zweiten Paper wurde der allgemeine Rahmen der transhumanten Migrationsbewegungen untersucht, zusätzlich zu den Faktoren und Zwängen, die die

Migrationsentscheindungen der transhumanten Herdenbesitzer beeinflussen. Zu diesem Zweck wurden die drei benachbarten Stämmen der Ait Mgoun, Ait Toumert und Ait Zekri ausgewählt, um eine ARGOS Tracking Studie und eine Interview Studie durchzuführen. Eine Ziegenherde jedes Stammes wurde für ein Jahr mit einem Argos Sender verfolgt und strukturierte Interviews wurden verwendet, um die Wanderbewegungen der Hirten zu beschreiben. Semi-sedentäre Wanderungen (weniger als 20 km vom Wohnort entfernt), Kurzstrecken-Transhumanz (20-40 km), Mittelstrecken-Transhumanz (40-100 km), und Langstrecken-Transhumanz (mehr als 100 km). In allen drei Stämmen treten verschiedene Arten von Transhumanz auf und die Art der Transhumanz, die praktiziert wird, kann sich zwischen den Jahren innerhalb des gleichen Stammes und sogar beim gleichen Hirten ändern. Ökologischen und sozio-ökonomische Einflussfaktoren beeinflussen die Wanderungsentscheidungen der Hirten. Die wichtigsten Faktoren waren erstens die Verfügbarkeit des Futters und zweitens das Klima, das die Hirten zwingt, die kalten Hochgebirge im Winter und die heißen Tiefebenen im Sommer zu verlassen. Andere Einflussfaktoren betreffen spezifische Risiken für die Herden, die Einschätzung der Wanderungskosten sowie persönliche Lebensumstände der Hirten. Diese Studie erbrachte wichtige Erkenntnisse über die Transhumanz im Südlichen Marokkos und kann damit zu einer besseren Planung von weidewirtschaftlichen Entwicklungs-und Management-Strategien beitragen.

Im dritten Paper über sesshafte Herden wurden die jahreszeitlichen Änderungen der Beweidungsmuster und -intensitäten von Ziegenherden sowie ihre täglichen Weidegänge untersucht. Zu diesem Zweck wurde eine Herde aus jedem der drei Dörfer Ameskar, Taoujgalt und Bou Skour ausgewählt. auf Einer Ziege aus jeder Herde wurde mit einem GPS-Halsband ausgerüstet, um die Bewegung ihrer Herde für einen Zeitraum von einem Jahr zu verfolgen. Zwei unterschiedliche zeitliche Auflösungen, 2 Stunden und 15 Minuten, wurden verwendet, um die Wirkung der GPS-Auflösungen auf die kalkulierte tägliche Wanderungsstrecke zu bewerten. Beweidungsintensitäten wurden mit ArcGIS auf der Grundlage von 4-ha Gitterzellen berechnet. Die höchsten Beweidungsintensitäten wurden in den ersten 250 m vom Stall gefunden, während sie in Entfernungen zwischen 2000 und 4000 m vom Stall sehr niedrig waren. Die jahreszeitlich durchschnittliche tägliche Strecke des Weidegangs variiert zwischen 3480 und 4460 m. Sie war in Ameskar und Taoujgalt im Sommer am längsten, während sie in Bou Skour im Frühjahr am längsten war. Die kürzesten Weidegänge fanden sich im Herbst und Winter. Dieser Unterschied wird vor allem durch die Verfügbarkeit des Futters, klimatische Bedingungen, und die Tageslänge erklärt. Die Beziehung zwischen GPS-Auflösung und der täglichen Strecke des Weideganges wurde durch eine Exponentialfunktion erklärt.

Diese Funktion ermöglicht die Extrapolation von längeren zeitlichen Intervallen der Positionsdaten auf die tatsächlich zurückgelegten Strecken. Die Abnahme der Beweidungsintensität mit zunehmender Entfernung vom Stall wurde besser mit Potenzfunktionen beschrieben und zeigte, dass die Beweidung direkt rund um die Ställe stark konzentriert ist. Nach den Ergebnissen dieser Studie ist das Gebiet innerhalb eines Radius von 500 m um das Dorf am stärksten durch Überweidung betroffen und benötigt daher spezifische Management-Strategien.

In ihrer Gesamtheit geben die drei Studien Antworten auf wichtige Fragen im Zusammenhang mit Weideland und nachhaltiger Landnutzung in Südmarokko, insbesondere in Bezug auf die Bewertung der Weidelandproduktivität und Beweidungsintensität sowie auf Migrations-Muster der transhumanten Herden. Abschließend habe ich die Daten der Einzelstudien genutzt, um die Tragfähigkeit der Beifuß-Steppe von Taoujgalt schätzen. Die Tragfähigkeit lag zwischen 0,34 SSU ha^{-1} in trockenen Jahren unter kontinuierlich Beweidung und 2,32 SSU ha^{-1} in nassen Jahren bei Weideausschluss (SSU = *small stock unit* = Kleinvieheinheit). Die Tragfähigkeit im ausgezäunten Bereich war zwei- bis fünfmal höher als außerhalb des Zauns. Die tatsächliche Beweidungsintensität in den 250 m rund um das Dorf war fast 13-mal höher als die Tragfähigkeit, während die Flächen in über 1000 m Entfernung vom Dorf „unterbeweidet“ waren. Die Tragfähigkeit wurde stark vom Niederschlagsgeschehen und dem Zustand des Weidelandes beeinflusst. Daher sollte die Tragfähigkeit nicht als eine fixe Größe betrachtet, sondern fallspezifisch berechnet werden. Diese Daten sollten Weidelandmanager dann bei der Festlegung des Flächenmanagements berücksichtigen. Ergänzend empfehle ich, ähnliche Studien in anderen Dörfern und Stammesgebieten der Region durchzuführen, um die Verallgemeinerung der Ergebnisse für ein größeres Gebiet zu erlauben.

Résumé

La problématique de la dégradation des terrains de parcours constitue une menace réelle aux systèmes écologiques et à l'aménagement des pâturages. Cette problématique s'accentue avec le changement global. La dégradation des terrains de parcours est plus marquée dans les régions arides et semi-arides. Elle est due principalement au surpâturage. Dans ces écosystèmes fragiles, les parcours constituent la ressource fourragère incontournable pour le bétail. Pourtant, les stratégies d'aménagement de ces parcours ne sont pas pour autant satisfaisantes. Par le sujet, la présente recherche a été conduite au Sud du Maroc afin d'analyser les deux modes de pâturage – sédentaire et transhumant – fréquents dans la zone et évaluer leurs interactions avec la productivité des terrains de parcours. Cette recherche a fait objet de trois articles:

Article 1: Etude des placettes de mesure pâturées et autres mises en défens.

L'objet de ces mesures est d'évaluer la variabilité interannuelle de la biomasse sur pied de trois espèces ligneux bas dominantes dans la steppe d'armoise; *Artemisia herba-alba*, *Artemisia mesatlantica* et *Teucrium mideltense* afin d'apprécier l'effet du pâturage sur les changements de la biomasse. La méthode suivie consistait à mesurer, au sein des placettes (pâturées et mises en défens), la longueur, la largeur et la hauteur de dix individus de chaque espèce puis calculer leurs volumes correspondants. Ces données ont été traitées par les fonctions de loi de puissance de la biomasse sèche sur le volume des individus des plantes. Ces fonctions ont été utilisées pour estimer la variation interannuelle de la biomasse de 2004 à 2009. L'interprétation des résultats de ces fonctions nous a permis de constater que le pâturage a affecté l'architecture des ligneux bas et par conséquent différentes fonctions pour les parcelles pâturées et non-pâturées ont été produites. Cette affectation ne suit pas la même tendance chez les trois espèces. Le pâturage a eu un effet négatif sur le changement de la biomasse d'*Artemisia herba-alba*, mais n'a eu aucun effet significatif sur *Artemisia mesatlantica*. La réaction de *Teucrium mideltense*, a varié en fonction des années. Le constat pourrait se justifier pas la concurrence de l'espèce la plus dominante *Artemisia herba-alba*.qui a réduit les chances des deux autres espèces de bénéficier de la mise en défens. Un autre résultat intéressant est que la biomasse sur pied des trois espèces a augmenté avec ou sans pâturage. L'augmentation sans pâturage était presque deux fois plus élevée qu'avec pâturage. Cette augmentation pourrait être due à la reprise des espèces étudiées après une longue période de sécheresse. Pour généraliser les conclusions de cette étude, nous recommandons la conduite d'autres études approfondies sur les mêmes espèces à plus grande échelle.

Article 2: Etude du cadre général des mouvements migratoires des transhumants et les facteurs et contraintes affectant leur décision de migration.

