INITIATIVE FOR A BALANCED WATER RESOURCE MANAGEMENT

INITIATIVE POUR UNE GESTION INTÉGRÉE DES RESSOURCES EN EAU

INICIATIVA PARA UNA GESTIÓN EQUILIBRADA DE LOS RECURSOS HÍDRICOS

water 4 future

Scientific decision support on the sustainable use of environmental resources in dry mountain areas

Compendium of cultural landscapes in the High Atlas Mountains and in the Antiatlas Mountains of Morocco

Results of the first year of the project 2015 / 16

Martin Wyss, Luzi Matile und Wolfgang Zierhofer
















May 2016

INITIATIVE FOR A BALANCED WATER RESOURCE MANAGEMENT
INITIATIVE POUR UNE GESTION INTÉGRÉE DES RESSOURCES EN EAU
INICIATIVA PARA UNA GESTIÓN EQUILIBRADA DE LOS RECURSOS HÍDRICOS

water 4 future

Scientific decision support on the sustainable use of environmental resources in dry mountain areas

Compendium of cultural landscapes in the High Atlas Mountains and in the Antiatlas Mountains of Morocco

Results of the first year of the project 2015/16

Martin Wyss, Luzi Matile und Wolfgang Zierhofer

May 2016

Initiative for a Balanced Water Resource Management

www.i-brm.ch

Office:
Oesterliwaldweg 4
CH-5400 Baden
+41 (0)56 222 07 10, +41 (0)79 534 46 36
martin.wyss@i-brm.ch

Table of contents

Part I Introduction

This report is a record of the landscapes in the Moroccan High Atlas and Antiatlas Mountains. Initially started as the annual report of the first year of our project, it grew with time into a comprehensive compendium of cultural mountain landscapes in arid and semi-arid Morocco.

1 The Project in brief

1.1 Context, objectives and impact

1.1.1 Context

The project aims to establish scientific foundations allowing a sustainable management of water, soil, and vegetation for rural populations in arid and semi-arid mountainous areas of the Global South. In many places precarious climatic conditions coupled with global climate change, rapid demographic transformation, economic growth and modernization drive social and ecological systems alike to their limits and beyond. The future water usage is thereby one of the key challenges to these areas. Particularly the human demand for water is driven in unprecedented heights, often beyond the carrying capacity. The consequence of these trends is an over-exploitation of water, soil and vegetation, resulting in lowering of groundwater levels, frequent drying out of rivers and lakes, soil erosion and degradation of the vegetation – thus: desertification.

Particularly rural populations in mountain areas are vulnerable to these trends. As a rule, their subsistence economy depends completely on the local availability of water, as well as on intact soil and vegetation, but they often lack the capacity to invest into improvements. Further pauperization, out-migration and the extinction of traditional local cultures may be the consequences, which in turn may spark social tensions.

Aiming for sustainable development, both, environmental and social conditions have to be taken into account likewise. Resources like water, soil or vegetation will only be sustained when local farmers, households, industries and tourist infrastructure will be enabled to balance their demand with the capacity of their environment and react to processes of global change.

Although many initiatives address this problem on a global scale, it is on the local level where people are confronted with existential problems due to dwindling resources. To allow well-informed decisions, the local population depends on reliable knowledge on the complex interrelations between human activities and environmental processes in terms of realistic scenarios concerning the interdependence of water supply, regional economic development and environmental change. For local actors, possibilities to investigate a broad spectrum of development options in respect of their benevolent or problematic consequences are therefore an important precondition for wise decision-making. In line with Liu et al. (2008), who call for more effective integration of science and decision-making in environmental management in general, science is invited to support them by providing a basis for rational and well-informed strategies also and above all on a local scale.

1.1.2 Objective and results

Our overall objective is to develop a data-based, integrated decision support system (DSS) that is to be used by the local population, authorities, and NGOs for planning and policies on various scales. It will allow to model the interplay of natural and human induced water flows within local catchment areas in order to visualize various scenarios of changing variables such as precipitation, vegetation cover, soil condition, evaporation, water consumption (households and all economic sectors) as well as demographic and economic change.

It thus enables a systematic assessment of development and resource use scenarios and the identification of opportunities and threads likewise, allowing to identify and partially calculate the consequences of potential developments and decisions on the local availability of water and its interdependences with soil and vegetation and vice versa. The DSS is intended for application to various locations, different scales and hypothetical conditions.

1.1.3 Impact

Through our project sustainable development in the Global South will become less of an imposed fate and more of a set of options deliberately chosen. By offering an instrument that produces plausible and comprehensive scenarios of local development, our project contributes to several of the Sustainability Development Goals of the United Nations (SDGs) and reduces the risks of further pauperization and depopulation of peripheral areas.

The project will contribute to conservation and regeneration of environmental resources, thus raising the ecological and economic potentials of areas affected by desertification. By securing the given resources, the rural population will be empowered to live a self-determined life in their native environment. Underdevelopment and vulnerabilities caused by scarcity of resources can be reduced, the health of the population improved, and poverty-induced migration diminished. Successfully applied in a few cases, our DSS may generate a remarkable multiplier effect.

1.2 Approach

Neither our aim nor our approach are unique in respect of the involved scientific methods or the commitment to sustainability goals, but they are outstanding in the way these methods are combined in order to pursue these goals. The development of the envisaged DSS requires transdisciplinary fieldwork in representative study areas in dry, mountainous areas, integrating disciplines from the natural and social sciences as well as practical local knowledge. The collection of the data for the development as well as the first implementations of the envisaged DSS will take place in Morocco.

1.2.1 Transdisciplinarity

Research activities related to the development of DSSs concerning environmental resources are often pluridisciplinary (contributions of various disciplines) and less often interdisciplinary (integrated contributions). Projects, however, that integrate investigations of natural, economic and social contexts are comparatively rare[1], not to mention strictly transdisciplinary projects, which co-operate with the target population and integrate their knowledge into research, as we will do it.

We intend to elaborate a model that follows the water from nature to human activities and vice versa, and thus integrates natural- and social science from the scratch and in a highly functional and goal oriented way. In order to create knowledge specifically adapted to local conditions and needs, the population will be involved in the knowledge production. Moreover, our empirical research shall feed participatory planning processes and political decision-making.

1.2.2 Worldwide suitability on the local scale

So far DSSs concerning water usage and related environmental resources are mostly determined for the use on regional or even larger scales like entire catchment areas of large river systems and large-scale water usage systems (e.g. *GLOWA*, *WATERMAN*, *mDSS/MULINO*, WaterWare, *AQUATOOL or* SimBaT[2]). Research activities in this field contribute to the comprehension of large-scale interrelationships and the related DSSs are designed for large-scale predictions and scenarios mainly. They are, however, not suitable for decision-making processes on a local scale and they are only rarely successfully implemented in developing countries. Whereas Giupponi & Sgobbi (2013) claim lacking structural preconditions as the main reason for the modest success of DSSs in developing countries, we consider the lack of usability of these systems by actors on a local scale as the main limiting factor.

The envisaged DSS will therefore be developed for a worldwide suitability on the local scale. This means that it will be developed first for local scale water usage systems the size of villages or valleys in a few study areas in the Moroccan Atlas Mountains. Then, step by step, it will it be adapted to become applicable to more general natural and societal conditions.

[1] IMPETUS or GLOWA are examples for this kind of projects; see bibliography on page 10.

[2] See bibliography on page 10.

1.2.3 Comparable projects

In the way we are envisaging in this project, local water usage systems in dry areas and specifically in Morocco have never been investigated and represented by integrated hydrological and socio-economic models. However, we also intend to integrate results from the large-scale interdisciplinary programme IMPETUS (Speth et al. 2010), carried out inter alia along the Drâa river catchment in Morocco, the GLOWA project, including data from the Alps (Mauser & Pratsch, 2015), the WOCAT initiative, showing options for sustainable dryland management (Schwilch et al., 2012), and the ongoing Moroccan programme AGIRE (http://www.agire-maroc.org), which focuses on capacity building in respect of institutional, legal and organisational frameworks[3].

1.2.4 Morocco as a 'research, development & test lab'

Morocco is the ideal country when it comes to developing and testing a DSS for the environmental management:

- The country has varied natural habitats with different climatic, ecological, hydrological and geological conditions at differing altitudes above sea level.
- A targeted environment management is most urgent in countries which have neglected or over-exploited their environmental resources in the past, or which are climatically speaking at a disadvantage, e.g. in the wide-spread dry areas. Both of these apply to Morocco.
- In Morocco, there is a great demand in planning and decision-making foundations for a sustainable management of water and the environment at all levels. This has been repeatedly pointed out in various critical reports of the Moroccan government as well as non-governmental organisations.
- Morocco is politically stable, situated at a reasonable travel distance from Switzerland and has moderate consumer prices so that longer sojourns for research work there will not over duly strain the project budget.

1.2.5 Environmental context in Morocco

Due to changing climate conditions, its economic and demographic development, and the increasing demands that go hand in hand with a rapidly changing lifestyle, Morocco is one of those countries that has become subject to the most severe environmental changes:

- Less precipitation and distinct and longer dry periods.
- A more frequent drying up of surface waters and a lowering of the groundwater levels.
- More droughts with severe crop failures.
- Contamination of ground- and surface water with pollutants.
- Hazards to the water supply of households, agricultural land, trade and industry.
- Increasing degradation of the vegetation and acceleration of the desertification.
- Soil erosion as a result of over-exploitation, degradation and desertification.

The responsible ministries, regional authorities and communes as well as many NGOs in the domains of water and environmental issues are well aware of this highly complex situation. Therefore, there is a great demand in planning and decision-making foundations for a sustainable management of water and the environment.

1.2.6 Methodology

We plan empirical case studies in several rural areas the size of villages or valleys in the High Atlas Mountains and in the Antiatlas Mountains of Morocco, representing a wide range of physio-geographic and socio-economic variables typical for semi-arid or arid mountain areas. The core of the case studies is the detailed, qualitative und quantitative modelling of the local water balances, based on a detailed investigation of ground- and surface water systems, soils and vegetation as well as their anthropogenic usage through various activities. For this we will measure the relevant natural and human induced water flows, and we will identify the factors that may influence them (see fig. 1). Fieldwork will include hydrological, geological, ecological, climatological and pedological investigation, as well as interviews with representatives of the local population concerning farming, household, tourism, industries and other water-relevant activities. The physical and chemical measuring and analysis techniques, and the socio-economic field studies and investigations are summarized in table 1.

[3] See bibliography on page 10.

Tab. 1: Methodology of fieldwork in the case studies.

1 - Physical and chemical measuring and analysis techniques (see also fig. 1)	
1a - Natural water balance	**1b- Influences from human activity**
• Precipitation and evaporation • Discharge of surface water • Aquifer parameters • Volume and rate of recharge of aquifers • Water chemistry (surface- / groundwater) • Geological / geophysical investigations • Density / composition of the vegetation • Volumetric soil water- / matrix potentials	• Water consumption of households, agriculture, industry, tourism • Flow back of waste water into the surface- and groundwater • Polluting substances (organic / anorganic) in surface- and groundwater • Impacts from waste water on eco-systems
2 - Socio-economic field studies and investigations	
• Development / changes of settlement / land use (aerial photographs, literature analysis, structured interviews) • Demographic / economic development (structured interviews, literature analysis) • General handling of water in households, agriculture, industry and tourism (structured interviews) • Standardised surveys by means of random samples (structured interviews) • Discussion and evaluation of the results with representatives of the concerned population • Estimates of the representational character of the data by statistics	

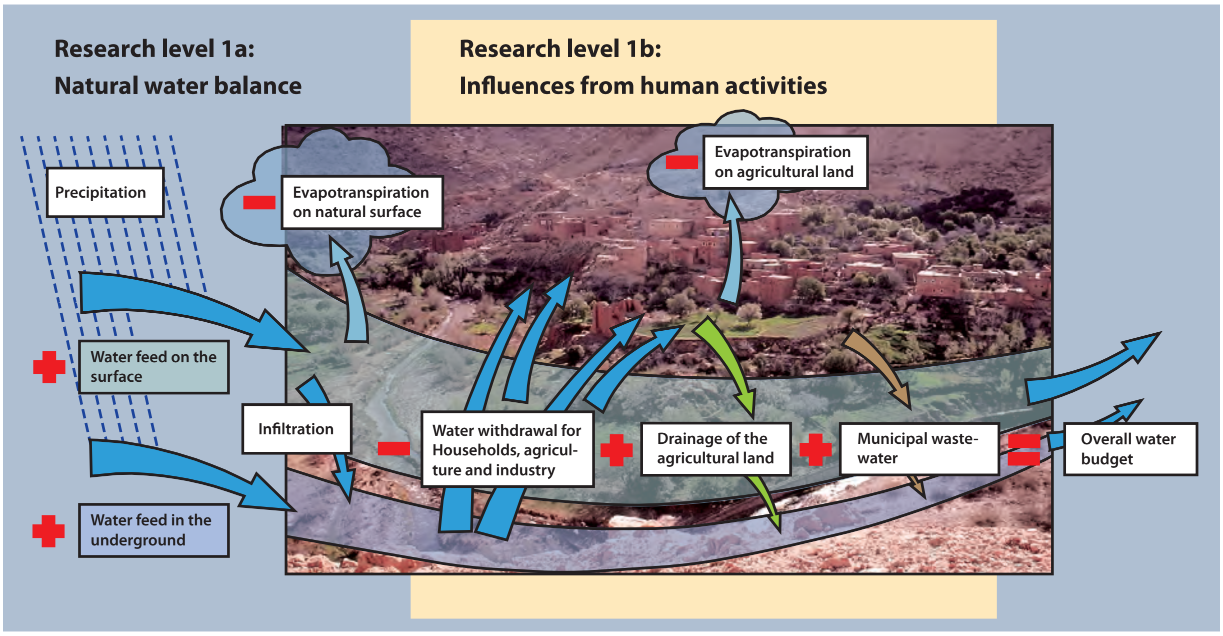


Fig. 1: *Overall water budget in a system with variables that are influenced partly by the natural water balance and partly by human activities. Components with red „+“ and „-“ are part of the water budget equation.*

Figuratively speaking, we plan to establish water-network models the size of villages or valleys as the core of the envisaged DSS, which consist of inputs, pipes, nodes, valves and outputs, whereas precipitation and evaporation, ground- and surface water flows, the chemical and mechanical loads of the currents, irrigation and all other kinds of activities, that involve water consumption, will be variables. The water-network models thus gained will be integrated with information on economic, social, cultural, but also ecological development (e.g. climate change) on regional, national and global scale, as well as information on possible forms of co-operations, regulations or policies concerning the use of resources. A simple and exemplary water use system that is suitable to establish such a model is depicted in fig. 2.