Pour cette fin, nous avons sélectionné trois tribus voisines; Ait Mgoun, Ait Toumert et Ait Zekri. Ces trois tribus ont fait objet d'étude menée avec les colliers ARGOS complétée par une étude d'enquêtes réalisée par nous-mêmes. Le processus de l'étude consistait, d'une part à identifier et suivre un troupeau de chèvre dans chaque tribu pendant un an et d'autre part à remplir des questionnaires structurées pour décrire les trajectoires de transhumance. Quatre modes de transhumance ont été distingués: semi-sédentaire (moins de 20 km), transhumance à courte distance (20-40 km), transhumance à moyenne distance (40-100 km), et transhumance à longue distance (plus de 100 km). Les quatre modes de transhumance existent au sein des trois tribus. La dominance de l'un ou l'autre varie entre les années, au sein de la même tribu et chez l'éleveur lui-même. Plusieurs facteurs écologiques et socio-économiques influencent la décision de migration des transhumants. La disponibilité du fourrage et le climat rigoureux qui oblige les éleveurs à quitter les hautes montagnes froides en hiver et les plaines chaudes en été constituent les deux facteurs majeurs. En outre, les éleveurs prennent en considération le risque de perte du troupeau (cas de maladies) et les coûts de transhumance, ainsi que leurs contraintes personnelles et familiales. Pour conclure, cette étude a réalisé des constats intéressants sur les mouvements de transhumance au sud du Maroc et qui peuvent contribuer à une meilleure planification des stratégies de développement et d'aménagement des parcours.

Article 3: Etude des modes et intensité de pâturage des troupeaux de chèvres sédentaires, ainsi que leurs trajectoires quotidiens.

Un troupeau au niveau de chaque village Ameskar, Taoujgalt et Bou Skour a été identifié. Par la suite, nous avons fixé un collier GPS sur une chèvre au sein de chaque troupeau afin de suivre ses mouvements et ceux de son troupeau pendant une année. Deux intervalles d'enregistrement différents (2 heures et 15 minutes) ont été utilisé et ont permis d'évaluer l'effet de l'intervalle d'enregistrement sur la distance quotidienne parcourue. L'intensité de pâturage dans des cellules de 4 ha a été calculée à l'aide du logiciel ArcGIS. Suite à l'analyse de la variation saisonnière des intensités de pâturage et les trajectoires quotidiennes des chèvres nous avons enregistrées qu'elles sont plus élevées dans les premières 250 m des étables et plus faibles entre 2000 et 4000 m de l'étable. La distance moyenne quotidiennement parcourue a varié entre 3480 et 4460 m. les distances les plus longues ont été parcourues en été à Ameskar et Taoujgalt et au printemps à Bou Skour. Les distances les plus courtes étaient parcourues en hiver et en automne. Cette variation est due principalement à la disponibilité du fourrage, les conditions climatiques, et la longueur de la journée. La relation entre l'intervalle d'enregistrement du GPS et la distance quotidienne a été bien expliquée par la fonction exponentielle. Cette fonction permet l'extrapolation des données de grand intervalle aux distances réelles parcourues. La diminution de l'intensité du pâturage avec la distance a été décrite mieux avec des fonctions de puissance et montre que le pâturage a été agglutiné autour des étables. D'après les résultats ce cette étude, la zone située dans les premières 500 m du village est la plus touchée par le surpâturage et par conséquent, elle nécessite plus de conservation et de stratégies d'aménagement.

En résumé, les trois études ont répondu aux questions importantes liées à la gestion des pâturages et à l'utilisation durable des terres; telles que l'évaluation de la productivité des parcours et l'intensité du pâturage et l'analyse des mouvements migratoires des troupeaux transhumants. Elles ont permis de déterminer un intervalle de la capacité de charge de la steppe d'armoise à Taoujgalt. La capacité de charge a varié entre 0,34 unités de petit bétail par hectare dans une année sèche sous pâturage continu et 3,32 unités de petit bétail dans des années pluvieuses dans la mise en défens. La capacité de charge dans la mise en défens a été deux à cinq fois plus élevée qu'à l'extérieur. L'intensité du pâturage est presque 13 fois plus élevée que cette capacité de charge dans les 250 m autour du village, tandis que les zones à plus de 1000 m du village étaient sous-pâturées par les troupeaux sédentaires. La capacité de charge était fortement influencée par les précipitations et les conditions du parcours. Par conséquent, elle ne doit pas être considérée comme un chiffre fixe, mais ajustée en fonction des précipitations et de la disponibilité du fourrage. Les responsables d'aménagement des pâturages doivent prendre en considération les capacités de charge fournie dans leurs stratégies de conservation des terres de parcours. Afin de compléter la présente étude et de généraliser les résultats à plus grande échelle, il est recommandé de faire des études similaires dans d'autres villages et d'autres tribus.

ملخص

إن إشكالية تدهور المراعي، خاصة مع التغير المناخي العالمي، أخذت اهتماما بالغا في علم البيئة وحماية المراعي. وتزداد حدة هذه الإشكالية في المناطق الجافة وشبه الجافة، كما يساهم الرعي الجائر في تأزيم الوضعية. ورغم كون المراعي تشكل المصدر الأساسي لعلف المواشي داخل هذه النظم البيئية الهشة فإن مخططات استصلاح هذه المراعي لاتزال دون المستوى. في نفس السياق، يندرج البحث الحالي الذي أنجز بجنوب المغرب والذي اهتم بدراسة نظامي الرعي المستقر وشبه المترحل في المنطقة وتفاعلهما مع البيئة وإنتاجية المراعي.

البحث الأول: تتبع نمو النباتات في سهوب الشيح

لهذا الغرض تم تحديد قطع أرضية صغيرة تضم قطعا خاضعة للرعي وأخرى محمية وذلك من أجل تتبع نمو النباتات فيها بصفة مستمرة. بعد ذلك قمنا بتقييم تغيرات الكتلة الحيوية للشجيرات الثلاث الأكثر انتشارا في المنطقة *Artemisia herba-alba*،*Artemisia mesatlantica* و *Teucrium mideltense* من أجل دراسة تأثير الرعي على كتلتها الحيوية. حيث قمنا بقياس طول وعرض وارتفاع عشرة شجيرات من كل نوع لحساب أحجامها في المحمية وخارجها. ثم تمكنا من حساب تغيرالكتلة الحيوية من سنة 2004 إلى 2009 عن طريق دوال القوة بين الكتلة الحيوية الجافة للشجيرات وأحجامها. من أهم نتائج هذه الدراسة تبين أن الرعي يؤثر على بنية الشجيرات . علاوة على ذلك وجدنا أن الرعي يؤثر بشكل متفاوت على الشجيرات الثلاثة. حيث أن الرعي كان له تأثير سلبي على الكتلة الحيوية ل *Artemisia herba-alba*ولم يكن له تأثير واضح على *Artemisia mesatlantica*. بينما كان تأثير الرعي على *Teucrium mideltense* متغيرا بين السنوات. ويمكن تفسير الاستفادة الضعيفة للنوعين الأخيرين من عدم الرعي بزيادة المنافسة لهما من أكثر الأنواع انتشارا *Artemisia herba-alba*. النتيجة الأخرى المثيرة للاهتمام هي أن الكتلة الحيوية ارتفعت سواء بوجود أو بدون وجود رعي. هذه الزيادة تمت بمقدار ضعفين داخل المحمية مقارنة مع خارجها. قد تكون هذه الزيادة نتيجة لانتعاش النباتات بعد جفاف السنوات السابقة. لتعميم نتائج هذه الدراسة، نوصي بالقيام بدراسات أخرى على نفس الشجيرات على نطاق أوسع.

البحث الثاني: دراسة الإطار العام لهجرة الرعاة الرحل والعوامل التي تؤثر على قرارهم بالهجرة

لهذا الغرض،قمنا باختيار قطيع واحد من كل من القبائل المتجاورة الثلاث قبيلة آيت مكون وقبيلة آيت تومرت وقبيلة آيت زكري وأجرينا دراسة باستعمال أطواق العنق ARGOS

(Advanced Research and Global Observation Satellite)

اخترنا معزة واحدة من كل قطيع و تتبعنا حركة القطعان لمدة سنة. كما قمنا أيضا باستجواب الرعاة لتتبع تحركات هجرتهم وفهم العوامل الكامنة وراء قراراتهم بالهجرة. لتحديد طول طريق هجرة الرعاة، حددنا أربعة أنواع من الأنظمة. نظام شبه مستقر حينما يكون مسار الهجرة أقل من 20 كيلومترا ونظام هجرة قصيرة المسافة من 20 إلى 40 كلم ، ونظام هجرة متوسطة المسافة من 40 إلى 100 كلم ونظام هجرة طويلة المسافة أكثر من 100 كلم. بتشخيص هذه الأنظمة داخل القبائل، وجدنا انها تتبع مختلف أنواع الهجرة كما أن نوع الهجرة يمكن أن يتغير بين السنوات داخل القبيلة نفسها و حتى بالنسبة لنفس الراعي. وجدنا أن العوامل التي تؤثر على هجرة الرعاة إما بيئية أو إجتماعية أوإقتصادية. من أهم تلك العوامل توفر الأعلاف في المراعي والظروف المناخية القاسية التي تفرض على الرعاة مغادرة الجبال العالية

الباردة في الشتاء والسهول الشديدة الحرارة في الصيف. إضافة إلى المخاطر التي قد يتعرض لها القطيع وتكاليف الهجرة، فضلا عن الظروف الشخصية للراعي. وللخلاصة فإن هذه الدراسة تقدم معلومات هامة حول هجرة الرعاة في جنوب المغرب ويمكنها أن تساهم في تحسين التخطيط لاستراتيجيات التنمية وإصلاح المراعي.

البحث الثالث: الرعي المستقر، دراسة أنماط وشدة رعي قطعان الماعز إضافة إلى تحديد مساراتها اليومية

لهذا الغرض، اختارنا قطيعا واحدا داخل كل من القرى التالية: أمسكاروتاوجكالت و بوسكور.حيث قمنا بتثبيت طوق GPS (Global Positioning System) على معزة واحدة من كل قطيع لتتبع حركة القطيع لمدة سنة. قمنا خلالها باختيار فترتي تسجيل GPS مختلفتين وهما فترة ساعتين وفترة 15 دقيقة لتقييم تأثير الفاصل الزمني للتسجيل على مسافة المشي المحسوبة يوميا. بعد حساب شدة الرعي في خلايا مساحتها 4 هكتارات باستخدام نظام المعلومات الجغرافية ArcGIS، درسنا التغير الموسمي لشدة الرعي والمسارات اليومية للماعز.وقد أسفرت النتائج على أن أعلى شدة للرعي في 250 متر الأولى من الحظيرة، في حين أن شدة الرعي كانت منخفضة جدا بين 2000 و 4000 متر من الحظيرة كما أن المسافة اليومية التي يمشيها الماعز تراوحت بين 3480 و 4460 متر. وقد سجلت أطول المسافات خلال فصل الصيف في أمسكار وتاوجكالت بينما كانت أطول مسافة مسجلة في بوسكور خلال فصل الربيع. أما أقصر المسافات فسجلت في فصلي الشتاء والخريف. ويرجع هذا الاختلاف أساسا إلى مدى توفر العلف، والظروف المناخية، وطول النهار. وقد تم التعبير عن العلاقة بين مسافة المشي اليومية و الفاصل الزمني للتسجيل ب GPS بشكل جيد بواسطة الدالة الأسية. هذه الدالة تسمح لنا باستنتاج مسافة المشي الفعلية من خلال معطيات ذات فاصل زمني طويل. أما انخفاض شدة الرعي مع زيادة المسافة فقد وصفت بشكل أفضل بواسطة دالة القوة وأظهرت تركز الرعي حول الحظائر. وفقا لنتائج هذه الدراسة، فإن المنطقة الموجودة على مسافة 500 متر من القرية هي الأكثر تضررا من الرعي الجائر، وبالتالي فإنها تتطلب المزيد من استراتيجيات المحافظة و الإصلاح.

إجمالا لقد قدمت الدراسات الثلاث إجابات مهمة حول قضايا أساسية متعلقة بإدارة المراعي والاستخدام المستدام للأراضي من قبيل تقييم إنتاجية المراعي وشدة الرعي، فضلا عن أنماط الهجرة لقطعان الرحل.، هذا بالإضافة إلى حساب الحمولة الرعوية في سهوب الشيح التي تراوحت ما بين 0,34 وحدة حيوانية صغيرة (معزة أو خروفا) في الهكتار خلال سنة جافة و تحت رعي مستمر و 2,32 وحدة حيوانية صغيرة في السنوات الرطبة داخل المحمية. و مثلت الحمولة الرعوية في المحمية ضعف إلى خمسة أضعاف مثيلتها خارج المحمية. كما أن شدة رعي القطيع المستقر المطبقة هناك قاربت 13 أضعاف الحمولة الرعوية في المنطقة المتواجدة على مسافة 250 متر من القرية، أما المناطق الموجودة على مسافة أكثر من 1000 متر فشدة الرعي بها ضعيفة. وقد تغيرت الحمولة الرعوية بشدة مع كمية الأمطار وحالة المراعي .لذلك، فإنه لا ينبغي أن تعتبر الحمولة الرعوية قيمة ثابتة ولكن يجب تعديلها اعتمادا على كمية هطول الأمطار وتوافر الأعلاف في المراعي. وفي الأخيرنقترح على المسؤولين عن حماية المراعي أخذ قيم الحمولة الرعوية المحسوبة في هذه الدراسة بعين الاعتبارداخل استراتيجيات الحفاظ على المراعي. ولتعميق هذه النتائج وتعميمها على نطاق أوسع، فإننا نوصي بإنجاز دراسات شبيهة داخل قرى وقبائل أخرى بالجنوب المغربي.

Chapter 1

General Introduction

Dry rangelands play an important role in the subsistence of rural populations and support 50% of the world's livestock (World Resources Institute 2005). However, these rangelands are subject to severe degradation and continuous reduction of their areas. Approximately 15% of dry rangelands were converted to farmland between 1900 and 1950, and this conversion has accelerated in the decades since (World Resources Institute 2005). Likewise, 73% of dry rangelands worldwide are affected by soil degradation (WOCAT & CDE 2009). Overgrazing – defined as continued heavy grazing which exceeds the recovery capacity of the rangeland and leads to its deterioration (Mullahey et al. 2006) – can be considered the main driver of degradation and reduction in long-term productivity of dry rangelands (Todd & Hoffman 1999). Other frequently mentioned causes of degradation include drought, firewood extraction, and the irresponsible use of pastoral plant species for industrial uses such as oil extraction (Le Houérou 1990; Fikri Benbrahim et al. 2004).

In Morocco, dry rangelands suffer a dramatic loss of quality and productivity: 81% are considered as fairly degraded, and 12.5% as strongly degraded (World Bank 2003). The socio-economic and ecological consequences of this are significant (Cuzin 1996; Cuzin 2003) and exacerbated by climate change. From the mid-1970s to the mid-1990s rangeland areas declined by 10% (Abdelguerfi and Laouar 2000) due to conversion to dryland agriculture (Nefzaoui 2002), and forage production on rangelands decreased between 1984 and 1992 from 4.3 to 3.6 billion forage units (FUs). The Moroccan government undertook several initiatives to combat degradation (MADRPM 1999; MADREF 2000); nevertheless their implementation falls short of expectations, partly due to institutional investment constraints on "collective" rangelands and the lack of acceptance of a top-down planning and management approach (Finckh and Kirscht 2008). This situation requires that decision-makers and resource managers look for best management solutions in order to restore the productivity of rangeland ecosystems and thus improve economic conditions for the local communities.

In order to define sustainable rangeland use intensities, the concept of carrying capacity is widely used in rangeland resource management (Scarnecchia 1990). Carrying capacity is defined as the maximum livestock or wildlife population that an ecosystem can support on a sustainable basis (Dijkman 1999). This definition was revised by Scarnecchia (1990) as the optimum number of individuals or units to achieve specific objectives given specified management options. However, the assessment of carrying capacity, which is based on stocking rates (Galt et al. 2000) and fodder production, remains a challenge in arid and semi-arid rangelands due to the high interannual and seasonal variability of plant growth (Cook and Stubbendieck 1986; De Leeuw and Tothill 1990; Gillson and Hoffman 2007; Jahantigh and Pessarakli 2009). Moreover, problems arise due to different approaches being used to assess carrying capacity in management studies. These approaches can be qualitative or quantitative. The qualitative assessment is based on the visual observation of the rangeland by experienced managers and scientists, with grazing intensity being expressed as light, moderate or heavy grazing (Holecheck and Galt 2000).Meanwhile, quantitative assessment approaches use quantitative parameters such as the stocking rate – defined as the number of specific kinds and classes of animals grazing or utilizing a unit of land for a specified time period (animal unit months per area) (Mullahey et al. 2006) – or the percentage of forage utilized to express grazing intensity (Holecheck and Galt 2000). However, all these parameters that express the carrying capacity vary between ecosystems, and between years and seasons in the same ecosystem, due to variations in vegetation production. Thus, what could be considered as heavy grazing in a dry year could be regarded as light grazing in a rainy year. Therefore, for sustainable rangeland management it is important to quantify the production of, and fluctuations in, plant production and thus to assess annual or even seasonal carrying capacities for each ecosystem.

Despite their importance and their degradation, dry rangelands are understudied in southern Morocco. Few studies have addressed the dynamics and resilience of these rangelands and their carrying capacity, which informs appropriate stocking rates, has not been estimated. Thus, I conducted this study in southern Morocco to evaluate the effects of pastoral systems on rangeland production as well as to assess the carrying capacity of these rangelands and their actual grazing intensities.

This thesis is based on three studies and consists of six chapters.

Chapter 4 (paper I) is a study of biomass estimation of the three most dominant dwarf shrubs – *Artemisia herba-alba*, *Artemisia mesatlantica* and *Teucrium mideltense* – in an exclosure experiment over five years in a sagebrush steppe. Its aim was to estimate the interannual variability in standing biomass and thus study the effect of browsing on biomass production by comparing browsed and unbrowsed plots. Regression functions of volume on biomass were used to estimate the standing biomass. This paper is published in *The African Journal of Range and Forage Science*.

Chapter 5 (paper II) presents a study of transhumant migration within the three neighboring tribes of Ait Mgoun, Ait Zekri and Ait Toumert in the Atlas Mountains. Its aim was to describe the grazing trajectories of the transhumant pastoralists belonging to the tribes and to discuss the social and ecological factors influencing their migration decisions. For this purpose, we used ARGOS trajectories and interview data to describe the migration pattern of the transhumant pastoralists. This paper is published in the *Journal of Mountain Science*.