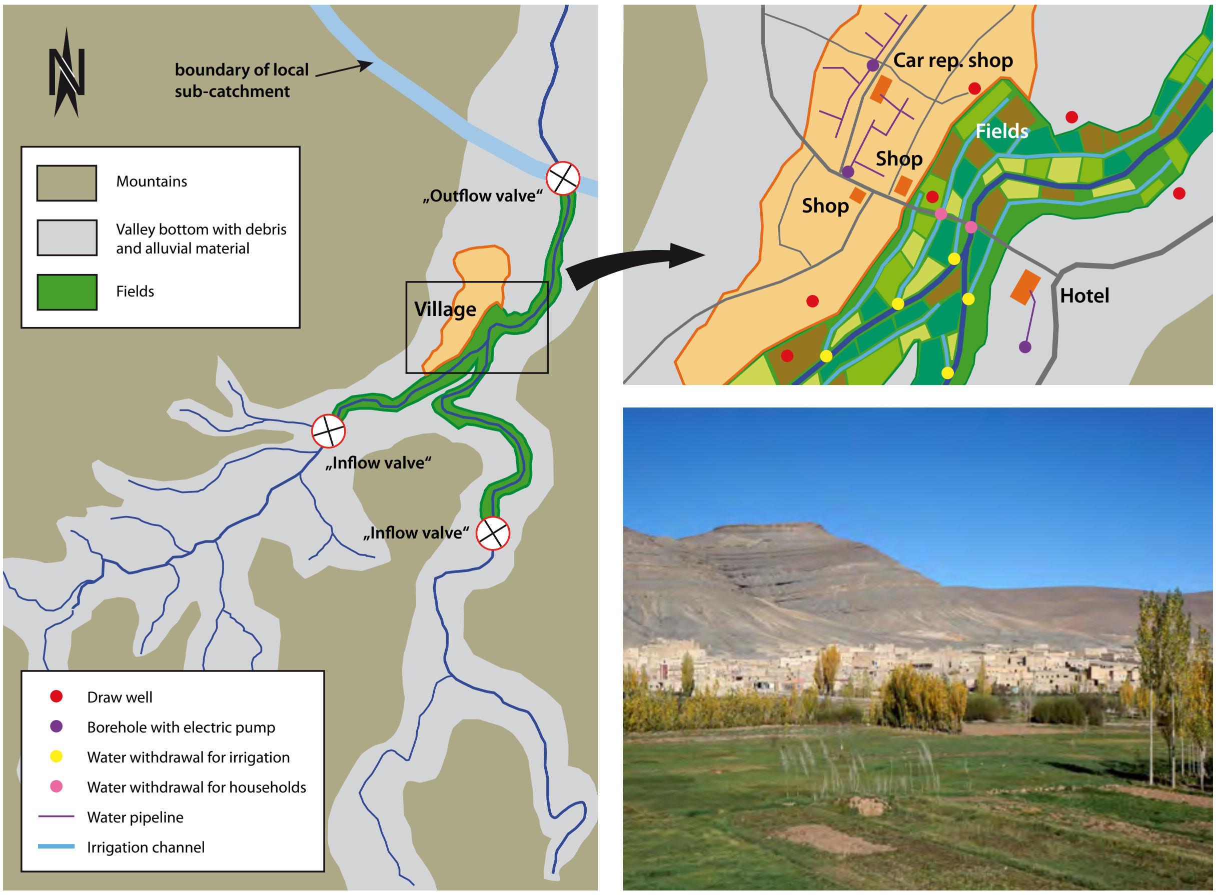


Fig. 2: *Simplified example of a water use system that is suitable to start the intended case studies. Agoudal is the highest village in the Asif Melloul Valley in the eastern High Atlas Mountains and disposes of a well controllable hydrological catchment. Inflow and outflow as well as the agricultural land and the outlines of the village are well defined. The village disposes of several wells and boreholes with some pipelines leading to selected houses. A little used, but locally important pass road crosses the village, where the livelihoods of most inhabitants are based on agriculture on fields along the Asif Melloul and on semi-nomadic animal husbandry. The mountain slopes are completely deforested, leading to strong erosion. The services sector is represented through some small shops, a car repair shop and three "auberges" (simple hotels).*

The project is run as a co-operation of the Institute of Natural Resource Sciences, Zurich University of Applied Sciences and the Swiss NGO "Initiative for a Balanced Water Resource Management". Fieldwork in Morocco will be carried out in close co-operation with authorities, interested locals and local NGOs (particularly for the interviews).

1.2.7 Selection of appropriate study areas

The selection of appropriate study areas for the case studies is crucial for the success of the project. A high representativeness of the study areas is first of all essential for an optimal applicability of the data – and thus also for the intended DSS – to larger areas and to more general natural and societal conditions. However, not only the scientific prerequisites must be met as precisely as possible, it is also essential to find locals in every study area that are able to understand the background of the project, that show an interest for the research questions, and that are willing to support the project team during field work on site – thus: that act as multipliers. Last but not least, a good choice of appropriate study areas is also of vital importance for the intended transdisciplinary involvement of the communities into the problem-solving process and for in the subsequent first attempts to implement the DSS.

The search for appropriate study areas was one of the most important issues of the first year of the project that lasted from April 2015 to March 2016; see next chapter.

2 The first year of the project

2.1 Fieldwork

During the first year of the project two field trips to the Moroccan High Atlas and Antiatlas Mountains have been carried out with the duration of nine weeks altogether, including 56 days of fieldwork on site.

The main goal of the first year of the project, and therefore also the main goal of the two field trips to Morocco, was to pre-select a series of appropriate study areas that would allow for the selection of 2 to 4 definitive study areas. Although we were partly familiar with Morocco, its geology, hydrology, landscapes, towns, cities, and infrastructure already before the project started, we were still far from being able to draw a differentiated picture of the country – and specifically of the Atlas Mountains – that could serve as a basis for a sound scientific proceeding. Apart from the aim of identifying appropriate study areas, a comprehensive general overview concerning geological, hydrological and geomorphological conditions, types of landscapes, forms of agriculture, settlements and traditions was therefore our concern, that will help to evaluate the representativeness of the selected study areas and finally also of the project results.

The field trips to Morocco took place in April / March and October / November / December 2015. The search for appropriate study areas included most of the High Atlas and the Antiatlas Mountains. The Middle Atlas Mountains were not included as they are not suitable for the intended studies according to their settlement structure with predominant scattered settlements / farmsteads and towns instead of compact villages. Whereas the first, shorter field trip in spring of 2015 mainly focused on features that could be studied along main roads, the longer field trip in autumn 2015 also lead to more remote areas. The itineraries are depicted in fig. 5. The field trips were carried out with a Land-Rover Defender that was able to deal with the locally very rough road conditions (figs. 3 and 4). Covering a distance of about 16’000 kilometres, a total of over 7’000 documentary photos have been taken and 120 rock samples have been collected from important geologic units for comparison during subsequent project phases. A selection of the documentary photos is to be found on our website under ‘http://www.i-brm.ch/m01a.html’. In annex II an overview of all photo locations on a satellite image is given. The photos associated are archived in the scientific archive of the association ‘Initiative for a Balanced Water Resource Management’.

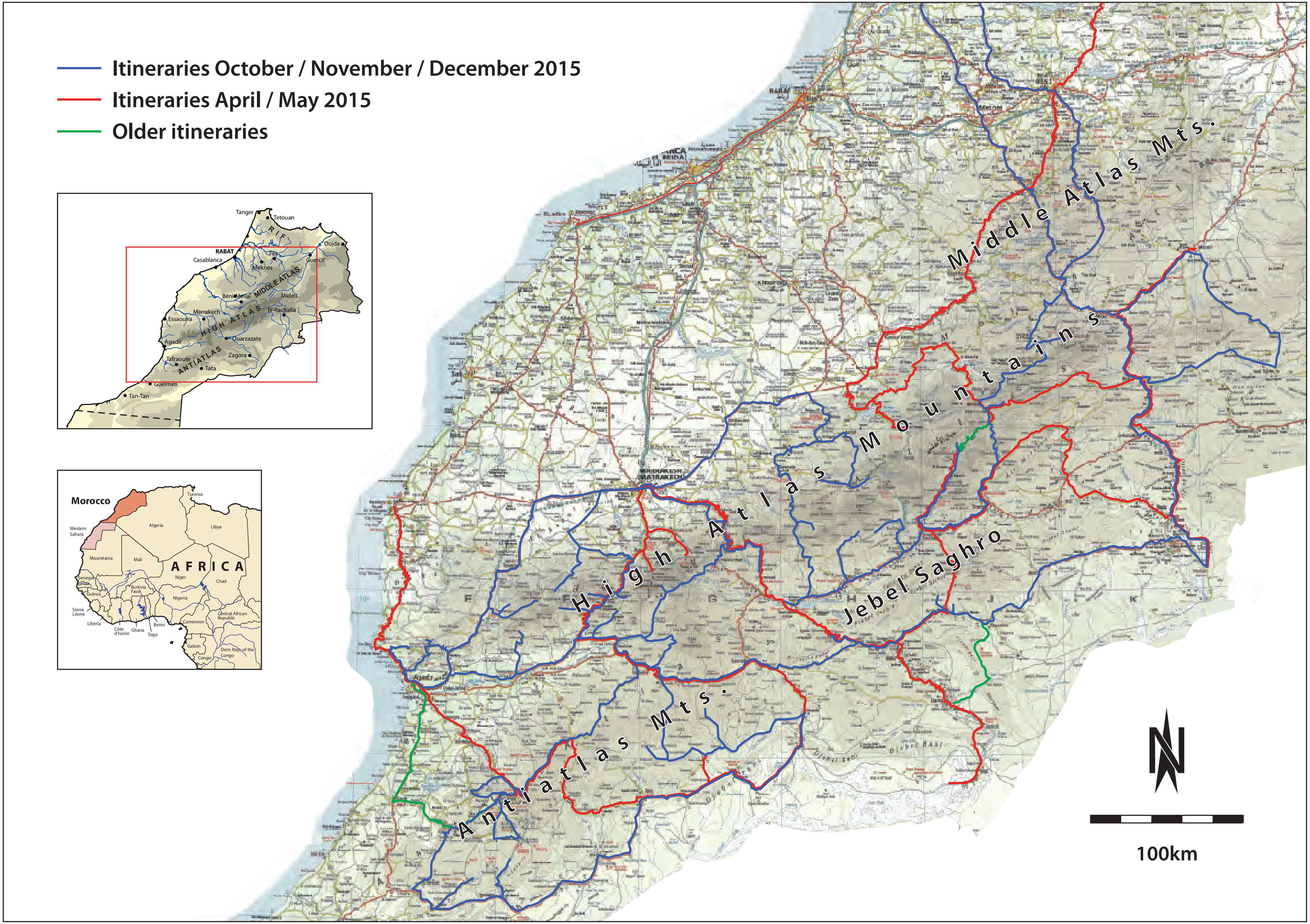
***Fig. 3:** On the way in the central High Atlas Mountains between Tounfite and Tagoudit, where the mud road was washed away by flooding in autumn 2014 (photo: autumn 2015).*

***Fig. 4:** Rocky mud road in the Jebel Saghro north of Nekob, seen from inside the Land-Rover; autumn 2015.*

The results of field trip one have been documented in a comprehensive preliminary report (148 pages) that is not accessible to the public. Due to their adaptation to a greater overview within this final report, numbers of potential study areas as well as categorisations of types of natural vegetation and types of farming as presented in the preliminary report have been changed in the meantime, so that they are not comparable within the two reports.

***Fig. 5 (opposite page):** Simplified road map of Morocco with the itineraries of spring and autumn 2015. Older itineraries are from 2006 and 2011.*

Main map: Low-resolution scan of World Mapping Project Morocco 1:1’000’000, Reise Know-How publishers, Germany.



Itineraries October / November / December 2015
Itineraries April / May 2015
Older itineraries
Middle Atlas Mts.
High Atlas Mountains
Jebel Saghro
Antiatlas Mts.
100km
Tanger
Tetouan
RIF
Oujda
RABAT
Casablanca
Fez
Meknes
Guercif
MIDDLE ATLAS
Béni Mellal
Midelt
Marrakech
Er-Rachidia
Essaouira
HIGH ATLAS
Agadir
Quarzazate
Tafraoute
Zagora
ANTIATLAS
Tata
Guelmim
Tan-Tan
Morocco
Tunesia
Western Sahara
Algeria
Libya
Mauretania
Mali
AFRICA
Niger
Chad
Senegal
Guinea
Burkina Faso
Nigeria
Sierra Leone
Liberia
Côte d'Ivoire
Ghana
Togo
Benin
Cameroon
Central African Republic
Gabon
Congo
Dem. Rep. of the Congo

2.2 Selection of appropriate study areas

2.2.1 Natural and social scientific criteria

The essential natural and social scientific criteria for the selection of appropriate study areas are:

- Well delimitable hydrological sub-catchments as local water usage systems.
- Well controllable inflow and outflow of the local water usage systems.
- Modular expandability of the local water usage systems over neighbouring valleys that belong to the same catchment, allowing a 'step-by-step' expansion of the study areas.
- The villages are of a manageable size, display a clear structure, and their outlines are well defined (no confusingly rampant settlements).
- No artificial inflow of water from outside the local water usage system or, if unavoidable, only within clearly defined limits.
- The outlines of the agricultural land are well defined (no confusingly rampant agricultural areas).
- Intact future prospects for a sustainable development of settlements and agriculture. Indicators are:
    - No agricultural land is abandoned without clearly visible environmental reasons (e.g. flooding).
    - New houses are built for the younger generation.
    - Services sector exists in the village.
    - Younger generation participates in the village life.
    - Development of modest, gentle tourism.
    - Returnees from the big cities with higher education.
- Integrity with regard to major development plans with influence on the hydrological balance, such as big dams or roads, and on the social fabric.

Some of these criteria are also addressed chapter 1.2.6 'Methodology' and in part III, chapter 2 'Appropriate regional structuring'.

2.2.2 Representativeness

It is one of the essential reasons for this report to demonstrate the representativeness of the selected study areas for dry, mountainous areas worldwide. A good representativeness is given, if they in sum represent:

- Different climatic conditions (e.g. arid hot and semi-arid cold).
- Different flow regimes (permanent, periodic, episodic).
- Different natural vegetation covers (e.g. herbaceous shrubs and sparse forest cover).
- Different degrees of deforestation / desertification.
- Different expositions (northern slope and southern slope).
- Different geological conditions and morphologies of the valleys.
- Different types of agriculture.

2.2.3 Logistic criteria

The essential logistic criteria are:

- Good accessibility by car in all seasons:
    - No extremely long and exposed mud roads.
    - No long closing of roads during the winter due to snowfall.
- Modest touristic infrastructure ('auberge', 'gite d'étape') in the study area or closely outside as accommodation for the project team during fieldwork.
- Existence of one or more local multipliers, willing to support the project team during fieldwork on site and to make the project ideas accessible to the public.

2.2.4 Classification and presentation of the study areas

The study areas are mainly classified according to their morphology that is the result of different geologic, climatic and hydrologic conditions and that in its turn influences the layout of settlements and agricultural land. All pre-selected study areas are summarized in part III (fig. 2 and tabs. 1 and 2), and introduced in the parts IV, V and VI. Areas that were not selected are either difficult to access or their natural water balance is disturbed by large dams.

2.2.5 Name assignment

Local names

Local names do often not correspond to each other on different maps or on GoogleEarth, or they are written differently. In addition, the identification of the names of smaller villages that are not recorded on maps is difficult where no place-name signs exist on the road, since it is not possible to stop in every village and to ask for its specific name. Local names and their spelling are thus anything but clear. In this report, spelling is primarily in accordance to the place-name signs on the road. Where they are lacking, we rely on the map of 'World Mapping Project Morocco 1:1'000'000'[4], or GoogleEarth.

Names of streams / rivers and valleys

On maps the names of streams and rivers – if any – frequently change. A logic naming, where the main river bears the same name from its source to its confluence to another river, a lake or the ocean, is not apparent. A similar problem occurs with the names of valleys. Local inhabitants, however, are not a big help as they usually do not understand, why a foreigner asks for such names, or the spelling of the supposed name is unclear to a large extent due to difficulties when transferring it from the local Berber language to Latin letters.

Names of study areas

In terms of the project issues dealing with water, the names of streams, rivers or valleys should be essential when naming study areas. Unfortunately they are rarely known. In the absence of reasonable names, we often used the name of a main river, even if it is not clearly assignable to the respective river section, to name the valley in question; or we named a valley according to the most important village(s). As a result, the naming of the study areas is largely artificial and does certainly not correspond to the correct local naming in the respective Berber language.

A general glossary is to be found in annex I.

2.2.6 Documentation of the study areas

The study areas are subdivided into well-documented study areas and study areas with poor or even no documentation. Whereas the former are drawn with a white line on all overview maps showing study areas (part III, fig. 2 and all maps in the parts IV, V and IV), the latter are drawn with a bright yellow line. Areas with poor or no documentation that are selected as appropriate study areas are identified on satellite images and they are always similar to well-known neighbouring areas.

The study areas are documented by means of photos of the landscape in general, of streams, rivers, the local geology, villages, and agricultural fields. The photos, however, should not only document local conditions, they should also help to get a feel for the peculiarities of the landscape. Most of the photos were taken when driving through the areas, without waiting for optimum conditions concerning location, light, or the activities of locals.

[4] World Mapping Project Morocco 1:1'000'000'[4], Reise Know-How publishers, Germany

References:

Giupponi, C., 2007: Decision Support Systems for implementing the European Water Framework Directive: The MULINO approach; Env. Modelling & Software, 22/2, 248-258.

Giupponi, C., Sgobbi, A., 2013: Decision Support Systems for Water Resources Management in Developing Countries: Learning from Experiences in Africa; *Water* 2013, *5*, 798-818.

Liu, Y., Gupta, H., Springer, E., Wagener, T., 2008: Linking science with environmental decision making: Experiences from an integrated modelling approach to supporting sustainable water resources management; Env. Modelling & Software 23, 846-858.

Manos, B., Bournaris, T., Silleos, N., Antonopoulos, V., Papathanasiou, J., 2004: A decision support system approach for rivers monitoring and sustainable management; Env. Monitoring and Assessment 96, 1-3, 85-98.

Mauser, W., Prasch, M. (eds.), 2015: Regional Assessment of Global Change Impacts – The Project GLOWA-Danube, Springer Int. Publishing, 670p.

Pedro-Monzonís, M., Jiménez-Fernández, P., Solera, A., Jiménez-Gavilán, P., 2016: The use of AQUATOOL DSS applied to the System of Environmental-Economic Accounting for Water (SEEAW); J. Hydrol., 533, 1-14.

Pierleoni, A., Camici, S., Brocca, L., Moramarco, T., Casadei, S., 2014: Climate change and decision support systems for water resource management, Procedia Engineering 70, 1324-1333.

Schwilch, G., Hessel. R., Verzandvoort, S. (eds.), 2012: Desire for Greener Land – Options for Sustainable Land Management in Drylands; University of Bern - CDE, Alterra - Wageningen UR, ISRIC - World Soil Information and CTA - Technical Centre for Agricultural and Rural Cooperation, 283p.

Speth, P., Christoph, M., Diekkrüger, B. (Eds.), 2010: Impacts of Global Change on the Hydrological Cycle in West and Northwest Africa; Springer-Verlag Berlin Heidelberg, 674p.

Part II General observations

1 Natural Vegetation

1.1 Natural vegetation cover

The species-specific composition of the natural vegetation cover and its density both depend on location factors such as geology, soil, climate, water availability, elevation and exposition. For the needs of the project, the density of vegetation particularly plays a central role, as the susceptibility of soils to erosion strongly depends on it. Thus, 21 vegetation types have been roughly distinguished independently from their species-specific composition. They are easily distinguishable also from a distance in the field or on satellite photos as they meet simple criteria only, like plant types (herbaceous perennials, shrubs, trees), average plant height and plant density. Some vegetation types, however, are closely affiliated to specific plant species as for example the 'artemisia steppes' (Artemisia herba alba) or the 'Halfah grass steppe' (Stipa tenacissima).

The vegetation types are sorted here separately for mountainous regions and for alluvial plains / river valleys in ascending order from small to large average plant height and from small to big density (figs. 1 - 21). All photos were taken in spring 2011 and 2015. Species-specific distribution areas of the original vegetation are presented in fig. 22.

1.1.1 Mountainous regions

Fig. 1: *Type 1 – Completely barren of vegetation (Jebel Tadrart, east of Zagora).*

Fig. 2: *Type 2 – Patchy plant cover with herbaceous perennials and shrubs (Jebel Beni, southwest of Nekob).*

Fig. 3: *Type 3 – Uniform, but loose plant cover with herbaceous perennials and dwarf shrubs (northern slope of High Atlas Mountains, southwest of Midelt).*

Fig. 4: *Type 4 – Uniform plant cover, neither loose nor dense, with dwarf shrubs, referred to as 'Artemisia steppe' (northern slope of Jebel Saghro, High Atlas Mountains, near Amjdadar).*

Fig. 5: *Type 5 – Uniform, but loose plant cover with herbaceous shrubs and Halfah grass, referred to as 'colline Halfah grass steppe' (northwest of Talsinnt, eastern High Atlas Mountains).*

Fig. 6: *Type 6 – Uniform, dense plant cover with herbaceous perennials and dwarf shrubs (southern slope of Jebel Saghro, north of Nekob).*

Fig. 7: *Type 7 – Plant cover with perennials and occasional shrubs (Oued Taribante Valley, High Atlas Mountains).*

Fig. 8: *Type 8 – Plant cover with mainly shrubs (Oued Tichka Valley, High Atlas Mountains).*

Fig. 9: *Type 9 – Plant cover exclusively with loose trees (juniper, cypress, holm oak) and without undergrowth (northern slope of Tizi N'Test, High Atlas Mountains).*

Fig. 10: *Type 10 – Plant cover exclusively with more dense trees (juniper, cypress, holm oak) and without undergrowth (northern slope of Tizi N'Test, High Atlas Mountains).*

Fig. 11: *Type 11 – Plant cover with loose trees (juniper, cypress, holm oak) and with undergrowth consisting of perennials and dwarf shrubs (southern slope of Tizi N'Tichka, High Atlas Mountains).*

Fig. 12: *Type 12 – Dense plant cover with mixed forest consisting of juniper, cypress, holm oak and pines (foothills of the High Atlas Mountains near Glaoua, southeast of Marrakech).*

Fig. 13: *Type 13 – Dense plant cover with coniferous forest consisting mainly of pines (in the foreground floodplain forest, south of Tilouguite, northern slope of High Atlas Mountains).*

Fig. 14: *Type 14 – Dense plant cover with cedar forest as it formerly existed on the northern slope of the High Atlas (Rif Mountains, outside the target regions of the project).*

1.1.2 Alluvial plains, river valleys

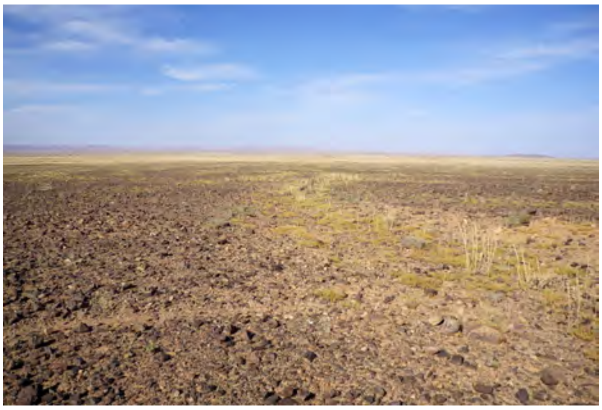


Fig. 15: *Type 15 – Patchy plant cover with herbaceous perennials and dwarf shrubs (south of Goulmina).*

Fig. 16: *Type 16 – Uniform, but loose plant cover with herbaceous perennials and dwarf shrubs (south of Boumalne - Dadès, view towards the High Atlas Mountains).*

***Fig. 17:** Type 17 – Uniform, but loose plant cover with Halfah grass, referred to as 'Halfah grass steppe' (southern part of the Oued Moulouya plain, foot of the High Atlas Mountains).*

***Fig. 18:** Type 18 – Patchy plant cover with herbaceous perennials, dwarf shrubs and occasional acacias (Jebel Bani, southeast of Tata).*

***Fig. 19:** Type 19 – Uniform, dense plant cover with herbaceous perennials, dwarf shrubs and occasional, loose assemblies of acacias along the Oueds (Oued Zguid north of Alougoum, Antiatlas Mountains).*

***Fig. 20:** Type 20 – Gallery forest with date palms (Oued Ziz near Ifri, southern slope of the High Atlas Mountains).*

***Fig. 21:** Type 21 – Floodplain forest with deciduous trees, among them numerous poplar trees (south of Tilouguite, northern slope of the High Atlas Mountains).*

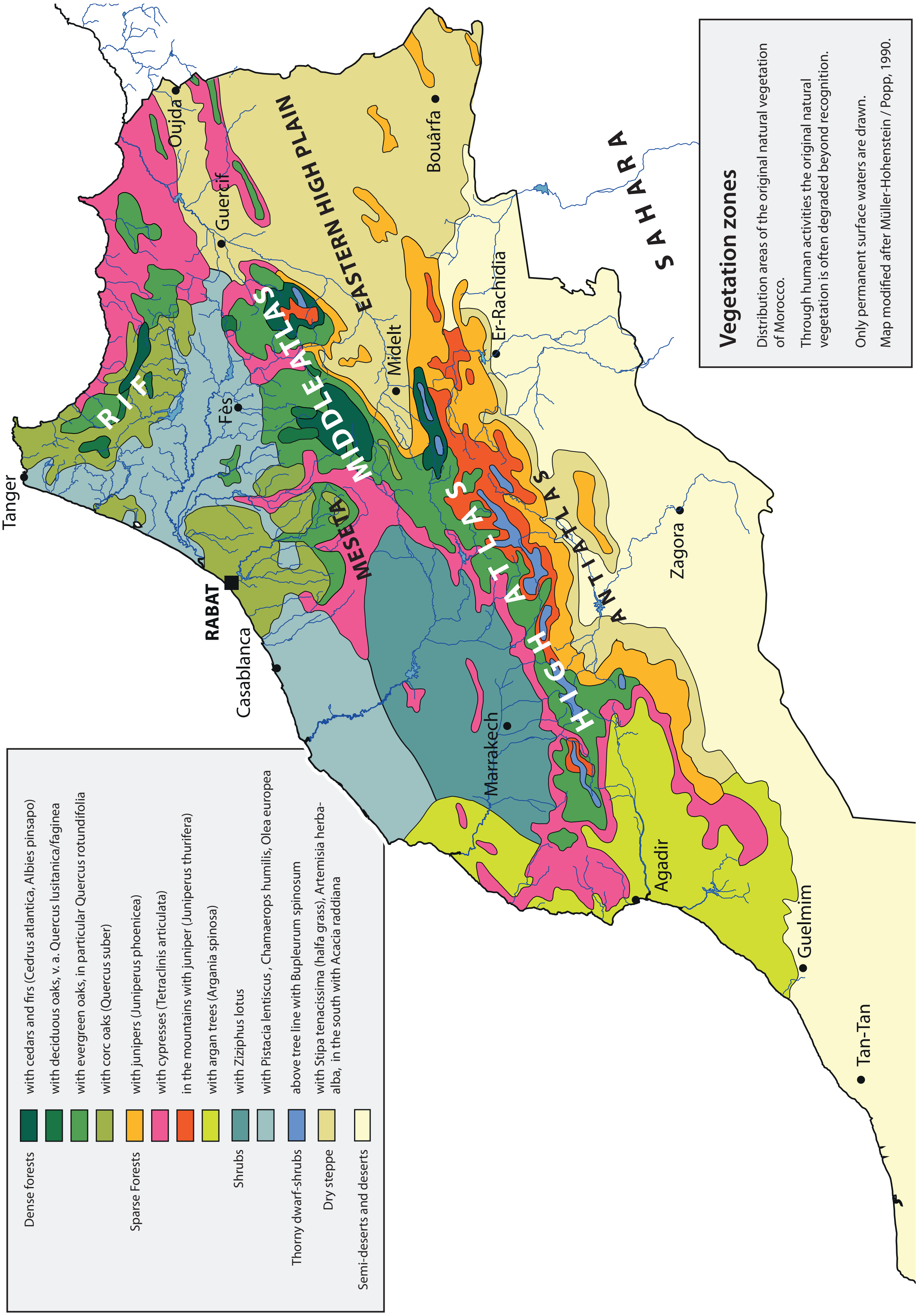


***Fig. 22:** Distribution areas of the original natural vegetation of Morocco. Through human activities, however, the original natural vegetation is often degraded beyond recognition. Map modified after Müller-Hohenstein / Popp, 1990.*

1.2 Degradation of the natural vegetation cover

In many places the natural vegetation cover actually observed cant be explained with the location factors mentioned in chapter 1.1. From this and from depictions of the local population about long-tem environmental changes “since time immemorial” we conclude that today part of the vegetation cover represents different stages of degradation of the natural vegetation due to human activity over the last centuries, such as logging of entire forests, repetitive cutting off of all branches of trees to feed cattle, pulling out of shrubs with their roots as combustible material for heating and kitchen, and overgrazing by goats and sheep.

Fig. 23: *The mountain barren of vegetation above the village Agoudal in the Asif Melloul Valley (south of Imilchil, High Atlas Mountains) is named „Green Mountain“ in the local language. Older inhabitants of Agoudal remember that the slopes of the mountain were covered with trees during their youth. However, it is not clear how dense this forest was, since the locals were not able to answer questions with this level of abstraction.*

For the selection of appropriate study areas and even more for a better understanding of the data of the planned case studies it is essential to recognise and identify anthropogenic changes of the natural vegetation and to trace them back to the original vegetation cover, if possible. This is complex as it is often neither clear, which type of vegetation could be expected to be the original one, nor to which extent it has been influenced by human activities. To simplify matters, the following questions arise:

- Which type of natural vegetation should grow under natural conditions in a certain area?
- Does it grow there or not?
- If not, why does it not grow there (natural or anthropogenic reasons)?
- If there are indications for anthropogenic reasons, what are these reasons?

Degradation of the natural vegetation and degradation of the soil go hand in hand. These processes can run very quickly or be gradual and thus hardly detectable. Thinning out or logging of the natural vegetation exposes the soil to water- and wind erosion. Particularly water erosion during rainstorms leads to the formation of deep erosion gullies on mountain slopes. Vice versa, where the soil is destabilized on slopes, natural vegetation better than loose perennials or shrubs that never will replace a former forest will not grow any more without human support, including perhaps also technical measures.

Indicators of anthropogenic degradation are: (see also figs. 24 - 38)

- Vegetation cover that does not correspond to the maximum possible cover for a certain climatic zone.
- More trees or denser vegetation in higher altitudes ore in more remote regions than in lower altitudes and / or around settlements.
- Dead, bleached three stems, standing upright or fallen over, isolated or in groups.

- Tree stumps on bare ground.
- Old, isolated, vital trees on mountain peaks, crests or in other inaccessible places in otherwise treeless environments.
- Tress with mutilated main branches, often with not woodened sprouts, cut again and again and used as cattle feed.
- Argan trees with main branches that bear no leafs or side branches on their upper side due to tree climbing goats grazing on them.
- “Bonsai”-trees that cannot grow due to ongoing overgrazing of their leafs and branches by goats.
- Recent, often regular erosion gullies cutting through bare mountain slopes that should be covered with vegetation.
- Large amounts of bundles of pulled out shrubs drying on special places around villages, used as combustible material for heating and kitchen.
- Numerous herds of sheep and goats on limited grazing grounds.

However, even if none of these indicators is unequivocally observed, it does not necessarily indicate that no degradation had taken place at all. As in the case of the “Green Mountain” above Agoudal (fig. 23), degradation may have taken place so long ago that the present conditions have become the basis of a general impression of ‘normality’ in the meantime and that the detection of indicators becomes difficult.

The main reason for anthropogenic degradation is an overuse of the limited resources due to a lack of alternatives under sparse environmental conditions. Many practices such as grazing of sheep and goats have been established and ensuring survival of the population over centuries and they are well adapted to the scarce mountainous environment on the condition of a strictly limited application, allowing regeneration of the vegetation. Particularly in the 20th century, however, due to population growth and new demands that go hand in hand with modernization, ecological systems have been driven beyond their limits in many places. The negative impacts of these processes could be mitigated today with relatively simple state measures such as a comprehensive coverage of the mountain regions with gas depots for cooking and heating, thus reducing the pressure upon forests and scrublands, and decisive campaigns against corruption in the environmental authorities. The development of the local services sector by creating additional jobs could help farmers to generate new and alternative sources of income, so that they do not depend any more on the pillaging of the remaining natural resources.