Chapter 6 (paper III) presents a study of three sedentary goat herds in the three villages of Ameskar, Taoujgalt and Bou Skour in southern Morocco. Its aim was to characterize the spatio-temporal grazing patterns and intensities of the three herds and assess their daily grazing distances. For this purpose, one goat was selected from one herd in each village and was tracked for a year using GPS collars to follow the movement of its herd. This paper is under review in *The Rangeland Journal*.

Chapter 2 is an introduction to the study area in southern Morocco. It includes some general information about the rangelands in southern Morocco, and gives information about the location, climate, vegetation types, soils and geology as well as land use types.

Chapter 3 consists of a general discussion of the research. It presents a broader explanation of the three studies and the calculation of the carrying capacity of the sagebrush steppe in Taoujgalt (Figure 2) within and outside the exclosure for rainy years (2007–2009) and a less rainy year (2005). In addition some management recommendations, research perspectives and conclusions are presented.

Chapter 2

Study Area

2.1. General context of the study

This research was conducted within the context of the BIOTA Maroc project (www.biota-africa.com). This project, a co-initiative of scientists at the University of Hamburg and the Institut Agronomique et Vétérinaire Hassan II in Rabat, monitored biodiversity changes on the Saharan fringe of the High Atlas Mountains in southern Morocco. The objectives of BIOTA Maroc were twofold: (1) to use the biodiversity monitoring results to create suitable tools for sustainable land use and resource management under changing environmental and socio-economic conditions; and (2) to develop, together with the Moroccan partners, adequate intervention schemes and knowledge transfer formats for participative resource planning processes at the communal level.

2.2. General location of the study area

The study area is located in Morocco, a country in North Africa with a climate spanning from Mediterranean to Saharan (Figure 1). The country is crossed by four major mountain chains: the Rif Mountains in the north, the Middle Atlas in the centre, and the High Atlas and Anti-Atlas in the south (Figure 1). Rangelands cover more than 60 million ha and constitute 82% of the drylands (Croitoru and Sarraf 2010). These rangelands are the main source of fodder for livestock and contribute to the subsistence of thousands of people (Mahyou et al. 2010).

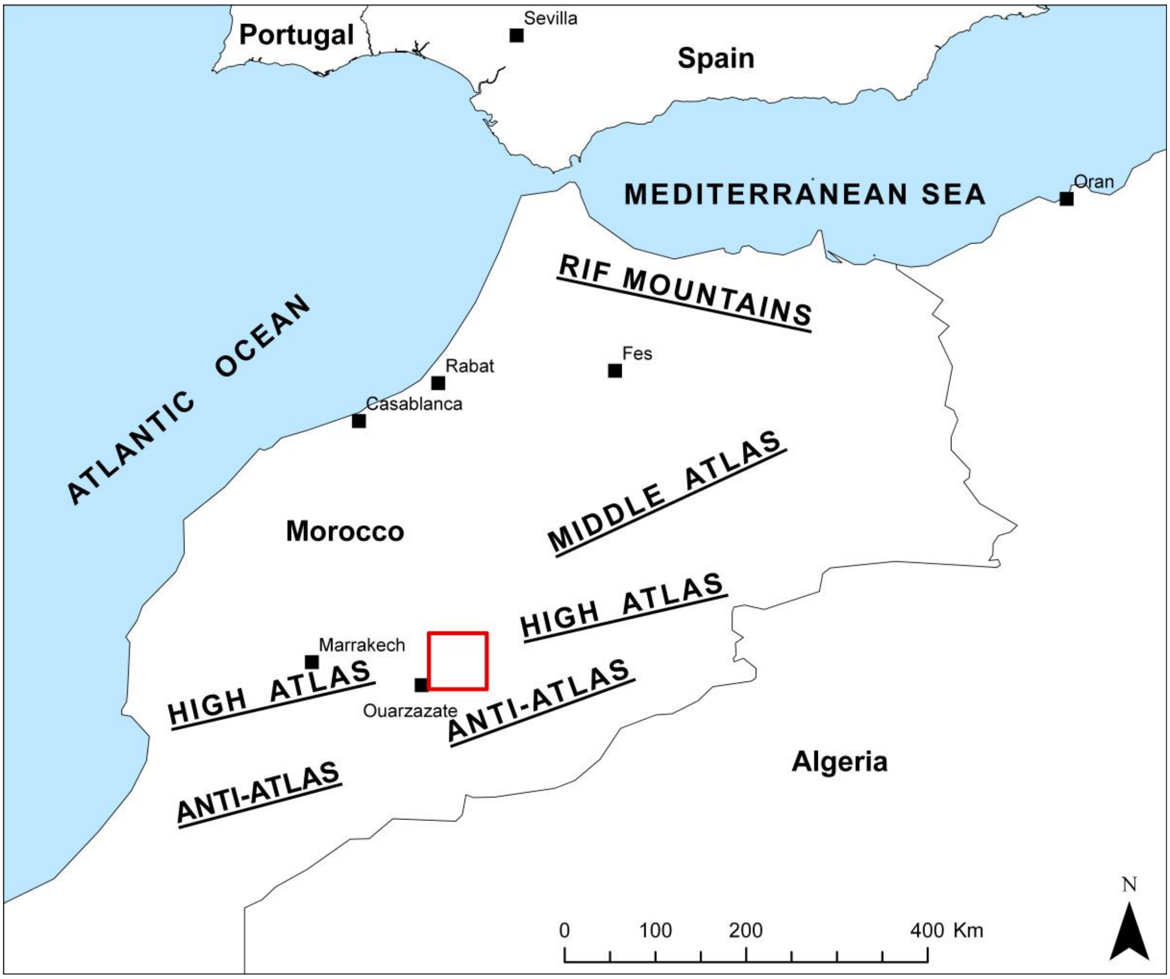

Figure 1. Arrangement of the main mountain chains in Morocco. The red rectangle shows the location of the study area.

2.3. Location of the study area

This study was conducted in the transition zone between the Central High Atlas and the Pre-Saharan Anti-Atlas in southern Morocco (Figure 2). The elevation ranges between 4071 m in the Jebel Mgoun and 1100 m a.s.l. in the Basin of Ouarzazate. The climate in the study area ranges from cold and cool semi-arid in the High Atlas mountains to per-arid cool in the Anti-Atlas with hot and dry summers (Oldeland et al. 2008). The precipitation varies between 600 mm/yr in the summit region of the High Atlas and 110 mm/yr in the Basin of Ouarzazate (Schulz 2008a).