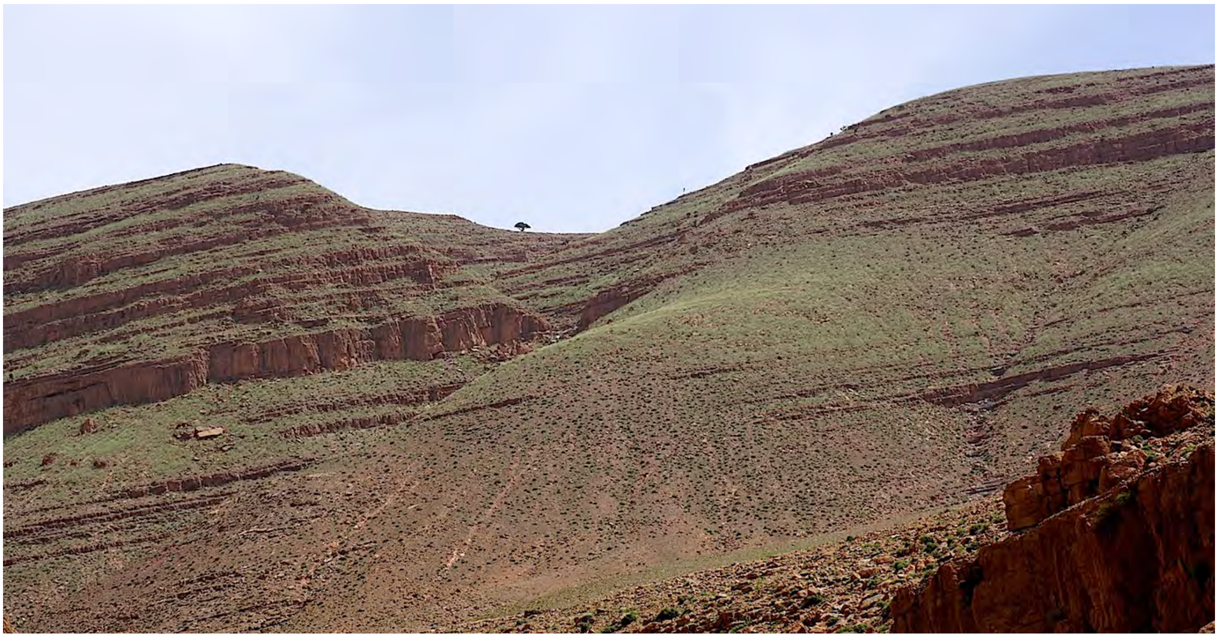


Fig. 24: *Isolated, old, but vital tree on an otherwise treeless crest. Such trees can – in the best case – be relics of more favourable climatic conditions, surviving also subsequent, more difficult conditions due to their strength. In the Alps numerous larch trees and Swiss stone pines can survive in the alpine ecology (above the treeline) since the Late Medieval climate optimum. In most of the cases in Morocco, however, we must assume that these trees are remnants of the original vegetation cover that has been overused and destroyed by mankind.*

***Fig. 25:** Dead cedars (yellow arrow) due to repeated cutting of the branches to feed animals in wintertime, whereas evergreen oaks (orange arrow) are not, or at least less affected by this treatment. Near Amelgou, High Atlas Mountains, autumn 2015.*

***Fig. 26:** Remnants of an at once dense cedar forest. Violent soil erosion on a marly slope in the foreground due to exposition of the soil to rainfall. Near Amelgou, High Atlas Mountains, autumn 2015.*

***Fig. 27:** 'Inverted tree line' (arrow) due to logging of the forest in the surroundings of villages. Algou / Chafarni, Tizi N'Test southern slope, High Atlas Mountains, autumn 2015.*

***Fig. 28:** Crippled evergreen oaks due to repetitive cutting off of all branches as cattle feed. Near Aït Hammodo, High Atlas Mountains, autumn 2015.*

***Fig. 29:** Crippled evergreen oaks due to repetitive cutting off of all branches as cattle feed. Aït Bou Oulli Valley, High Atlas Mountains, autumn 2015.*

***Fig. 30:** Erosion gullies in a marly slope with partial deforestation (crippled evergreen oaks). Carbonate plateau south of Aït Mhamed, High Atlas Mountains, autumn 2015.*

Fig. 31: *Remains of a conifer forest on land frequently used by nomads. Tizi N'Talrhemt, southeast of Midelt, High Altlas Mountains, spring 2015.*

Fig. 32: *Argan tree with crippled branches (no leafs and side branches on their upper side) due to overgrazing of the branches by tree climbing goats. Western High Atlas Mountains, spring 2015.*

Fig. 33: *"Bonsai" - argan tree due to overgrazing by goats. Western High Atlas Mountains, spring 2015.*

Fig. 34: *"Bonsai" - thorn shrubs due to overgrazing by goats. Tizi Tirherhouzine, south of Agoudal, High Atlas Mountains, autumn 2015. Image width is about 50 cm.*

Fig. 35: *"Bonsai" - woody shrubs due to overgrazing by goats. Tizi Tirherhouzine, south of Agoudal, High Atlas Mountains, autumn 2015. Image width is about 20 cm.*

Fig. 36: *Procurement of shrubs that are pulled out together with their roots in a huge quantity and used for firewood; near Agoudal, High Atlas Mountains, autumn 2015.*

Figs. 37 and 38: *Clearing of the natural juniper forest on steep slopes to reclaim new agricultural land near Ouaouizarth, Middle Atlas Mountains, spring 2015. This procedure contributes to soil erosion through the formation of deep erosion gullies, where rainwater flows down during the winter month, when the soil is not covered with cereal plants.*

1.3 Reforestation and measures against soil erosion

Reforested areas in Morocco are mainly planted with non-indigenous, species-poor cultures of pines, cedars or junipers. Even where reforestation is successful, it never compensates for all the degraded forests so far. First of all, reforestation is very rarely observed where severe deforestation is actually in progress, presumably because the local population would again cut all the trees newly planted. It also never occurs on often highly degraded nomadic land. Fences to save the new trees against cattle-damage would apparently not be accepted by the nomads and destroyed. Last but not least, reforestations or its remnants are also observed in areas where trees obviously never grew before, and where tree nurseries cannot succeed due to climatic conditions that are unfavourable for trees, giving the impression of tokenism. Reforestation is illustrated in figs. 39 - 45.

Traditional measures against soil erosion like terraced fields are a widespread cultural technique in the Atlas Mountains. The positive effect on erosion of such terraces, however, is only a side effect of the need for horizontal fields that are more convenient for irrigation and ploughing. Measures against erosion outside agricultural land in contrast are extremely rare, as apparently communities do not feel responsible, in spite of frequent and obvious damage from erosion as for example debris flows affecting roads or triggering flash floods (figs. 46, 47).

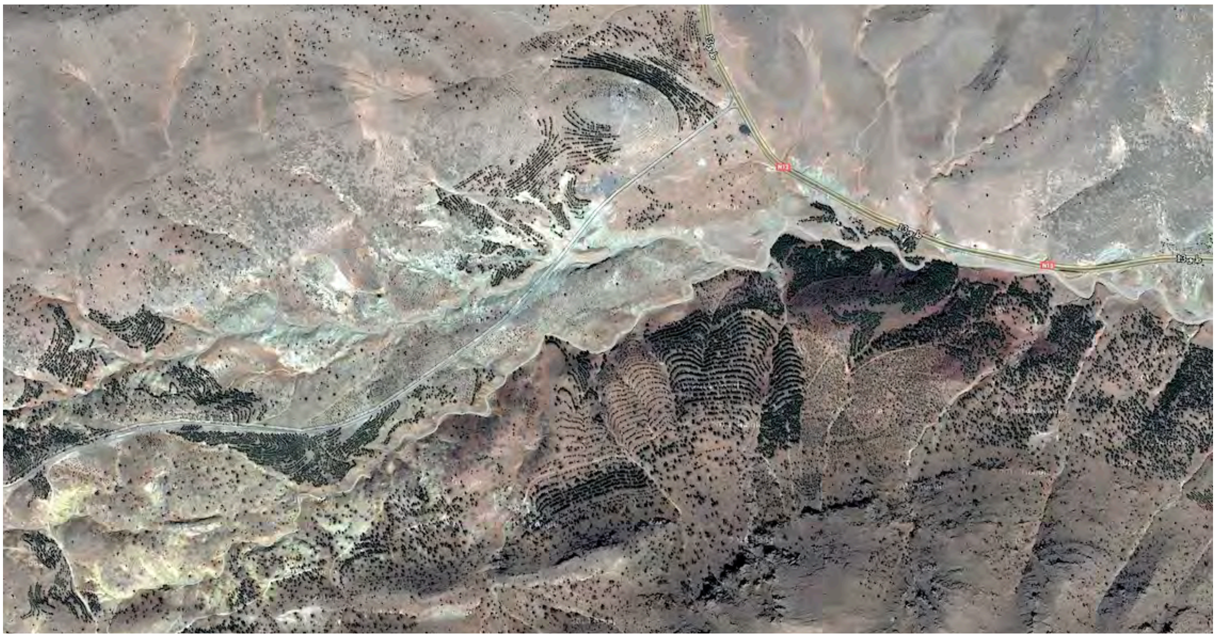


Fig. 39: *Reforestation on Tizi N'Talrhemt, southeast of Midelt, High Atlas Mountains; image width is 2.5 km.*
Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

***Fig. 40:** Reforestation with pine trees on Tizi N'Talrhemt at the entrance to the 'Parc National Haut Atlas'. Southeast of Midelt, High Atlas Mountains, spring 2015 (see also fig. 39).*

***Fig. 41:** Reforestation with conifers between the already existing evergreen oaks on a steep marly slope. Carbonate plateau of Aït M'Hamed, High Atlas Mountains, autumn 2015.*

***Fig. 42:** Deforested area with a sheep shelter in the foreground and reforestation in the background. Southern slope of Tizi N'Tichka, High Atlas Mountains, spring 2015.*

***Fig. 43:** Reforestation with conifers on the southern slope of Tizi N'Tichka, High Atlas Mountains, spring 2015.*

***Fig. 44:** Building up of a deciduous forest west of Ouarzazate (south of High Atlas Mountains), where never a forest occurred before. Among others Australian eucalypt trees were planted that are known for their high water consumption. This modern tree nursery is irrigated with groundwater from deep boreholes over drip tubes. Spring 2015.*

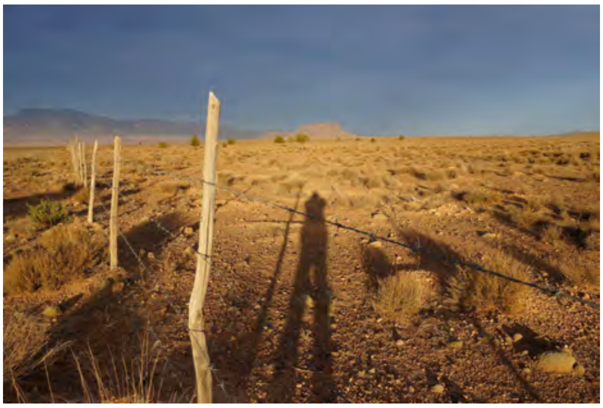


***Fig. 45:** Unsuccessful attempt to plant trees west of Gourrama (High Atlas Mountains), where never a forest occurred before. The only remnant is a fence. Autumn 2015.*

Fig. 46: *Erosion gullies that developed in the deforested part of a steep slope are stabilized with micro-dams. East of Aït Ouiksane, High Atlas Mountains, autumn 2015. For details see fig. 47.*

Fig. 47: *Detail of fig. 46; erosion gullies that developed in the deforested part of a steep slope are stabilized with micro-dams. East of Aït Ouiksane, High Atlas Mountains, autumn 2015.*

2 Agriculture

2.1 Types of farming

Agricultural land use is a central component of local water balances since most of the agriculture in the Moroccan mountains is based on irrigated cultivation with high water consumption. Irrigated agriculture occurs in all valleys with permanent, periodic or episodic streams and rivers. For the most part, agriculture is traditional, small-structured and reliant on much hand labour (figs 48 - 51). Mechanised agriculture – and when it is only a tractor – is largely inexistent in the mountains. Most of the irrigation water is transported to the fields by means of open irrigation channels that are derived from streams and rivers leading enough water from spring until about June. After the harvest, the fields dry out completely. For smaller gardens also during the dry summer months groundwater is used, if available.

Fig. 48: *Traditional agriculture: Loading of mules with simple hand ploughs in the morning. Village Amelgou, High Atlas Mountains, autumn 2015.*

Fig. 49: *Traditional agriculture: Ploughing by mules is the most common form in the mountains all over Morocco. Near Agoudal, High Atlas Mountains, autumn 2015.*

An exception on a large scale are parts of the Antiatlas Mountains, where extensive areas aside of streams and rivers are used for dry farming, either cultivated with hand ploughs on narrow terraces on steep slopes as in the westernmost Antitalas near Tafraoute, or with tractors on large, more or less horizontal fields as for example south and west of Tazenackht. Dry farming as an exception also exists in parts of the High Atlas Mountains. In the Middle Atlas Mountains, however, it is the predominant type of farming. Successful cultivation of dry land largely depends on the same location factors as growth of the natural vegetation. It is interesting to observe, how cultivated dry land

Fig. 50: *Traditional agriculture: Corn harvest near village Amelgou, High Atlas Mountains, autumn 2015.*

Fig. 51: *Traditional agriculture: On the way back from the fields with a hand plough as it is common in the whole High Atlas Mountains. Aït Bouguemez, autumn 2015.*

and natural vegetation merge with each other. For example it is often unclear to what extent argan trees, almond trees or palm trees are wild or cultivated varieties. Land for dry farming is often ploughed once only far outside the villages – which is an acceptable effort with a tractor – and then abandoned again, presumably because the harvest was too small or rainfall stood out in the following years. Often the natural vegetation is not cleared completely for dry cultivation so that cereal fields are interspersed with wild trees. In areas with predominantly sandy and argillaceous rocks of Triassic and Upper Jurassic age with a high water storage capacity, more dry farming is possible and also more villages occur aside of watercourses, supplying themselves with groundwater only.

A development program that was started by the government in 2004 enables a land use free of cost for agricultural purposes in areas that were not used for agriculture before. In addition, a subsidized access to electricity and water makes even dry areas attractive for large plantations. As a consequence, this program has the potential to change the Moroccan landscape from scratch in those dry areas that are suitable for mechanised agriculture. Thus, in particular in the alluvial plains containing groundwater resources at the southern foot of the High Atlas and the Antiatlas Mountains and in the broad longitudinal valleys of the eastern High Atlas, extended olive and fruit plantations emerge. The impact, however, of a continuously increasing need for groundwater in these areas is not known.

2.2.1 Most characteristic types of farming

19 characteristic types of farming are roughly distinguished mainly for the High Atlas and the Antiatlas Mountains, including some frequent types from the Middle Atlas Mountains, too (figs. 52 - 79).

Fig. 52: *Type 1 – Nomadic animal husbandry: Nomads with sheep in the Rheris gorge, High Atlas Mountains, spring 2015.*

Fig. 53: *Type 1 – Nomadic animal husbandry: In the width of the mountains, nomads are usually difficult to find. The most frequent signs of their presence are living caverns. Bou Nou Valley, Antiatlas Mountains, autumn 2015.*

Fig. 54: *Type 2 – Semi-nomadic animal husbandry: sheep shelter, southern slope of Tizi N'Tichka, High Atlas Mountains, spring 2015.*

Fig. 55: *Type 2 – Semi-nomadic animal husbandry: Herd of sheep southwest of Tizi N'Inouzane, near Aït Yekkou, High Atlas Mountains, autumn 2015.*

Fig. 56: *Type 3 – Argan trees with intensive grazing outside of cultivated fields. Southern slope of Tizi N'Test, High Atlas Mountains, spring 2015.*

Fig. 57: *Type 4 – Almond trees with intensive grazing outside of cultivated fields. Near Aït Abdallah, Antiatlas Mountains, spring 2015*

Fig. 58: *Type 5 – Dry farming with cereal fields far outside the villages. West of Tazenackht, pring 2015.*

Fig. 59: *Type 6 – Dry farming (right) in combination with pas-ture farming (background left). West of Tizi N'Isly, Middle Atlas Mountains, spring 2015.*

Fig. 60: *Type 7 – Dry farming with cereal fields in combination with argan trees on lage fields. Near Tahougat, Antiatlas Mountains, spring 2015.*

Fig. 61: *Type 8 – Dry farming with cereal fields in combination with argan trees on narrow terraced fields. Near Tahougat, Antiatlas Mountains, spring 2015.*

Fig. 62: *Type 9 – Dry farming with cereal fields in combination with almond trees. Near Azoura. Antiatlas Mountains, spring 2015.*

Fig. 63: *Type 10 – Dry farming with cereal fields in combination with remnants of the original vegetation consisting of cypress, juniper and evergreen oak. Near Ouaouizarth, Middle Atlas Mountains, Spring 2015.*

Fig. 64: *Type 11 – Terraced, irrigated cereal and vegetable fields below village Larba, High Atlas Mountains, autumn 2015.*

Fig. 65: *Type 12 – Irrigated, slightly terraced cereal fields on an alluvial fan near Telouet. High Atlas Mountains, spring 2015.*

Fig. 66: *Type 13 – Irrigated fields with fruit and poplar trees on alluvial land along Oued Dadès. The poplar trees are used for construction purposes. Near village Aït Toukshine, High Atlas Mountains, spring 2015.*