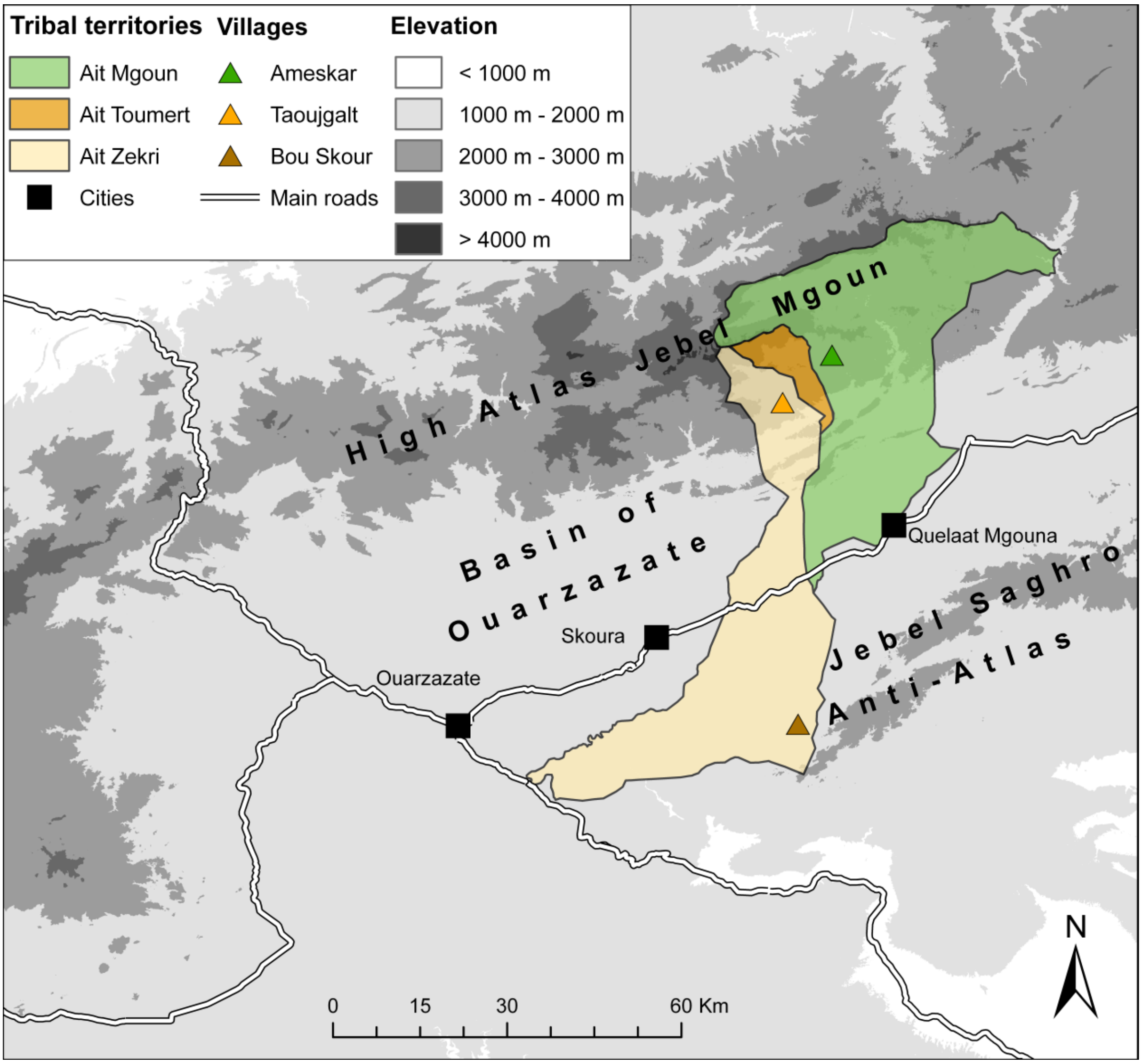

Figure 2. Location of the study area in southern Morocco. Paper I is set in Taoujgalt (chapter 4), paper II in the three tribal territories (chapter 5), and paper III in the three villages Ameskar, Taoujgalt and Bou Skour (chapter 6).

2.4. Vegetation units

The study area comprises different vegetation units (Finckh & Fritzsche 2008): from Oromediterranean high mountain ecosystems with vegetation development in summer, across sagebrush steppes with bimodal vegetation growth in spring and autumn, down to Pre-Saharan steppes and semi-deserts with an ephemeral vegetation development in spring in the Basin of Ouarzazate and in the eastern Anti-Atlas (Jebel Saghro) (Finckh & Poete 2008).

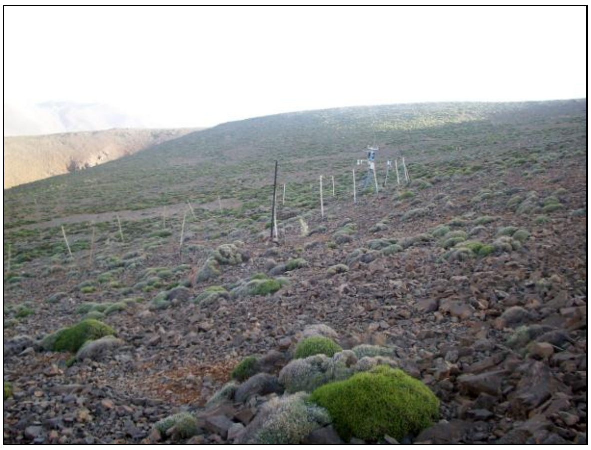


Figure 3. The Oromediteranean ecosystem, test sites of Tichki (left) and Tizi n Tounza (right)

The Oromediterranean ecosystem at high altitudes of the High Atlas (above approximately 2900 m a.s.l.) is dominated by thorny cushion shrubs (Finckh and Poete 2008) such as *Bupleurum spinosum* Gouan, *Alyssum spinosum* L., *Erinacea anthyllis* Link and *Cytisus purgans* Spach (Figure 3). At lower altitudes of down to about 2200 m a.s.l. occurs the Mediterranean Juniper steppe ecosystem dominated by *Juniperus* tree species, *Artemisia* species and *Teucrium mideltense* Humb. (Figure 4). The southern slopes of the High Atlas consist of Ibero-Mauretanian sagebrush steppes dominated by dwarf shrubs such as *Artemisia* species, *Teucrium mideltense* Humb. in addition to different perennial grasses like *Stipa parviflora* Desf. and *Lygeum spartum* L. (Finckh and Poete 2008).


Figure 4. Mediterranean Juniper steppe of the Ameskar test site (left), and the sagebrush steppe of the Taoujgalt test site (right)

Finally, the semi-desert ecosystem from the Ouarzazate Basin to the Jebel Saghro is dominated by dwarf shrubs such as *Convolvulus trabutianus* Schweinf. and Muschl. and *Hammada scoparia* (Pomel) Iljin. (Figure 5).

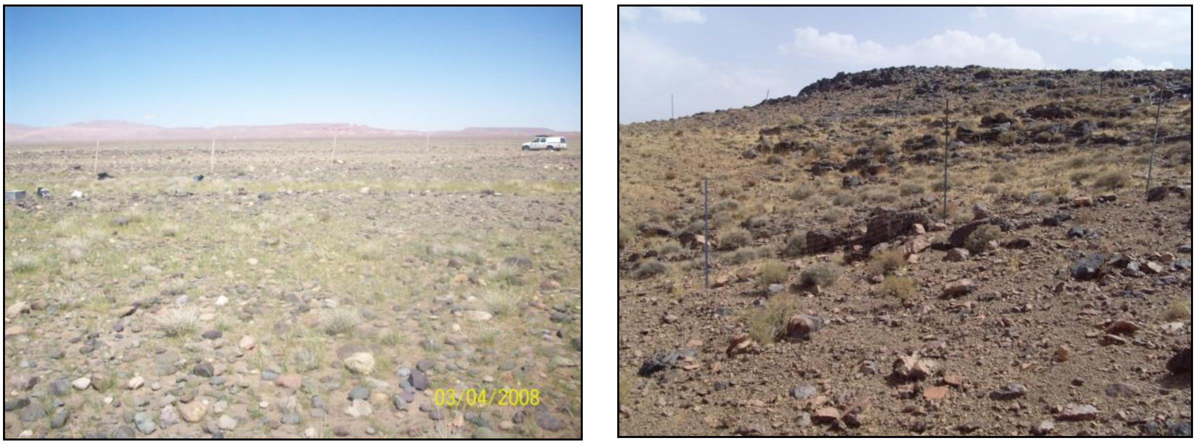

Figure 5. Semi-desert in the basin of Ouarzazate at the Trab Labied test site (left) and in the Anti-Atlas at the Bou Skour test site (right).

2.5. Geology and soils

The study area comprises three main geological units. From north to south they are the High Atlas, the Ouarzazate Basin and the Anti-Atlas. In the High Atlas Mountains as well as in the sediment-filled basins on the fringe of the Saharan Desert, we find a mixture of Mesozoic and Tertiary calcareous and silicate rocks (Menz 2010), while in the Anti-Atlas we find a Proterozoic basement of crystalline bedrocks of Precambrian age with a Paleozoic cover of mainly shallow marine origin (Burkhard et al. 2006; Menz 2010).

The soils in the study area are little developed (Schulz 2008b) and fragile because of their low organic-matter content (World Bank 2003; Klose 2009) and they suffer from water and wind erosion (Croitoru and Sarraf 2010). The most common soil types in the study area are Calcisols, Regosols and Leptosols (Klose 2009). Other predominant types are Luvisols, Fluvisols and occasionally Cambisols, Vertisols and Solonchaks (Miller 2002). In the Anti-Atlas, calcaric Regosols as well as lithic and chromic Leptosols are more common (Weber 2004), interspersed with basaltic outcrops (Schulz et al. 2010). They are characterized by a high skeleton and $CaCO_3$ content, high pH values and partially strong salinity (Klose 2009). Different forms of soil erosion are found in the study area. The slopes exhibit moderate to heavy soil erosion (Miller 2002) with hotspots identified in the high mountain zones (Klose 2009). Higher altitudes are characterized by extensive-linear erosion forms with many rills, while lower altitudes show more linear erosion forms of a higher depth, often deep gullies (Miller 2002).

2.6. Land use types

The most important land use in the study area is pastoralism, mainly of goats, sheep and dromedaries and comprising more than 90% of the area. Sedentary herders share the collectively-owned rangelands with transhumant pastoralist and other mobile users. The use of these rangelands is regulated by traditional and customary rules within and between the different tribes and fractions (Saqalli 2002). Some of the traditional rules or institutions are the Agdals defined as collective pastures with fixed opening and closing dates (Hart 1981). The *Agdal* institution is also very common in other parts of the Moroccan High Atlas and has been studied by many authors (i.e. Mahdi 1999; Aubert et al. 2009; Dominguez et al. 2010). It was shown that the *Agdals* are very important for sustainable use of rangeland and forest resources (Auclair et al. 2011).

The second land use type in the rangeland commons is firewood collection. This activity is practised mainly by women who collect the wood and kindling from shrubs and dwarf shrubs in areas belonging to their village territory (El Moudden 2004). The collected wood is used to satisfy the energy requirements of the local population, mainly for cooking (80%), but also for warming water and heating the house (El Moudden 2004). Another land use type in the study area is irrigated agriculture. This activity is practised mainly in river oases (Menz 2010) and near the villages.

Chapter 3

General Discussion

3.1. Research highlights of the three studies

In this thesis, I worked on the spatio-temporal grazing patterns of sedentary and transhumant pastoralism and their impact on rangeland biomass. The first topic was to estimate biomass variability in an exclosure experiment of the BIOTA Maroc project (www.biota-africa.com), focusing on the sagebrush steppe ecosystem (chapter 4). This study showed that browsing affected the architecture of the dwarf shrubs, and therefore different volume–biomass functions should be used for browsed and unbrowsed plots. Moreover, it showed that browsing affected biomass development of the three dwarf shrubs differently. While browsing showed a significant negative effect on the interannual biomass change for *Artemisia herba-alba*, its effect was not significant for *Artemisia mesatlantica*. For *Teucrium mideltense,* the effect of browsing was inconsistent between the years. In addition, the standing biomass of the three species increased with or without browsing. This increase is probably due to the recovery of the rangelands after a preceding long drought ending in the year 2000 (Born et al. 2008). This notable regeneration effect indicates that short-term exclosures, i.e. up to 5–10 years, could be beneficial for the rehabilitation of these ecosystems.

In a second step, transhumant pastoralism was studied within three neighbouring tribes (see chapter 5). The aim of this study was to outline social and ecological factors influencing migration decisions of transhumant pastoralists. In each tribe, different transhumance types were found, i.e. semi-sedentary pastoralism and short-, medium-, and long-distance transhumance. Migration decisions of the transhumant pastoralists depended on several factors. The most important factors shaping the migration direction were fodder availability and climate. Additionally, individual decisions allow for flexible adaptation within their tribal framework. Other factors were the proximity to members of the larger family, access to markets and risk control. This comprehensive study of migration movements of transhumant pastoralists and the drivers behind their migration decisions may contribute to providing management strategies for dry rangelands.

The third topic was to describe the seasonal patterns of daily trajectories of sedentary herds and assess their grazing intensities using GSP collars (see chapter 6). The grazing intensities were assessed at the level of grid cells of 4 ha. This spatially explicit approach was used for the first time in southern Morocco, contrasting with previous studies, which had only considered the mean grazing intensity within a large area. The highest grazing intensities occurred in the first 250 m from the stable. Generally the herds did not exceed distances of 3000 m from the stables. These results are in line with other studies showing that water points or villages are hotspots for grazing. The mean daily distance and maximum distance from the stable varied significantly between seasons and was driven by fodder availability, temperature and the day-length. In addition, this study provided two new methodological approaches. The first one was a regression function showing the decay of grazing intensity with increasing distance from the stable or village, and the concentration of grazing around the stables. The second one was the relationship between the daily walking distance and the GPS recording interval. This relationship could be useful for other studies because it allows the calculation of the actual walking distance even with long recording intervals. The use of small intervals requires changing the GPS collar battery frequently and this is generally impractical in this kind of field study. These results may be useful for rangeland managers to establish specific management strategies for areas near villages.

The three topics raised in this thesis concern dry rangelands in southern Morocco in terms of biomass production (chapter 4) and pastoral land use (chapter 5 and 6). The estimation of biomass in chapter 4, as well as unpublished data, allow for the estimation of the carrying capacity under different browsing and climatic conditions (see section 3.2). The estimated carrying capacity will then be compared to the grazing intensity assessed in chapter 6. The study of the trajectories of sedentary (chapter 6) and transhumant pastoralists (chapter 5), and the factors influencing their movements could help refine carrying capacity estimation, taking into account varying conditions such as drought, fodder availability, water availability, and thus enabling the settling of proper stocking rates.

3.2. Carrying capacity

The concept of carrying capacity (CC) is widely used to assess land use intensities that allow for sustainable use of rangelands (Sayre 2008). However, this concept has elicited controversial debate and several authors have questioned whether the concept is applicable in ecosystems with high seasonal variation in rainfall and fodder availability (e.g. Dijkman 1999; Cliggett 2001; Sayre 2008). Other critics, like Cliggett (2001), considered that the CC ignores the complexity of the human-environment relationship and De Leeuw & Tothill (1990) criticized the use of CC in sub-Saharan Africa because different authors calculated values of CC differently. These discrepancies were caused by taking different parameters into consideration for the calculation of the CC, including grazing efficiency (the proportion of total herbage livestock can harvest), forage loss (due to trampling, fouling, decomposition, etc.) and the allowable plant utilization percentage, which is the maximum proportion of forage that can be grazed without causing rangeland deterioration (FAO 1991). Moreover, biomass quality and fodder value for livestock are largely ignored in the calculations of CC (De Leeuw & Tothill 1990) despite its influence on the forage intake by grazing livestock (Launchbaugh 2008). However, there are also comments supporting the CC concept. For example McLeod (1997) stated that CC can be a useful tool in ecosystems with low environmental and climatic variability.

Criticism of the use of the CC concept in ecosystems with high seasonal and interannual climatic variability (e.g. the sagebrush steppe ecosystem of Taoujgalt) by some of the above-mentioned authors has mostly referred to the calculation of one single value for a system with a strongly fluctuating productivity. However, our data allow the estimation of a range of CCs for this rangeland under different ecological conditions, and the understanding of this range may contribute to its sustainable management. Therefore, I will estimate the CC range based on calculations under different climatic and browsing conditions. These calculations will allow the definition of the range within which the CC fluctuates for a given studied site.

3.2.1. Calculation of the carrying capacity under browsing for the years (2007–2009)

The carrying capacity can be calculated by dividing the *total usable forage* by the *forage demand*.

Calculation of the total usable forage

The average standing biomass of the three dwarf shrubs *A. herba-alba*, *A. mesatlantica*, and *Teucrium mideltense* in Taoujgalt from 2007 to 2009 was 1106 kg ha^{-1} outside of the exclosure. In terms of edible biomass, it was only 248 kg ha^{-1} (unpublished data). The edible biomass included the leaves and fresh stems and only excluded the woody parts of the plants. This estimation applied the volume–biomass functions to edible biomass values using a similar method based on total biomass in chapter 4. For a sustainable use of the sagebrush rangelands, the allowable plant utilization percentage is between 30 to 40% (Holechek 1988). In the following, I will use 35% as the allowable plant utilization percentage. Therefore:

Total usable forage = edible biomass × utilization percentage = 248 kg ha^{-1} × 35% = 86.8 kg ha^{-1}.

Calculation of forage demand

Forage demand is defined as the total amount of forage consumed by a grazing animal during the grazing period (Holechek 1988). Ruminants on rangelands consume about 2.5% of their body weight per day (Launchbaugh 2008). In the study area, the average body weight of an adult sheep or goat (Small Stock Unit: SSU) is 20 kg (White House 2004). Therefore:

Forage demand = 2.5% × average body weight × 365 = 0.025 × 20 × 365 = 182.5 kg SSU^{-1} $year^{-1}$. This means that 182.5 kg of forage is needed to feed each SSU for one year. Then:

Carrying capacity = total usable forage/forage demand = 86.8 kg. ha^{-1}/ 182.5 kg SSU^{-1} $year^{-1}$.

The *carrying capacity* in the sagebrush steppe of Taoujgalt for the period 2007–2009 was 0.47 SSU ha^{-1}.

Assessment of the grazing intensity

For the same period, I calculated the grazing intensity in Taoujgalt (chapter 6). Within the first 250 m around the village, the grazing intensity was 6.12 SSU ha^{-1} (Table 3). This is nearly 13 times higher than the carrying capacity of these rangelands, as calculated above. The grazing intensity was approximately equivalent to the carrying capacity at distances of 500–1000 m distance from the stable, and even lower grazing intensities occurred in areas more than 1000 m distant from the stable (0.14 SSU ha^{-1}).

However, the grazing intensities calculated in chapter 6 considered only the sedentary herds. If I considered the transhumant herds, the actual grazing intensities would be higher than the values given above. In particular, at higher distances from the village (> 1000 m) there is an increasing overlap with transhumant herds using the same area. This increase in grazing intensities affects mainly the remote areas because the transhumant pastoralists avoid grazing their animals close to the villages in order to avoid competition for forage (see chapter 5). The calculations shows that those remote areas (> 1000 m distance) are underutilized by sedentary herds. The only pastures clearly overgrazed are the direct surroundings of the village of Taoujgalt, i.e. within a radius of 250 m.

The carrying capacity calculated above was based on biomass production during October (2007), May (2008) and June (2009).

These measurements corresponded to three relatively rainy years with an annual precipitation of 289 mm. Therefore, during dry years, biomass production of the three species, and thus the carrying capacity, will be lower. This will be shown for the year 2005 in the same ecosystem (see next section).

3.2.2. Calculation of the carrying capacity under browsing for the year 2005

The edible biomass of the three dwarf shrubs was 177 kg ha^{-1} (unpublished data). Using the same calculation method given above, CC for 2005 = 177 kg ha^{-1} × 35% / 182.5 kg SSU^{-1} $year^{-1}$, therefore:

the *carrying capacity* for 2005 = 0.34 SSU ha^{-1}.

Rainfall in 2005 was 193 mm, representing just 66.8% of the annual precipitation for 2007–2009. As a result, the carrying capacity decreased by 0.13 SSU ha^{-1}, i.e by 27.6%. Whilst 2005 was not an especially dry year, it does show clearly that the carrying capacity has to be adjusted depending on the precipitation and biomass production of the year in question.