Fig. 67: *Type 13 – Irrigated fields with fruit trees (apples, cherries) on alluvial land at stream level. Akdim, Assif Melloul Valley, High Atlas Mountains, spring 2015.*

Fig. 68: *Type 14 – Temporary fields on alluvial deposits in the streambed, north of Imlil, High Atlas Mountains. Jebel Toubkal range in the background, spring 2015.*

Fig. 69: *Type 15 – Oases with deciduous trees along rivers as combinations of irrigated fields with cereals and alfalfa, and olive, almond and pomegranate trees. Wa-Ou-Nsamt, southern foothills of the High Atlas Mountains, spring 2015.*

Fig. 70: *Type 15 – Oases with deciduous trees along rivers: Irrigated cereal field and almond trees. Wa-Ou-Nsamt, southern foothills of the High Atlas Mountains, spring 2015.*

Fig. 71: *Type 15 – Oases with deciduous trees along rivers: Irrigated alfalfa field and almond trees. Wa-Ou-Nsamt, southern foothills of the High Atlas Mountains, spring 2015.*

Fig. 72: *Type 16 – Palm oases with irrigated, terraced fields in canyons. Aguinane Oasis, Antiatlas Mountains, autumn 2015.*

Fig. 73: *Type 16 – Palm oases with irrigated, terraced fields (cereal, cattle fodder crops and vegetables) in canyons. Azegza, Antiatlas Mountains, autumn 2015.*

Fig. 74: *Type 17 – Palm oases with irrigated fields on alluvial land in canyons. Anamir (left) and Ighir Smouguen (right), Antiatlas Mountains, autumn 2015.*

Fig. 75: *Type 17 – Palm oasis with irrigated fields on alluvial land in canyons (cereal, cattle fodder crops and vegetables). Near Anamir, Antiatlas Mountains, autumn 2015.*

Fig. 76: *Type 18 – Palm oases with irrigated fields (cereals, cattle fodder crops and vegetables) on alluvial land along rivers in the foothills or in alluvial plains. Al Ougoum, spring 2015.*

Fig. 77: *Type 18 – Palm oases with irrigated fields (cereals, cattle fodder crops and vegetables) on alluvial land along rivers in the foothills or in alluvial plains. Drâa valley near Agdz, spring 2011.*

Fig. 78: Type 18 – Palm oases with irrigated fields on alluvial land along rivers in the foothills or in alluvial plains. Mhamid, southern Drâa valley, spring 2015.

Fig. 79: Type 19 – Development of agricultural land for new plantations by means of subsidized groundwater use in arid areas. West of Ouarzazate, spring 2015.

2.2 Irrigation

In the High Atlas and the central and eastern Antiatlas Mountains with the adjacent foothills and alluvial plains, where surface water or groundwater occurs, irrigated agriculture is the most common type of farming. In areas with abundant permanent or periodic surface water, irrigation usually operates by means of open, concrete channels (séguias), leading water from the main stream / river or from lateral valleys on higher levels and parallel to the contour lines onto the fields (figs 80 - 87).

In the western Antiatlas Mountains permanent sources emerging at the foot of mountains that consist of quartzite and conglomerates play a central role for irrigation. To safe water, and because usually each family has its own source, modern plastic taps are used there to disentangle the water flow and to transport the water from the sources to the fields and also to the households (fig. 95).

Areas without abundant surface water rely on groundwater for irrigation. Traditionally, groundwater is pulled up manually from draw wells and then poured directly on the fields also by hand. However, many draw wells are equipped with petrol engine-driven pumps today and the water is transported on the fields with plastic pipes (figs. 88 - 94). Modern plantations in contrast are usually equipped with boreholes. Groundwater is pumped during a few hours per day into large, open cisterns, from where it is distributed onto the fields by mostly open irrigation channels (figs. 96 - 98).

In areas without abundant permanent or periodic surface water and without substantial groundwater resources, but where episodic heavy rainstorms occur, the rainwater that runs off too quickly on the completely dried-out soils is collected in micro-dams (figs 99, 100) or so-called 'matfias', a kind of superficial or underground cisterns with a sophisticated inlet system to clean the muddy flood water (figs. 101, 102).

Fig. 80: Damming of Assif Melloul to supply irrigation channels on both sides near Tissila. High Atlas Mts., autumn 2015.

Fig. 81: Irrigation channel near Aït Toukshine with irrigated fields along Oued Dadès. High Atlas Mountains, spring 2015.

***Fig. 82:** Irrigation channel near Akdim with irrigated fields on alluvial land along Assif Melloul. High Atlas Mountains, spring 2011.*

***Fig. 83:** Irrigation channel in the oasis of Wa-Ou-Nsamt (north of Aït Ben Haddou), southern foothills of the High Atlas Mountains, spring 2011.*

***Fig. 84:** Irrigation channel in the Todhra Gorge north of Tinerhir, High Atlas Mountains, spring 2015.*

***Fig. 85:** Building of a dam with stones and sandbags to branch off an irrigation channel from Oued Dadès. Boumalne du Dadès, southern foothills of the High Atlas Mountains, spring 2015.*

***Fig. 86:** Irrigation channels on different levels above Oued Drâa, south of Agdz, spring 2015.*

***Fig. 87:** Irrigation channel in the palm gardens of Amtoudi. Antiatlas Mountains, autumn 2015.*

Fig. 88: *Draw wells ensure the water supply of nomads in the arid southernmost Antiatlas Mountains. Jebel Beni, east of Zagora, Spring 2011.*

Fig. 89: *Draw well with troughs to water herds. West of Tazenackht, Antiatlas Mountains, spring 2015.*

Fig. 90: *Draw well for the irrigation of almond trees near Azoura. Antiatlas Mountains, spring 2011.*

Fig. 91: *Bucket in a draw well made of a truck tyre. Antiatlas Mountains, spring 2011*

Fig. 92: *Former draw well recently equipped with a motor pump. Wa-Ou-Nsamt, High Atlas Mountains, spring 2015.*

Fig. 93: *Well with a mobile motor pump near Outerbate. High Atlas Mountains, spring 2011.*

Fig. 94: *Draw well with an additional motor pump for irrigation of fields south of Tazzarine. Jebel Beni, Antiatlas Mountains, spring 2011.*

***Fig. 95:** Plastic taps for irrigation in Oumesnat, upper Ammeln Valley. Each tap is connected to a specific 'family source' in a lateral valley. Antiatlas Mountains, autumn 2015.*

***Fig. 96:** Open cistern for irrigation of palm gardens near Aguerd (*lowermost Assif N'Innt). *Antiatlas Mountains, autumn 2015.*

***Fig. 97:** Open cistern and groundwater pump with irrigated fields in the upper part of the Handour canyon. North of Ne-kob, Jebel Saghro, autumn 2015*

***Fig. 98:** Open channel for irrigation of large-scale plantations east of Ouarzazate. The water is pumped up from the artificial El Mansour Eddahbi lake near Ouarzazate. Spring 2011.*

***Fig. 99:** Modern micro dam for irrigation and household water supply made of concrete, collecting water from rare rainstorms in a stream. North of Tizi N'Tazarine, Jebel Saghro, Spring 2015.*

***Fig. 100:** Traditional micro dam for irrigation, made of mud, col-lecting water from small, episodic streams. Near Almgho, Assif Melloul Valley, High Atlas Mountains, spring 2015.*

***Fig. 101:** Traditional matfia (cistern) for the storage of rain water running off quickly in the carstic underground on the carbonate plateau north of Imi Ouaddar. Westernmost High Atlas Mountains close to the Atlantic coast, autumn 2015.*

***Fig. 102:** Modern matfia (cistern) for the storage of rain water running off quickly on dry soils (direction of water flow see arrow). North of Souk El Had Azghar N'Irs, Antiatlas Mountains, autumn 2015.*

The use of water for irrigation that is branched off from a stream or river is regulated down to the last detail within each single village. In Contrast, there are apparently no regulations between all those villages that share the same stream or river concerning the common use of its water resources. As a consequence, the highest villages have an advantage over lower villages as they can use as much water as they like, and it is not regulated to what extent they have to be considerate towards the needs of lower villages.

2.3 Natural and human-induced risks for the agricultural land

In the mountainous areas of Morocco, agricultural land is jeopardized mainly through four processes with partly natural and partly anthropogenic causes:

- Erosion of agricultural land at the concave bank of streams and rivers (fig. 103).
- Flooding of agricultural land by streams and rivers and subsequent covering with sediment such as sand and gravel at the convex bank (fig. 103).

***Fig. 103:** Farmland eroded at the concave bank (red arrow) and covered with sediment at the convex bank (yellow arrow) during flooding in autumn 2014 and spring 2015. Tiourassine, Asif Ounila Valley, southern foothills of the High Atlas Mountains, spring 2015.*

- Landslides affecting agricultural land (agricultural land sliding down or being covered with a debris flow), particularly in areas with degraded vegetation (fig. 104).
- Soil salinisation (figs. 105, 106).

Most of the intensively used and irrigated agricultural land is located along watercourses. These are essential for survival of the population, but at the same time they are also the greatest threat to agriculture because episodic floods can wash away farmland or cover it with sediment. The situation is particularly delicate for meandering streams and rivers with pronounced concave and convex banks. At the concave banks farmland is eroded during floods, while it is covered with sediment up to a meter thick at the convex banks (fig. 103). Riverbank protection measures such as walls are largely absent or the walls are of such a bad quality that they are easily washed away.

Figs. 104: *Debris flow near Aït Hammodo due to deforestation of the slope. High Atlas Mountains, autumn 2015.*

Fig. 105: *Soil salinization and related reduction of soil fertility on cereal fields near Aït Ben Haddou due to irrigation with surface water from Asif Ounila containing salt, and subsequent evaporation. Asif Ounila Valley, southern foothills of the High Atlas Mountains, spring 2015.*

Fig. 106: *Soil salinization and related reduction of soil fertility on cereal fields near Goulmima due to irrigation with groundwater containing salt and subsequent evaporation. Alluvial plain south of the High Atlas Mountains, spring 2015.*

For soil erosion on farmland see figs. 37 and 38.

3 Rural settlements in Moroccan mountainous regions

3.1 Types of rural settlements

High Atlas Mountains: In most parts of the High Atlas Mountains including its southern foothills, farmland and areas of settlement are clearly separated from one another. As a consequence, the traditional villages are usually compact, sometimes displaying two or more parts that may for instance be located on each side of a river. In traditional village cores the footpath between the houses are frequently narrow and contorted, whereas more modern parts are adapted to car traffic (figs. 107 - 113). Loose villages and scattered settlements are rare in these areas and mainly occur on the northern slope of the High Atlas Mountains in the transition zone towards the Middle Atlas Mountains (figs. 114, 115).

Antiatlas Mountains: With regard to settlements, the Antiatlas Mountains are quite inhomogeneous. In the western Antiatlas, villages are often loose or, rather, scattered settlements, whereas in the central and eastern Antiatlas compact villages predominate (figs. 116 - 118).

Middle Atlas Mountains: In the Middle Atlas Mountains in contrast, most settlements are scattered or even isolated farmsteads. Villages are rare. If compact settlements occur, these are usually souks (marketplaces with weekly markets) that are favourably located along trade routes and that are inhabited by few people only. These souks do, however, not assume further functions of centrality, whereas rare small towns play the more important role as centres for the scattered settlements in the surrounding areas (figs. 119, 120).

Rif Mountains: The agriculturally usable surfaces of the Rif Mountains are coated with a network of scattered settlements. Souks and towns by contrast are very rare (figs. 121, 122).

Areas with predominantly scattered settlements, loose villages or villages with too many parts are not suitable for the envisaged case studies due to dissipated water supply systems and responsibilities, which make fieldwork difficult. As a consequence, the Rif Mountains and the Middle Atlas Mountains are not part of the target area of our project, although they could contribute comparative studies in areas with higher precipitation rates and denser vegetation cover.

In the main valleys, most villages are easy to access on paved roads that connect towns or that lead over passes into neighbouring valleys. In lateral valleys or in sparsely populated higher mountainous areas, paved roads frequently turn into mud roads. In hilly areas with rather weak rocks, these mud roads are usually easy to pass and save. In rough areas, however, where hard rocks form step slopes or rock walls, or in the highest parts of the Atlas Mountains, were there is often snow, mud roads can be very exposed and technically difficult, and thus dangerous to drive. Numerous mud roads are actually converted into narrow paved roads by the government. Villages or hamlets in very remote areas are accessible on footpath only, a situation that is not about to change in the near future.

Fig. 107: *Traditional rural hamlet (douar) near Mouldikht. Oued N'Fis Valley, High Atlas Mountains, spring 2015.*

Fig. 108: *Traditional rural hamlet (douar), part of village Telouet. High Atlas mountains, spring 2015.*

Fig. 109: *Compact village Oudeddi in the upper Rheris-Gorge with a clear allocation of agricultural land on the fertile alluvial land, and land for settlement on the infertile debris cone. High Atlas mountains, spring 2015.*

Fig. 110: *Compact village with mainly traditional stone houses in the uppermost Oued N'Fis Valley. High Atlas Mountains, autumn 2015.*

Fig. 111: *Compact village Ighil with mainly traditional stone houses in a lateral valley of Oued N'Fis Valley. High Atlas Mountains, autumn 2015.*

Fig. 112: *Compact village Tourbiste with many traditional clay houses on the lower course of river Mgoun. Southern foothills of the High Atlas Mountains, autumn 2015*

Fig. 113: *Compact villages Anamir (left) and Ighir Smouguen (right). Note the many abandoned and collapsed clay houses in Anamir that are difficult to distinguish from the rocks (arrow), whereas the inhabited houses are all modern concrete/ brick houses. Antiatlas Mountains, autumn 2015.*

Fig. 114: *One of the rare areas in the High Atlas Mountains with loose villages: Settlements on a terrace below the main ridge of the High Atlas Mountains north of Taroudannt, autumn 2015.*

__Fig. 115__: Scattered farmsteads on the carbonate plateau south of Aït Mhamed. Transition zone of the High Atlas Mountains towards the Middle Atlas Mountains, autumn 2015.

***Fig. 116:** Loose village Aferni, western Antiatlas Mountains, spring 2015.*

***Fig. 117:** Scattered settlement near Tazka. Western Antiatlas Mountains north of Tafraoute, autumn 2015.*

***Fig. 118:** Loose village Imi N'Tizght with numerous new buildings in pink in the upper Ammeln Valley. Antiatlas Mountains, spring 2015.*

***Fig. 119:** Scattered farmsteads in the Middle Atlas Mountains. Between El Arba and Ouaouizarth, spring 2015.*

***Fig. 120:** Scattered farmstead in the Middle Atlas Mountains. Between El Arba and Ouaouizarth, spring 2015.*

Fig. 121: Scattered farmsteads in the Rif Mountains between Ketama and Chefchaouen, spring 2015.

Fig. 122: Scattered farmsteads in the Rif Mountains between Ceuta and Tangier, spring 2015.

3.2 Construction material

Traditionally, construction material is always collected locally, which is the basis for the markedly earthbound aspect of traditional villages. In the Atlas Mountains, few rock types are suitable for construction of houses. Most of the rock types are either not erosion-resistant enough, forming too weak or too small blocks, such as marls or argillaceous rocks, or they are hard to process by hand, such as granite or coarsely bedded dolomite and limestone. The only rock types used frequently to build houses are sand- and limestones with a thin bedding between 5 and 20 cm (figs. 123, 125). In all other cases, clay is the preferred construction material, that is usually abundant everywhere. Most of the Moroccan clay houses are built with the ‘pisé’- or ‘stamp clay’-technique, where a mixture of wet clay, gravel and straw is stamped between wooden planks, comparable with the modern concrete building method, but without armour and mechanical compacting (figs. 124, 125). Clay houses are very prone to weathering and without careful maintenance they tend to disintegrate quickly (see fig. 129). Clay walls are not painted, the colour of traditional villages therefore strictly depends on the colour of the clay that is locally available. Under changing geological conditions, the colour of the houses sometimes changes within the same village. Most houses are one- or two-storied, with flat mud roofs, the floors and roofs being carried by poplar stems. Burnt clay bricks were completely unknown in the traditional architecture of the Atlas Mountains. Unburnt clay bricks are rarely used and, if at all, then only for special buildings like Tigrhemts, Ksour or Kasbahs (see next chapter).