3.2.3. Calculation of the carrying capacity within the exclosure

In the exclosure, the edible biomass of the three dwarf shrubs for the relatively wet period of 2007–2009 was 1211 kg ha^{-1} (unpublished data). Thus:

the *carrying capacity* was 1211 kg ha^{-1} × 35% / 182.5 kg SSU^{-1} $year^{-1}$= 2.32 SSU ha^{-1}.

For the comparatively dry year 2005, the edible biomass for the three species was 516 kg ha^{-1} within the exclosure and correspondingly:

the *carrying capacity* was 516 kg ha^{-1} × 35% / 182.5 kg SSU^{-1} $year^{-1}$= 0.99 SSU ha^{-1}.

Table 1. Summary of the carrying capacity results in (SSU ha^{-1}).

Carrying capacity	Inside the exclosure	Outside the exclosure	Proportion (inside /outside)
2005	0.99	0.34	2.91
2007–2009	2.32	0.47	4.94

The carrying capacity inside the exclosure is much higher than outside the exclosure (Table 1). The CC of the Taoujgalt rangelands fluctuates between 0.34 (dry year, pasture in poor condition) and 2.32 SSU ha^{-1} (wet years, pasture in good condition). This example shows how pastoral management that maintains rangelands in good conditions enhances the CC between 2.91 and 4.94 times. The calculation of CC within the exclosure was based on biomass recovery after several (4–9) years. Therefore, short term exclosures of rangelands could subsequently allow for the grazing of more than double the number of animals and thus be an efficient management tool to restore standing biomass and improve rangeland productivity in these areas. Stocking rates should be adjusted flexibly to rangeland conditions with varying climatic conditions, fodder availability, and fodder quality.

3.3. Recommendations for management practices

Rangelands are the main source of animal fodder in the study area, while supplementation is rarely practised: only in the case of severe droughts, or for lactating females during cold winters (White House 2004). During a drought, the pastoralists generally reduce animal numbers by selling them in the market in order to reduce the expensive fodder supply. This reduction of animal number is beneficial for rangeland conservation because it decreases grazing pressure on these rangelands. Moreover, transhumant migration plays an important role in rangeland conservation. In very dry years, the transhumant pastoralists reach far pastures in other provinces searching for fodder resources (chapter 5). Additionally, customary rules, such as the *Agdals*, regulate land use rights between the transhumant pastoralists (see chapter 2) and thus rangelands have time to recover. These rules are evidence of the awareness of the pastoralists of the importance of resource conservation, despite the absence of environmental and ecological education in the region. However, sedentarisation policies applied to transhumant pastoralists, contributed to conversion of rangeland to farmland and thus their degradation (Aït Hamza 2002).

Therefore, I recommend that the local authorities encourage transhumance as opposed to sedentarisation. In addition, development strategies should be a priority in this poor region because the improvement of the living conditions of the population will attenuate population dependence on the resources. This will have a very positive impact on natural resources. Additionally, I recommend that decision-makers and rangeland managers take into consideration the provided carrying capacities (see section 3.2) in their management strategies and to evaluate the impact of carrying capacity on land users, vegetation and soil resources. Moreover, sensitising the local population about sustainable land use would improve their knowledge and have a positive effect on rangeland conservation. Rangeland managers should implement conservation strategies as well as improvement strategies for the rangelands in order to produce more resources to satisfy the feed requirement of the grazing animals in these poor regions.

3.4. Conclusions

In this thesis, I studied animal–vegetation interaction in semi-arid rangelands through biomass production estimation and the analysis of the sedentary and transhumant pastoralism. With this work, I suggest management strategies for rangelands and their sustainable use. The main findings are as follows:

- Browsing exclusion can have a differential effect on the plant species, depending on their dominance and palatability. While browsing had a negative impact on *Artemisia herba-alba*, *A. mesatlantica* and *Teucrium mideltense* hardly benefited from browsing exclusion (chapter 4). This is due to the increased competition of the former species.
- Biomass production could quickly recover in the studied (non-equilibrium) ecosystems. This recovery was observed by biomass increase for the three species after a previous drought. Nevertheless, this increase was higher without browsing (chapter 4).
- The actual grazing intensity was nearly 13 times higher than its carrying capacity near the village of Taoujgalt, i.e. up to 250 m distance (chapter 3 and 6).
- The carrying capacity should be adjusted according to precipitation, fodder availability and fodder quality (section 3.2).
- Sedentary herds graze mostly within 3000 m of their villages (chapter 6), and trajectories vary between seasons.
- Migration movement of the transhumant pastoralists is mainly driven by fodder availability and harsh climate (chapter 5).
- Transhumance could be cancelled by herders when there is a risk of losing the herd, e.g. to disease.

3.5. Research perspectives

Although this research provided important data for rangeland management, it is not sufficient to respond to all the urgent questions in the study area due to its large extent and the complex interaction between the ecological and social conditions. In addition, the carrying capacity calculations are based on an individual plot and exclosure, therefore, their extrapolation to the whole ecosystem would require more research. Thus, I recommend follow-up studies to be carried out in the region in order to complement my work and to extend the findings to a larger spatial and temporal scale. I suggest a number of topics for further studies:

- A study on biomass production along an altitudinal gradient using similar methods used in this study and thus assessing the carrying capacity of the different ecosystems in the region.
- To study the impact of grazing on biodiversity along an altitudinal gradient from the Oromediterraneen ecosystem to the Sahara.
- A study on transhumant movement in the other tribes existing in the region such as Ait Sedrat, Ait Atta, and Imaghrann. For this study, I recommend the use of GPS collars instead of ARGOS collars because the latter were not precise enough, due to signal problems in mountainous terrain.
- A study on the impact of grazing exclusion on soil fertility.
- Estimation of the actual grazing intensities of the rangelands in the study area by including other animal species such as dromedaries, equids and wild animals (rabbits) as well as the grazing intensities of the transhumant herds.

This thesis offers a basis for future studies and contributes to the sustainable use of dry rangelands and their management.

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References

Abdelguerfi, A., Laouar, M. (2000). Conséquences des changements sur les ressources génétiques du Maghreb. *Options Mediterraneennes Sér. A n*°39 : 77-87.

Aït Hamza, M. (2002): Etude sur les Institutions Locales dans le Versant Sud du Haut Atlas. – Projet CBTHA, Ouarzazate, Morocco. p. 90.

Aubert, P.M., Leroy, M., Auclair, L. (2009). Moroccan forestry policies and local forestry management in the High Atlas: a cross analysis of forestry administration and local institutions. *Small-scale Forestry* 8:175–191.

Auclair, L., Baudot, P., Genin, D., Romagny, B., Simenel, R. (2011). Patrimony for resilience: evidence from the forest Agdal in the Moroccan High Atlas Mountains. *Ecology and Society* 16(4): 24.

Burkhard, M., Caritg, S., Helg, U., Robert-Charrue, C. and Soulaimani, A. (2006). Tectonics of the anti-atlas of Morocco. Comptes Rendus Geoscience 338(1-2): 11-24.

Cliggett, L. (2001). Carrying Capacity's New Guise: Folk Models for Public Debate and Longitudinal Study of Environmental Change. Africa Today 48 (1): 3-19.

Cook, C.V., Stubbendieck, J., (1986). Range research. Basic problems and techniques. Denver: Society for Range Management. p. 317.

Croitoru, L., and Sarraf, M. (2010). The costs of environemental degradation. Case studies from the Middle East and North Africa. The World Bank, Washington D.C.

Cuzin, F. (1996). Répartition actuelle et statut des grands Mammifères sauvages du Maroc (Primates, Carnivores, Artiodactyles). *Mammalia* 60 : 101-124.

Cuzin, F. (2003). Les grands mammifères du Maroc méridional (Haut Atlas, Anti Atlas, Sahara). Distribution, écologie et conservation. – Thèse Doctorat, EPHE, Montpellier II, Montpellier.

De Leeuw, P.N., Tothill, J.C. (1990). The concept of rangeland carrying capacity in sub-saharan africa - myth or reality. Land Degradation and Rehabilitation. Pastoral Development Network Paper 29b. Lon-don: Overseas Development Institute.

Dijkman, J. (1999). Carrying capacity: outdated concept or useful livestock management tool? Available at: http://www.odi.org.uk/work/projects/pdn/drought/dijkman.html [accessed on 03 May 2012).

Dominguez, P., Zorondo-Rodríguez, F., Reyes-García, V. (2010). Relationships Between Religious Beliefs and Mountain Pasture Uses: A Case Study in the High Atlas Mountains of Marrakech, Morocco. *Human Ecology* 38:351–362.

El Moudden, S. (2004). Impact du prélèvement du bois de feu sur les parcours steppiques cas d'Ighil n'Mgoun, province de Ouarzazate. Thesis. Institut Agronomique et Vétérinaire Hassan II. Rabat, Morocco. p. 125.

FAO (1991). 'Guidelines: land evaluation for extensive grazing' FAO *Soils Bulletin* 58. Rome. p. 158.

Fikri Benbrahim, K., Ismaili, M., Fikri Benbrahim, S., Tribak, A. (2004). Problèmes de dégradation de l'environnement par la désertification et la déforestation : impact du phénomène au Maroc. *Sècheresse* 15: 307–320.