Today, new houses are usually built with concrete and industrial bricks and painted salmon-pink or yellow. The architecture of new houses is usually functional, without any connection to traditional architecture. New houses can, however, also be pompously ornamented in a modern, nondescript ‘oriental style’. In both cases, they are often markedly unsightly.

Fig. 123: Village Imi N'Tatelate (Ait Yacoub), one of the rare villages constructed fully with stone blocks that are not plastered. Antiatlas Mountains, autumn 2015.

Fig. 124: Village Aït Ouanougdal, characteristic for the pisé-technique using stamped clay. Aït Bougouemez Valley, High Atlas Mountains, autumn 2015.

Fig. 125: *Village Imizilen in the Megdaz Valley, where part of the houses are built with stone blocks and part with stamped clay. High Atlas Mountains, autumn 2015.*

3.3 Extraordinary manifestations of rural architecture

Rural architecture in the Atlas Mountains has more to offer than only common houses. Tribal rivalries or rivalries between Berber family clans within the same tribal groups were part of a life under sparse environmental conditions with limited resources. Therefore, fortified houses, granaries or even villages were indispensable, particularly in those regions, where the habitats of sedentary groups practising agriculture overlapped with the habitats of nomadic groups that covered part of their livelihood through forays. Thus, family houses were often built as castles, called 'tighremt', with mostly three floors and four prominent corner towers (figs. 126 - 129). Several family houses (tighremts and / or normal houses) that are assembled to a fortified village with possibly a collective granary and oven, and a surrounding, continuous wall are named 'ksar', and several assembled ksar are a 'ksour' (fig. 130).

The term 'kasbah' is misleading. Initially, kasbahs were medinas or walled citadels, guarded by armed forces and inhabited by governors or leading families, that are found in most North African cities and towns and that are thus in most areas not part of the rural cultural heritage. In Morocco, however, the term is also used for fortresses outside the towns in the Atlas Mountains, where they were built to protect the hinterland against rebellious tribes. Since the end of the 19^{th} century the term is also used for Berber Ksour and Tighremt, which leads to an imprecise terminology, especially in touristic literature.

In the Antiatlas Mountains many Berber groups lived a semi-nomadic life, growing cereals in the surroundings of their villages and herding sheep and goats on remote pastures. To keep their stocks of cereals and their family valuables in a safe place during their absence, collective fortified granaries named 'agadir' were built on places difficult to access that were guarded by armed persons (figs. 131 – 133). Occasionally, additional sentinels on hilltops improved the safety.

Fig. 126: *Well-preserved and inhabited Tighremt 'Ighram N' Caid Ahansal' near Oued Lakhdar southwest of Aït M'Hamed, built with limestone blocks. High Atlas Mts., autumn 2015.*

Fig. 127: *Tighremt in Aït Moussa Wichou, built with unburnt clay bricks. Upper Dadès Valley, High Atlas Mountains, autumn 2015.*

Fig. 128: *Tigrhemt of Agafay, built with unburnt clay bricks and displaying ornaments in the upper part of the wall. Near Boumalne du Dadès, south of the High Atlas Mountains, spring 2015.*

Fig. 129: *Abandoned and disintegrationd Tigrhemts of Tajegnite that were built with the pisé-technique. Upper Asif Ounila Valley, southern foothills of the High Atlas Mountains, autumn 2015.*

Fig. 130: *Ksar Aït Ben Haddou in the lower Asif Ounila Valley is a United Nations World Heritage. It was built with the pisé-technique and is very prone to weathering. Despite of ongoing repair, its decay can hardly be stopped. Southern foothills of the High Atlas Mountains, spring 2015.*

Fig. 131: *Agadir Aguelloui is one of the best-preserved Berber storage castles, built above a steep rock wall near Amtoudi. Southern Antiatlas Mountains, autumn 2015.*

Fig. 132: *Entrance to Agadir Aguelloui (Berber storage castle) above Amtoudi. Note the ornamental triangles above the door that are to be found in Moorish architecture in Mauretania, too. Antiatlas Mountains, autumn 2015.*

Fig. 133: *Inside Agadir Tasguent (Berber storage castle) with single family safes for grain, oil and valuables behind each door. Antiatlas Mountains, autumn 2015.*

Rural architecture includes also simple, sacred buildings named ‘zawiyas’ that are tombs of venerated marabouts. Zawiyas are usually very old and have become holy centres and places of pious reflection in the course of time (figs 134, 135). Today ‘marabout’ means ’saint’ in the Berber language, and refers to Sufi Muslim teachers who head a lodge or school called a zaouïa, associated with a specific school or tradition. The roots of this tradition can be traced back to ancient times when the Berbers believed in polytheistic religions.

By contrast, old mosques are very rare in rural areas. Apparently most of them have been replaced by modern buildings in the last decades.

Fig. 134: *Old and newer Zawiya near Kiriwt. Aguinane canyon, Antiatlas Mountains, autumn 2015.*

Fig. 135: *Zawiya near Tassetifte. Oued Zguid Valley, north of Al Ougoum, Antiatlas Mountains, spring 2015.*

3.4 Drinking water supply

Many villages in the Atlas Mountains were equipped with drinking water supply networks by the government project PAGER[1] from the 1990s onward. However, there are villages that still wait for a drinking water supply network, or that have completed their network recently only with the support from non-governmental development agencies. Also within the same village, the water supply may be of a different quality. Whereas in one part of the village water pipes lead into the houses, in another part, water is drawn from wells and transported to the houses in canisters carried by donkeys. In most villages, a combination of public and private boreholes and wells with or without pump and supply network, respectively, and water withdrawal from streams and rivers is the common practice. Thus, the survey of the water use in the households is a complex task including multiple extraction points and methods.

Villages with a modern water supply network usually dispose of groundwater pumps and cisterns situated in an elevated position to guarantee the necessary water pressure in the pipes. In areas with a modern water supply, villages within the same valley may also be connected among each other with compensation pipes in order to ensure water supply in case of malfunctions in one of the villages (figs. 136 - 141).

Without a doubt, the establishment of water supply networks eases the access to drinking- and household water and thus facilitates the daily life, particularly for women and girls that are responsible for the households. However, it also leads to an increase in household water use of several hundred percents, whereby the surface- and groundwater resources do not increase. This development is highly problematic and may lead to water shortage within shorter or longer time span.

[1] PAGER: Programme d’approvisionnement groupé en eau potable des populations rurales

Fig. 136: *Draw well and groundwater pump (in the house) in the riverbed near Tifarki. Antiatlas Mountains, autumn 2015.*

Fig. 137: *Cistern filled with water by means of a plastic tube that is connected with a source (arrow). Tichka Valley, High Atlas Mountains, spring 2015.*

Fig. 138: *Cistern near Argue, High Atlas Mountains, spring 2015.*

Fig. 139: *Water pipe with shafts leading from cisterns on a hill down to the villages on the foot of the mountains. Alluvial plain south of Jebel Saghro (north of Nekob), autumn 2015.*

Fig. 140: *Groundwater pump of Al Ougoum (arrow). Oued Zguid Valley, Antiatlas Mountains, spring 2015.*

Fig. 141: *Cistern on the slope above Al Ougoum. Oued Zguid Valley, Antiatlas Mountains, spring 2015.*

3.5 Dealing with wastewater and solid waste

In rural villages wastewater is either not treated at all and disposed directly into the streams and rivers via sewage pipes (fig. 142), or it is discharged into the groundwater via seeping pits. The impact of these customs on the environment will be part of the intended case studies. Solid waste is in the best case burnt from time to time next to the houses or in public ditches, or it is, as it often can be observed, disposed in open dumps next to houses or villages (figs. 143, 144).

Cities and towns usually collect their waste and operate authorized waste disposal sites, where the waste is periodically set on fire. However, these sites are usually dry and not protected against wind effect, resulting in huge quantities of light waste such as plastic bags that are blown away and re-deposited on extended areas around the disposal sites (fig. 145).

Regardless of weather out of small village dumps or out of large waste disposal sites, huge amounts of plastic particles are thus released to the environment, where they are washed away in riverbeds or transported by the wind. During transportation, as well as through solar radiation, they are decomposed physically to micro-particles, the danger for health of which is obvious, but not clarified in every detail yet. It is evident that this problematic manner of handling solid waste contributes a substantial proportion to the worldwide threat by micro-particles.

Fig. 142: *Sewage pipe (arrow) and waste disposal in the village Aghbare in a lateral valley of Oued N'Fis Valley. High Atlas Mountains, autumn 2015.*

Fig. 143: *Waste disposal in the village Aghbare in a lateral valley of Oued N'Fis Valley. High Atlas Mountains, autumn 2015.*

Fig. 144: *Waste disposal outside village Askoun. Jebel Siroua, autumn 2015.*

Fig. 145: *Plastic bags dispersed around the official waste disposal site of Ouarzazate, spring 2015.*

4 The influence of geology on the density of settlement

It is striking how the density of settlement and of agricultural use can vary significantly on a small scale and under comparable climatic conditions. Field observations and thorough studies of satellite images suggest that the geological nature of the underground, i.e. the rocks with their specific characteristics concerning weathering, erosion, water infiltration and water storage capacity etc. plays a crucial role for the settlement density in the entire Atlas Mountains. The differences are particularly impressive in those areas of the Antiatlas Mountains, where streams and rivers dry out in April or May already, thus, where dry farming is possible only.

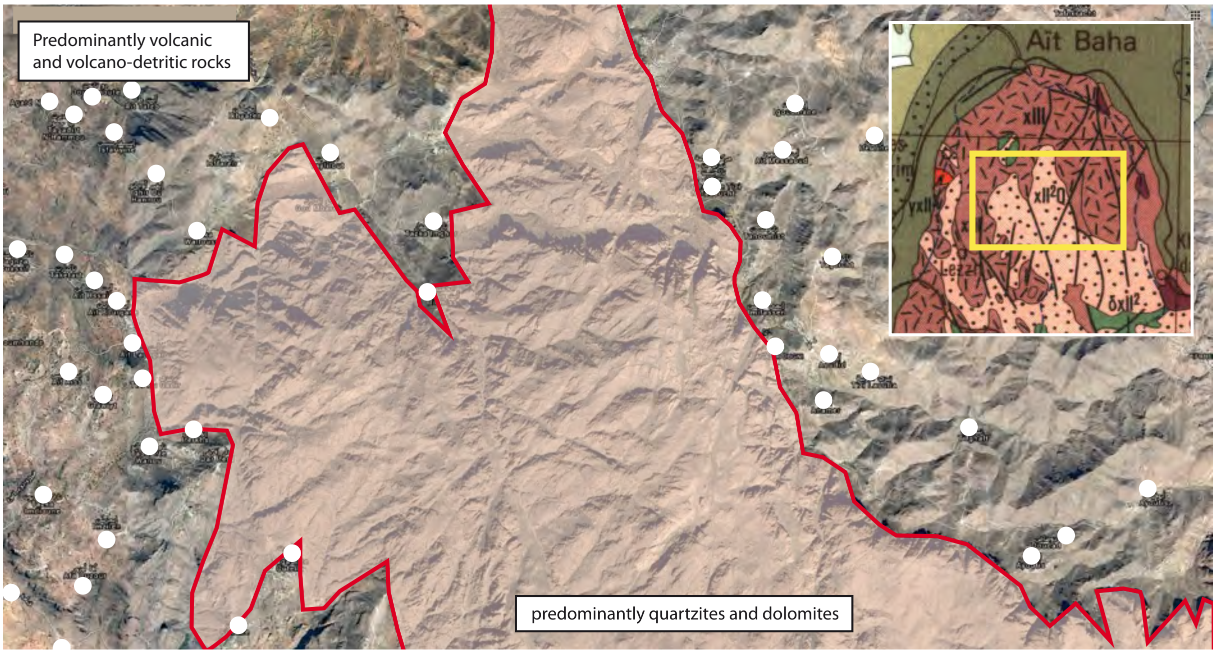


Fig. 146: *Precambrian rocks in the Antiatlas Mountains north of Tafraoute, showing striking differences in population density. Whereas in the volcanic rocks (xIII on the geological map) numerous small villages occur (white dots), the areas dominated by quartzites and dolomites (xII^2Q) are largely uninhabited. Image width: 16 km.*

Background: Satellite image © Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

5 Local development

In most rural villages local development associations are established. These associations may belong to a nationwide network of rural development agencies, coping with multiple, and partly large-scale development issues, like the ‘Initiative Nationale pour le Développement Humain’ (figs. 147-149), or they may be organized locally only and focus on the promotion of local products, like e.g. argan oil, fruit or handicraft. (fig. 150).

At least in theory, the agencies that are acting under the roof of the ‘Initiative Nationale pour le Développement Humain’ should be substantially financed by the regional or national administrations. In reality, however, many of their projects are financed by international NGOs, that remain more discretely in the background in Morocco than in most African countries. An actual example for this proceeding is the financing of the drinking water supply in the village Outerbate in the Taribante Valley (eastern High Atlas Mountains) by the ‘US Aid’ via the local ‘Initiative Nationale pour le Développement Humain’. Development associations like the ‘Initiative Nationale pour le Développement Humain’ also play an important role as intermediaries between the local population and the administration, when collecting and bringing order to the needs of the locals and then communicating them to the administration.

Whereas the impact of many private initiatives is very modest and locally limited, and also their presence in public usually remains limited to a label with peeling paint on a sheet of steel at the roadside, the ‘Association Akhiam’ (http:// www. akhiam.org) must be highlighted here as an outstanding example for successful, autonomous, local development associations. 'Akhiam' is locally anchored and focuses on education, farming and the fight against erosion in the uppermost Assif Melloul valley in the Imilchil region (eastern High Atlas Mountains). The association's website gives a good insight into their activities (fig. 151).

Fig. 147: *Administrative building and convention centre of the rural development agency of Oumesnat in the upper Ammeln Valley. Antiatlas Mountains, autumn 2015.*

Fig. 148: *Labelling of the administrative building and convention centre of the rural development agency 'Initiative Nationale pour le Développement Humain' in Outerbate. High Atlas Mountains, autumn 2015.*

Fig. 149: *Meeting room of the rural development agency 'Initiative Nationale pour le Développement Humain' in Outerbate. High Atlas Mountains, autumn 2015.*

Fig. 150: *Sign for a local development agency in Imi N'Tizght in the upper Ammeln Valley, Antiatlas Mountains, spring 2015.*

6 Results from conversations with locals

6.1 Risks for the project

Risks and opportunities of the project have been discussed with several persons with higher education that were born in the Atlas Mountains and that returned there after finishing their study time in one of the Moroccan cities, allowing an insight into the thinking and action of the local population in rural areas.

First of all, it became clear that traditional behaviour patterns still dominate the rural life and that developments and innovations are viewed with restraint or are even met with dissaproval. Secondly, it becomes apparent that in rural areas it is particularly difficult to find the balance between traditional values and ways of acting, respectively, on the one hand, and the revelations and requirements of a life within a modern nation on the other hand. This area of friction harbours a significant potential for conflict within families or communities as well as between local communities and superordinate authorities, and leads to disorientation particularly of the younger generation.