Finckh, M., Kirscht, H. (2008). The incongruity of territorial perceptions as an obstacle to resource management in communal land – southern Morocco. *Mountain Forum Bulletin* 8 (2):11–13.

Finckh, M., Fritzsche, P. (2008). Landscape Units of the Drâa Catchment. In: Schulz O. & Judex M. (eds.): IMPETUS Atlas Morocco. Research Results 2000–2007: 39–40. Department of Geography, University of Bonn, Germany.

Finckh, M., Poete, P. (2008) Vegetation map of the Drâa basin, in: Schulz O, Judex M (Eds.), IMPETUS atlas Morocco. Research results 2000–2007. Department of Geography, University of Bonn, Bonn, pp 31–32.

Galt, D., Molinar, F., Navarro, J., Joseph, J., Holechek, J. (2000). Grazing capacity and stocking rate. *Rangelands* 22: 7–11.

Gillson, L., Hoffman, M.T. (2007). Rangeland ecology in a changing world. *Science* 315: 53–54.

Hart, D. (1981). Dadda Atta and His Forty Grandsons: The Social Organization of the Aït Atta of Southern Morocco. Wisbech, Cambridgeshire, England: MENAS Press. pp, 260.

Jahantigh, M., Pessarakli, M. (2009). Forage production response of *Artemisia herba-alba* to variation in rainfall and changes in soil conditions in arid regions. *Journal of Food Agriculture and Environment* 7: 717–722.

Holechek, J. L. (1988). An approach for setting the stocking rate. Rangelands 10 (1): 10–14.

Holechek, J. L., and Galt, D. (2000). Grazing intensity guidelines. Rangelands22 (3):11-14.

Klose, A. (2009). Soil characteristics and soil erosion by water in a semi-arid catchment (Wadi Drâa, South Morocco) under the pressure of global change. PhD thesis. University of Bonn. Bonn.Germany. p. 346.

Launchbaugh, K. (2008). Forage production and carrying capacity: guidelines for setting a proper stocking rate. Available at: http://www.cnr.uidaho.edu/what-is-range/curriculum/MOD3/Stocking-rate-guidelines.pdf (Accessed on 04 June 2012).

Le Houérou, H.N. (1990). Agroforestry and sylvopastoralism to combat land degradation in the Mediterranean Basin: old approaches to new problems. *Agriculture Ecosystems and Environment* 33: 99–109.

MADREF (2000). Stratégie de développement des terrains de parcours. Stratégie de Développement de l'Elevage (Tome II, Filières de Production Animale). Colloque National de l'Agriculture et du Développement Rural 7' 2000.

MADRPM (1999). Conseil général du Développement Agricole. Stratégie 2020 de développement agricole. Edit Consulting, Casablanca.

Mahdi, M. (1999). Pasteur de l'Atlas : production pastorale, droit et rituel, Najah Press, El Jadida and Casablanca, Morocco, 346 p.

Mahyou, H., Tychon, B., Balaghi, R., Mimouni, J. and Paul, R. (2010). Désertification des parcours arides au Maroc. *Tropicultura* 28: 107–114.

McLeod, S.R. (1997). Is the Concept of Carrying Capacity Useful in Variable Environments? Oikos 79 (3): 529-542.

Menz, G. (2010). Topography and natural regions. In: P. Speth, M. Chritoph, B. Diekkrüger (Eds.). Impacts of global change on the hydrological cycle in West and Northwest Africa. Springer, Heidelberg, p. 40–44.

Miller, R. (2002). Böden und Bodenerosion auf ausgewählten Standorten im Hohen Atlas/ Südmarokko. Diplom thesis. Department of Agricultural Science and Environmental Management, Justus-Liebig University, Gießen. 147 p.

Mullahey, J. J., Tanner, G. W., and Coates, S. (2006). Glossary of Terms Used in Range Management. Range Sites of Florida. Available at: wfrec.ufl.edu/Subsites/RangeScience/rangelands/glossary.htm (Accessed on 08 May 2012).

Nefzaoui, A. (2002). Rangeland management options and individual and community strategies of agropastoralists in Central and Southern Tunisia. International conference on policy and institutional options for the management of rangelands in dry areas. CAPRI Work. Paper 23 : 14–16.

Oldeland, J., Finckh, M., Born, K. (2008). A bioclimatic map for southern Morocco, in: Schulz O, Judex M (Eds.), IMPETUS atlas Morocco. Research results 2000–2007. Department of Geography, University of Bonn, Bonn, Germany. pp 39–40.

Saqalli, M., Loireau-Delabre, M., D'Herbes, J.M. (2002). Diagnostic comparatif sur 2 sites circum-sahariens de suivi de la désertification. CIRAD, Montpellier, France, p 90.

Sayre, N. F. (2008). The Genesis, History, and Limits of Carrying Capacity, Annals of the Association of American Geographers 98(1): 120-134.

Scarnecchia, D.L. (1990). Concepts of carrying capacity and substitution ratios: a systems viewpoint. *Journal of Range Management* 43: 553–555.

Schulz, O. (2008a). Precipitation in the Upper and Middle Drâa Basin. In: Schulz, O. & Judex, M. (eds.): IMPETUS Atlas Morocco. Research Results 2000–2007: Department of Geography, University of Bonn, Germany. p. 19-20.

Schulz, O. (2008b). The Draa catchment. In: Schulz, O. & Judex, M. (eds.): IMPETUS Atlas Morocco. Research Results 2000–2007: Department of Geography, University of Bonn, Germany. p. 7-8.

Schulz, O., Finckh, M., Goldbach, H. (2010). Hydro-meteorological measurements in the Drâa catchment. In: Speth P, Chritoph M, Diekkrüger B. (eds), Impacts of global change on the hydrological cycle in West and Northwest Africa. Heidelberg: Springer. p. 122–133.

Todd, S.W., and Hoffman, M.T. (1999). Correlates of stocking rate and overgrazing in the Leliefontein Communal Reserve, central Namaqualand. *African Journal of Range & Forage Science* 17:36–45.

Weber, B. (2004). Untersuchungen zum Bodenwasserhaushalt und Modellierung der Bodenwasserflüsse entlang eines Höhen- und Ariditätsgradienten (SE Marokko) [PhD. thesis]. Bonn, Germany: Mathematisch-Naturwissenschaftliche Fakultät, University of Bonn. 235 p.

White House (2004). Etude relative à l'inventaire et la classification des populations ovines et caprines dans le versant sud du Haut Atlas (zone du projet CBTHA). Projet Mor/99/G 33/A/1 G/99. 80 p.

WOCAT and CDE (2009). Benefits of sustainable land management.WOCAT (World Overview of Conservation Approaches and Technologies)/ CDE (Centre for Development and Environment). University of Berne. Switzerland. p. 1–15.

World Bank (2003). L'évaluation du coût de dégradation de l'environnement au Maroc. Rabat.

World Resource Institute (Ed.). (2005). Ecosystems and human well-being: Desertification synthesis – A report of the Millennium Ecosystem Assessment. Island Press. Washington, DC. USA. World Resource Institute. 26 p.

Publication List

Akasbi Z., Oldeland J., Dengler J., Finckh M. (Submitted). Analysis of GPS trajectories to assess goat grazing pattern and intensity in southern Morocco. *The Rangeland Journal*.

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Akasbi Z., Oldeland J., Dengler J., Finckh M. (2012). Volume-biomass functions reveal the effect of browsing on three Moroccan dwarf shrubs. *African Journal of Range &Forage Science* 29 (1): 31–36.

Jürgens N., **Akasbi Z.**, Finckh M., Oldeland J., Schmiedel U. (2012). Les transects BIOTA de surveillance de la biodiversite en Afrique – Une approche pour un suivi environnemental à grande échelle. In Requier-Desjardins M., Ben Khatra N., Nedjraoui D., Issoufou W.S., Sghaier M., Briki M. Surveillance environnementale et développement, acquis et perspectives - Méditerranée, Sahara et Sahel. *Options Méditerranéennes, Série B : Etudes et Recherches* 68 : 113–127.

Conference Contributions

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Akasbi Z., Finckh M., Oldeland J., Jürgens N. (2011): The BIOTA approach to long-term monitoring in Morocco and the potential for wider use of the methodology in the Northern African region. Oral presentation at the International Workshop of the Observatories of the Sahara and Sahel in Tunis, 1– 2 June 2011.

Akasbi, Z., Finckh, M. & Dengler, J. (2010): Interannual changes of standing biomass in grazed and ungrazed steppes in the Atlas Mountains, Southern Morocco – Poster at the 9th international Meeting on Vegetation Databases in Hamburg.

Akasbi, Z. & Finckh, M. (2009): Pastoralisme transhumant et dynamique spatio-temporelle de la végétation dans le Haut Atlas Central au Maroc. Oral presentation at the Workshop „Végétation et pastoralisme au Maroc en transformation“ at the University of Hamburg 13. – 15. November 2009.

Finckh,M., **Akasbi, Z.** & Augustin, A. (2008): Pastoral resources in the transhumance system of the Mgoun region, Southern Morocco. Oral presentation at the GLOWA-IMPETUS Conference, 29.-30. October 2008, Ouarzazate, Morocco.

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