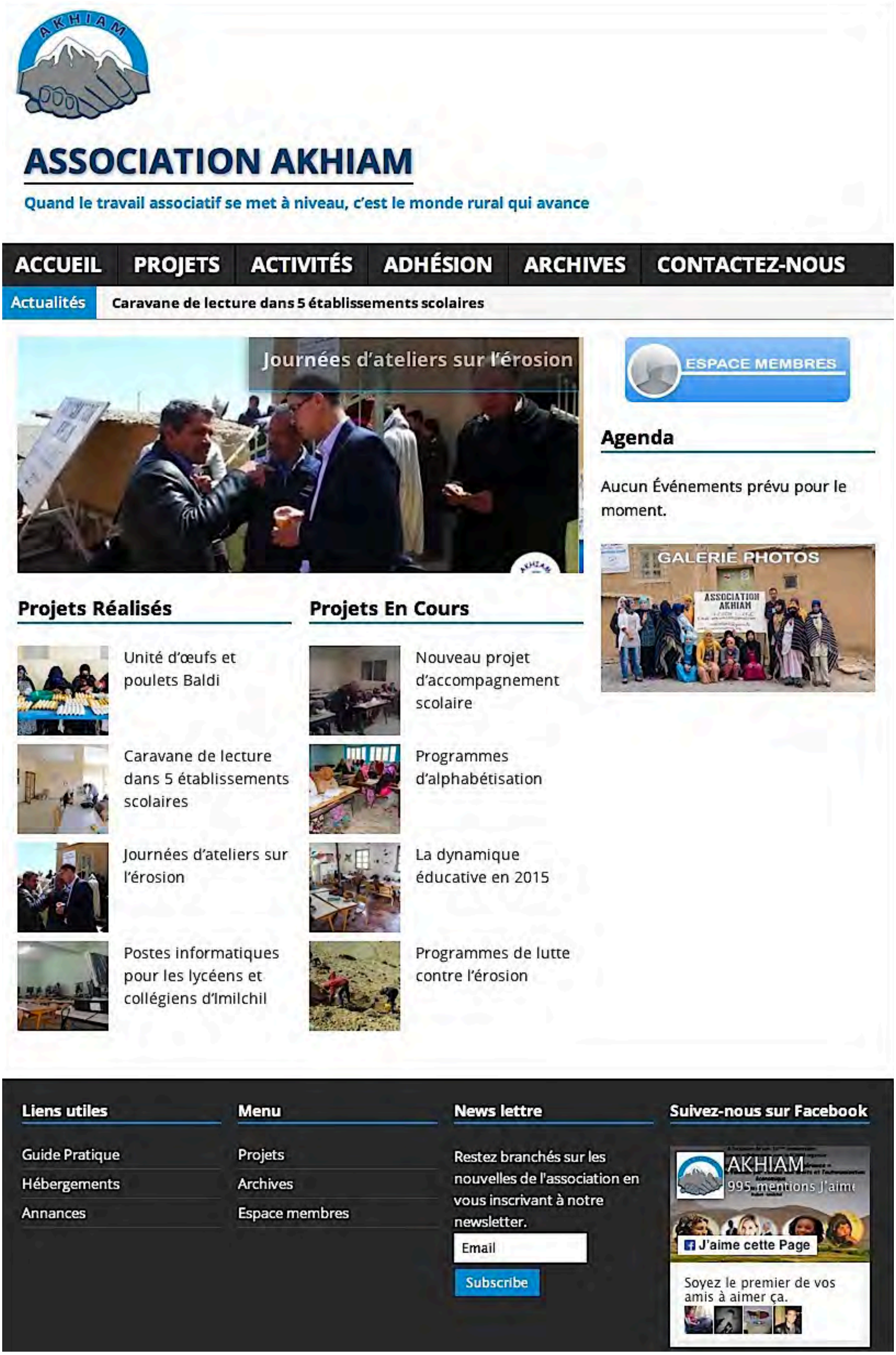


Fig. 151: *Web presence of the 'Association Akhiam', showing their fields of activity (http:// www. akhiam.org).*

The opportunities of the project are discussed in detail in the project documentation. Therefore, at this point, particularly the risks are discussed and conclusions are drawn that are of crucial importance to the success of the project.

6.1.1 Risks emerging from attitudes and values of local stakeholders

The following list of risks is based on conversations with local interlocutors and potential local multipliers.

1 – Too many deficiencies

Scarce natural resources are only one of numerous deficiencies. The population in the mountains is lacking mainly six things, whereby the priorities can differ from village to village:

- Traffic routes that are passable at any time
- Appropriate schools
- Hospitals
- Access to enough water for irrigation and to clean drinking water
- A comprehensive mobile phone network
- Unrestricted market access for their products

Thus, water and the environmental resources attached to water is only one of many problems and probably even not that which is regarded as the most urgent one.

2 – Dictate of the older generation with a modest education

The perception oft the men of the older generation dominates the villages. The younger generation has difficulty to obtain a hearing, and the influence of women on important decisions is generally low.

3 – Adherence to traditions and fear of the new

Persons trying to take the initiative for changes in a village often have a difficult position. The men of the older generation are very strongly tied to tradition. Besides lifestyle this relates particularly to agriculture. Suggestions or approaches of the younger generation to optimize things are acknowledged with great distrust or even rejection. This attitude, however, can be softened by the presentation of convincing results. Achievements of civilization, such as higher education, that are widely regarded as essential in all modern Moroccan societies, are sometimes perceived as a threat to the rural communities, so that they remain unattainable for many talented adolescents.

4 – Hardly developed spatial and temporal understanding

A spatial and temporal understanding that goes beyond the direct, locatable, short-term needs of the family or the close community (clan, village), is hardly anchored in those parts of the population that do not dispose of a higher education.

5 – The principle of cause and effect as "Allah's will"

Natural events perceived as positive or negative such as snow, rain, drought or floods or also long-lasting conditions such as a lack of environmental resources are hardly understood in the context of the principle of cause and effect, but rather considered as "Allah's will" and thus accepted resignedly. As a consequence, possibilities to optimize the human influence on negative events or conditions are restricted for both, individuals and communities, because strictly speaking they contradict to "Allah's will".

6 – Hardly developed abstraction ability

A certain capacity for abstraction is needed, if one tries to imagine the long-term consequences of a particular development, corresponding to the principle of cause and effect on an abstract level. This abstraction ability is obviously only weakly developed in the rural population. Thus, comprehensive and, possibly, even supra-regional, long-term solution approaches to tackle environmental or societal issues do hardly emerge locally.

7 – Lack of interest on the part of the young generation for a wise future planning

The future way of young woman in rural areas is still mapped by traditions. Young men, however, have much more liberties. Whereas a few of them try to grasp the opportunities that arise and make the best possible use of them, the large majority apparently sinks into lethargy after elementary school, and is not interested to invest their energy into a sustainable personal development and / or the development of their local environment. Instead of investing into a sound education that helps to generate a modest, but solid and long-lasting income, many of them prefer to make fast money in one of the big cities, with all the risks and chances that are related to this type of life – including dropping into criminality and prostitution or migration to Europe.

8 – Conflicts between ethnic groups, country and city dwellers, and highland and lowland dwellers

The Moroccan society is complex: Numerous Berber groups, representing the indigenous population, live mainly in rural, mountainous and desert areas, whereas ethnic Arabs that migrated to Morocco as a consequence of the Arab conquest in the 7th century mainly settle in the cities and in the lowlands. In Addition, a high percentage of the Berber population describes itself as Arabized. With this mixture of diverging ethnic, spatial and societal interests, internal conflicts for resources, political influence and autonomy are inevitable. The political affiliation to the Moroccan nation, however, is never called into question in Morocco's core country with the exception of the Western Sahara region.

9 – Rivalries between villages or valley inhabitants

Infrastructural projects such as roads or power supply lines are financed and commissioned by the national or regional governments. In more remote areas, where the self-interest of the superordinate authorities is small, this happens mainly at the request of village- or valley inhabitants that are represented by a network of local development agencies, mostly named 'Initiative Nationale pour le Développement Humain' (see chapter 5). The more a community contributes itself to financing a project, the more it is given preferential treatment and the faster a requested project will be realised. This leads to rivalries, not to say enmities, between villages or entire valleys.

10 – Distrust of the authorities

To avoid political agitation due to rivalries or enmities arising from disappointment over unmet local needs, authorities try to realise as many infrastructure projects as possible with limited financial resources. As a consequence, many new roads in remote areas are of a poor quality and begin to disintegrate shortly after their completion, causing new distrust of the authorities on the part of the rural population.

11 – Excessive demands

Although the willingness to pay taxes is apparently low in rural communities, their demands on the superordinate authorities are frequently excessive, sometimes even including a government responsibility for private misfortunes.

12 – Perception of the climatic change and of environmental changes in general

The rural population remarks a substantial decrease in precipitation, a reduction of the snow-capped summit areas and a general shortening of the winter season in the mountains. Persons with higher education associate these phenomena with global climate change, making mainly Europe accountable for it. In their anger, however, they ignore local environmental changes that favour local climatic changes such as degradation of the vegetation, lowering humidity and raising temperature. It is difficult to communicate these relationships to the local population because it provokes a confrontation with their responsibility for their own actions, that, in turn, is strongly influences by their hardly developed spatial and temporal understanding and abstraction ability, respectively.

13 – Risk of instrumentalisation for individual interests

Frequently there is disagreement on urgency and priorities concerning issues of community development within the local decision-makers. This may lead to fronts between families, political parties or other involved stakeholders, which may tend to exploit outsiders for their interests in such conflicts.

6.1.2 Conclusions

Comprehension of the concept of sustainability requires a well-developed spatial and temporal understanding. Neither the substantial absence of such an understanding in rural communities, nor a poorly developed abstraction ability, or adherence to traditions, fear of new, and acceptance of fate, are properties that favour a successful communication of our project and that can help to anchor it well locally.

It should, however, be kept in mind that these same properties made, and still make, a significant contribution to the fact that the communities in mountainous and desert areas in Morocco and in other countries of the Global South – especially in Africa – are facing natural and anthropogenic environmental changes, growth of population and a general scarcity of resources that became obvious already years ago without any clearly recognizable local action strategies, thus depending on the interventions of superordinate authorities or external NGOs. These properties must therefore be considered as a part of the challenge that hardly can be influenced in the short- and medium term. However, modernization proceeds quickly in Morocco and with each new generation, the proportion of those people will rise, which are reached by higher, modern education and new media, and which thereby are also open for solutions that reach far beyond traditional ways of acting.

There is no reason not to start with the necessary research work because of numerous obstacles emerging from attitudes and values of local stakeholders.

The question that is of central importance for the success of our project is therefore not "how can we change these attitudes?" – as nobody can change them on the rapid – but: "how can we reach the goals of the project despite the provisional unchangeableness of these attitudes?"

6.1.3 Handling of the term 'project'

Discussions showed that the term "project" is closely linked to the classical development cooperation in rural areas of Morocco. Thereby the term is connected to the expectation that within a limited period of time a specific, visible and usable performance is to be supplied, e.g. in the form of an improvement of the infrastructure, and that the local population should participate in the development process in terms of paid employment. If these expectations are not or only partially fulfilled, or if substantial target corrections are made in the course of the project, the interest of the local population can quickly be lost.

Our project with its long-term orientation and with its multi-phase time schedule that partially cannot be predefined in detail could easily fall into this trap. Therefore, it must be communicated in a way that a marked contrast is visible for the local population compared to classical development projects. It has therefore been suggested by potential local multipliers to strictly avoid the term 'project'. The terms 'research initiative' (in French: 'initiative de recherche') or 'study' (in French: 'étude') imply an open time frame as well as open results and, therefore, are not associated with direct material expectations, and target corrections would be less irritating for the population.

6.2 Local multipliers and starting points for the case studies

The case studies will be carried out in several rural villages and / or valleys in the Atlas Mountains, and they are thus exposed to many of the risks listed in chapter 6.1.1. It is therefore crucial for the success of the case studies to establish contacts with local development organisations or local key players (e.g. owners of guesthouses dedicated to low-impact tourism, mountain guides or school teachers), that are able to understand the background of the project, that show an interest for the research questions, and that are willing to support the project team during field work on site – thus: that act as local representatives and / or intermediaries, assuming the roles of multipliers for the project in their village or valley.

The way of starting the case studies is decisive for their success, too. It has for instance been proposed to start the case studies in the local schools using simple teaching material about the handling of natural resources that is adapted to the local needs. In this way the issue is carried into the homes, where it may fall on fertile ground here or there. In addition, schoolchildren can be good sources of information and help to understand handling of water in the villages. It was also suggested to arouse interest of the local population for environmental issues through a small investment that contributes to the conservation of resources, e.g. in the form of a drip irrigation system on a trial field that will serve as starting point for further studies.

References:

Müller-Hohenstein, K. and Popp, H., 1990: Marokko: Ein islamisches Entwicklungsland mit kolonialer Vergangenheit. Klett Länderprofile, Ernst Klett Verlag, Stuttgart, 229 S.

Part III Classification of potential study areas

1 Geographical division

1.1 High Atlas Mountains

The geographical division of potential study areas in the High Atlas mountains is given through natural conditions like mountain crests and watersheds, corresponding to the eight major river catchment areas Oued Tensift (T), Oued Sousse (S), Oued Drâa (D), Oued Oum Er Rbia (O), Oued Rheris (R), Oued Ziz (Z), Oued Moulouya (M), and Oued Guir (G). In the westernmost foothills of the High Atlas close to the Atlantic Ocean there are no major catchments, the study areas there are therefore all named “Westernmost Atlas” (WA). Most study areas in the High Atlas Mountains dispose of permanent streams and rivers as a result of a precipitation rate of 600-1200 mm/y in their source areas. Surface waters and precipitation rates are shown in figs. 1 and 3, respectively, and all potential study areas are summed up in tabs. 1 and 2, and in fig. 2.

1.2 Antiatlas Mountains and Jebel Saghro

In the westernmost Antiatlas Mountains all study areas are part of the Massa river catchment (Ma). In all other areas of the Antiatlas Mountains the water of local streams either never reaches a main river, or no main river exists under normal hydrologic conditions, wherefore a subdivision into watersheds is not appropriate. The potential study areas are thus subdivided into northern slope areas (AN) and southern slope areas (AS) only. The Jebel Saghro areas (JS) are not further subdivided. In many Antiatlas areas, watersheds are very flat and difficult to determine exactly. Due to very dry climatic conditions in the Antiatlas with a precipitation rate between 100 and 400 mm/y, even large areas that belong to the same hydrologic system are poor in water, creeks and rivers mostly disappearing in the underground already before they reach the foot of the mountains.

1.3 Watersheds

In the High Atlas Mountains the main crest and the main watershed, respectively, dividing the northern Tensift, Oum Er-Rbia and Moulouya catchments from the southern Sousse, Drâa, Rheris, Ziz and Guir catchments, are not central (fig. 2). In the western and central High Atlas Mountains the watershed is located on the southernmost range, whereas in the eastern High Atlas it is situated on the northernmost range. Accordingly the topography is different. In general, the western and central High Atlas Mountains show a steep southern slope and a gently descending northern slope, whereas in the eastern High Atlas the northern slope is steeper than the southern slope that is subdivided into several ranges with high plains in between, transforming gently into isolated foothills towards the east. In the High Atlas Mountains, the extension of the catchment areas remarkably increases from west to east. This is in correspondence with the precipitation rate that decreases from west to east.

The main watershed of the Antiatlas Mountains branches from the western High Atlas Mountains over Jebel Siroua towards south, where it divides the streams flowing towards north and west into Oued Sousse and Oued Massa, respectively from those flowing towards south into Oued Drâa. Under normal hydrologic conditions, however, Oued Sousse is rarely fed by surface water from the Antiatlas Mountains. Oued Drâa in these southern areas is only a dry riverbed without any evidence of surface water. This supports the presumption that today surface water from the Antiatlas streams hardly ever reaches the edge of its southern foothills.

There is a similar situation in the Jebel Saghro Mountains, where surface water only reaches the edge of the mountains after heavy rainfall. The watershed between the Drâa and the Rheris catchments is therefore more of a theoretical interest.

The Drâa catchment has by far the largest surface of all Moroccan catchments and therefore plays an important role for several potential study areas introduced in this report. This catchment, however, is extraordinary as the main volume of water is fed by tributaries descending from the southern slope of the central High Atlas Mountains and the eastern slope of Jebel Siroua that represent only a small part of the whole catchment. The tributaries de-

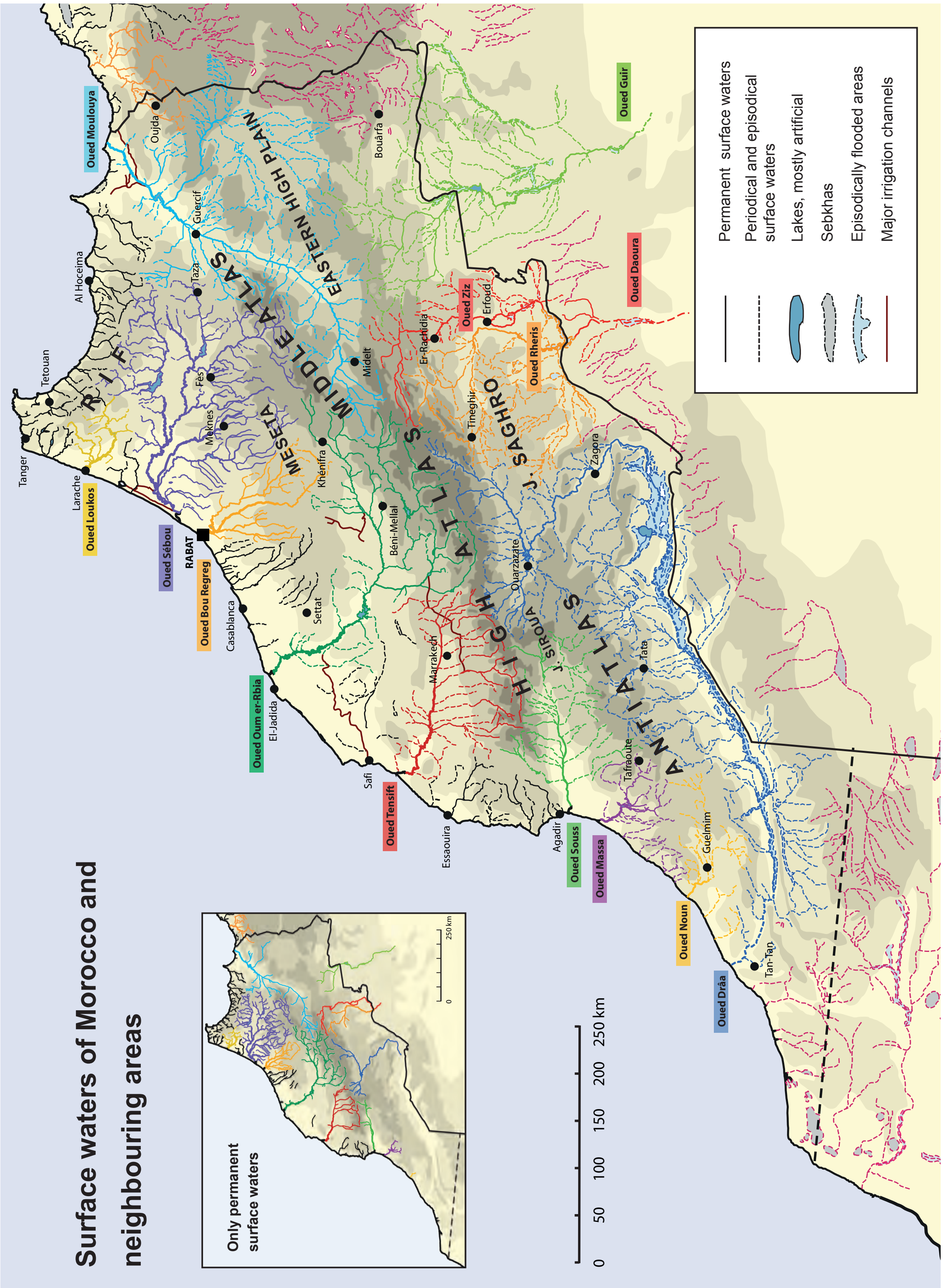
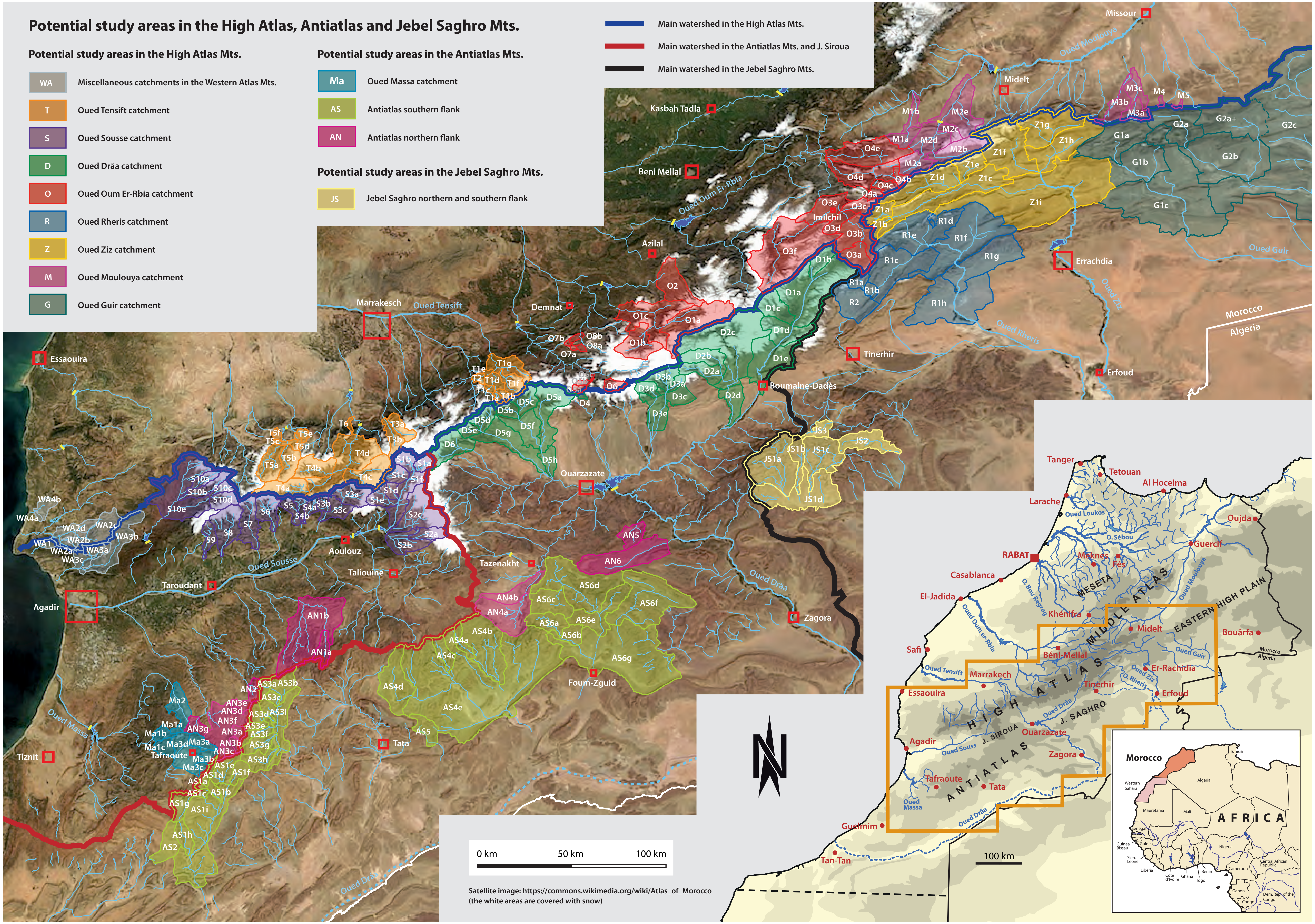
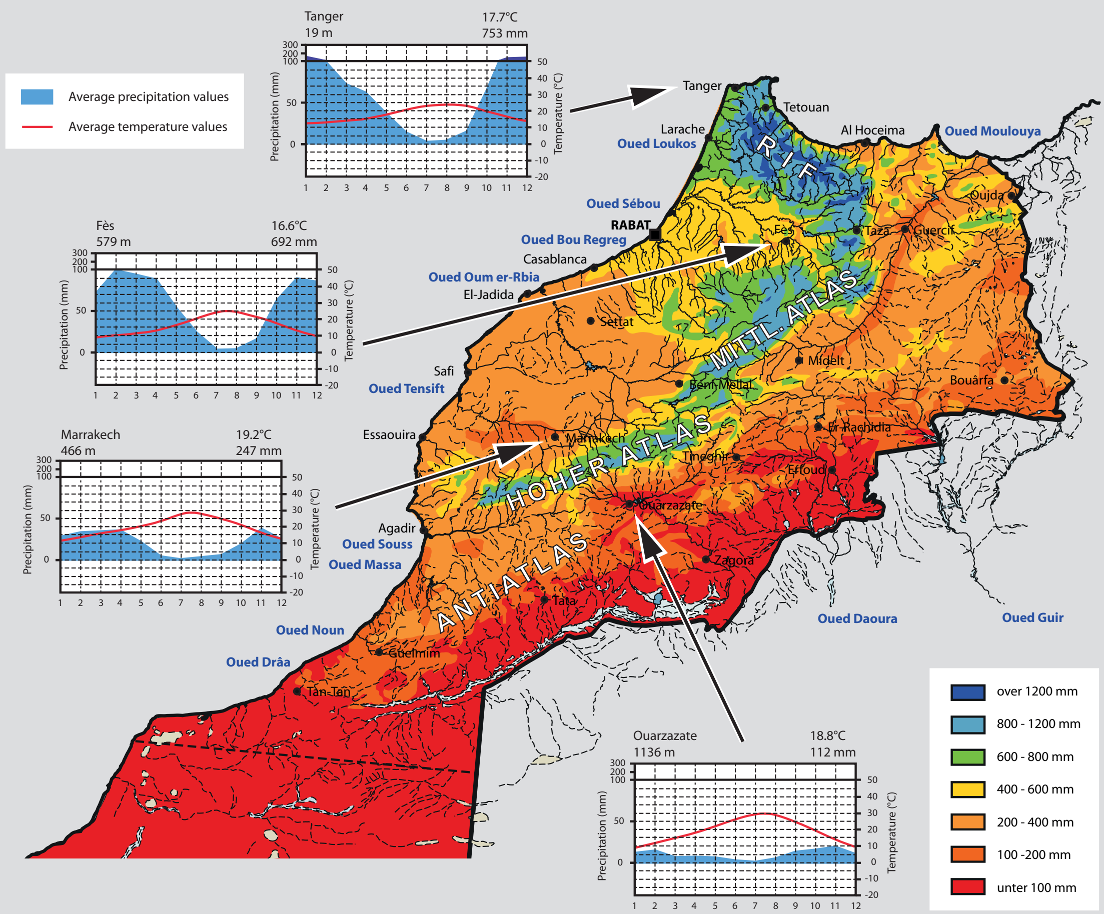


Fig. 1: *Main catchments of Morocco.*

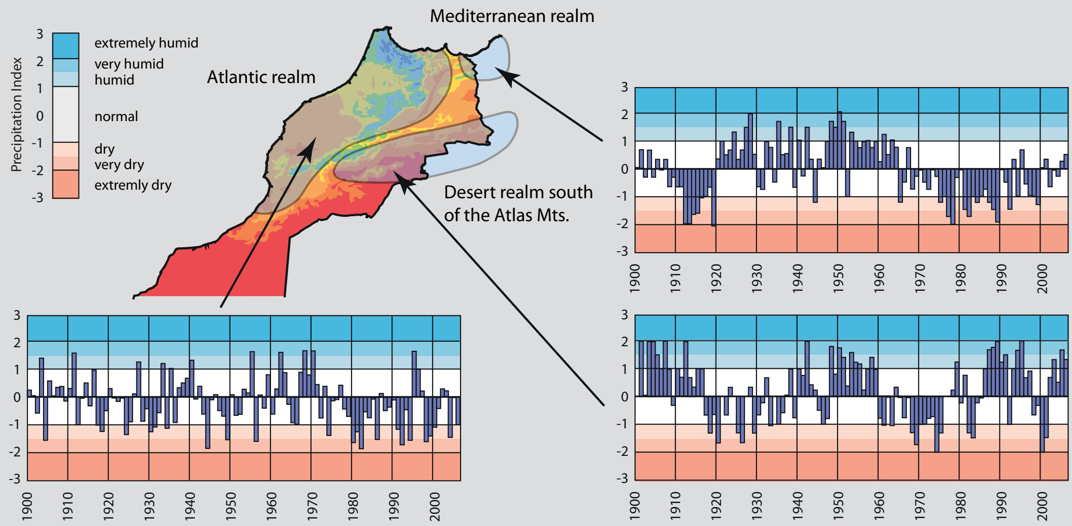
Fig. 2, fold-out plate: *Summary of all potential study areas sorted by watersheds in the High Atlas (T, S, D, O, R, Z, M, G) and the westernmost Antiatlas Mountains (Ma), and by exposure in the central and eastern Antiatlas Mountains (AN, AS). The Jebel Saghro areas (JS) and the areas in the westernmost High Atlas (WA) are not further subdivided.*



Potential study areas in the High Atlas, Antiatlas and Jebel Saghro Mts.
Potential study areas in the High Atlas Mts.
WA Miscellaneous catchments in the Western Atlas Mts.
T Oued Tensift catchment
S Oued Sousse catchment
D Oued Drâa catchment
O Oued Oum Er-Rbia catchment
R Oued Rheris catchment
Z Oued Ziz catchment
M Oued Moulouya catchment
G Oued Guir catchment
Potential study areas in the Antiatlas Mts.
Ma Oued Massa catchment
AS Antiatlas southern flank
AN Antiatlas northern flank
Potential study areas in the Jebel Saghro Mts.
JS Jebel Saghro northern and southern flank
Main watershed in the High Atlas Mts.
Main watershed in the Antiatlas Mts. and J. Siroua
Main watershed in the Jebel Saghro Mts.
Missour
Oued Moulouya
Midelt
Kasbah Tadla
Beni Mellal
Oued Oum Er-Rbia
Azilal
Imilchil
Errachdia
Oued Guir
Oued Ziz
Oued Rheris
Morocco
Algeria
Marrakesch
Oued Tensift
Demnat
Tinerhir
Erfoud
Boumalne-Dadès
Essaouira
Ouarzazate
Aoulouz
Oued Sousse
Taliouine
Tazenakht
Taroudant
Agadir
Oued Drâa
Zagora
Foum-Zguid
Tata
Tafraoute
Oued Massa
Tiznit
0 km
50 km
100 km
Satellite image: https://commons.wikimedia.org/wiki/Atlas_of_Morocco
(the white areas are covered with snow)
Tanger
Tetouan
Al Hoceima
Larache
Oued Loukos
O. Sébou
Oujda
RABAT
Meknes
Fès
Guercif
Casablanca
MESETA
MIDDLE ATLAS
EASTERN HIGH PLAIN
El-Jadida
O. Bou Regreg
Khénifra
Oued Oum er-Rbia
Bouârfa
Safi
Béni-Mellal
Midelt
Oued Guir
Oued Tensift
Marrakech
HIGH ATLAS
Er-Rachidia
Oued Ziz
O. Rheris
Tinerhir
Erfoud
Essaouira
Oued Drâa
J. SAGHRO
J. SIROUA
Ouarzazate
Agadir
Oued Souss
Zagora
ANTIATLAS
Tafraoute
Tata
Oued Massa
Oued Drâa
Guelmim
Tan-Tan
100 km
Morocco
Algeria
Western Sahara
Mauretania
Mali
AFRICA



Annual precipitation rates in Morocco, including climate diagrams of selected monitoring stations.



Deviation of annual precipitation rates from the long-term average (according to the precipitation Index).

Fig. 3: *Annual precipitation rates and their deviation from the long-term average, including climate diagrams of selected monitoring stations. Modified after Atlas du Maroc N°4a, Précipitations annuelles, 1958; and Schulz, O. and Judex, M. (ed.), 2008: IMPETUS Atlas Morocco, Research Results 2002-2007.*

scending from the Antiatlas and the Jebel Saghro Mountains in contrast only contribute water in case of extraordinary weather conditions such as rainstorms that last several days. The surface water of Oued Drâa therefore does often not flow much further than to Zagora. During Pleistocene however, before the Sahara started to dry out, the river must have reached the Atlantic Ocean north of Tan-Tan. Nowadays, the rate of flow in the lower Drâa Valley can be allocated to the needs of its oases over the year due to the El Mansour Eddahbi dam west of Ouarzazate.

2 Appropriate regional structuring

Most study areas introduced in the parts IV, V and VI are combinations of several sub-areas from the higher and / or inner mountains and from the foothills and / or alluvial plains at the foot of the mountains, belonging to the same hydrological system or regional catchment (fig. 4). This allows us to proceed step by step “from the small scale to the large scale” according to our scientific approach as defined in part I, chapter 1.2.2: In a first phase, detailed investigations will be carried out in one of the inner mountain areas (A or B in fig. 4). In a second phase, the results of phase one will be applied to other inner mountain areas to test their representativeness. Depending on the complexity of the hydrologic system, the research area will then be extended in several successive phases down to the foot of the mountains.

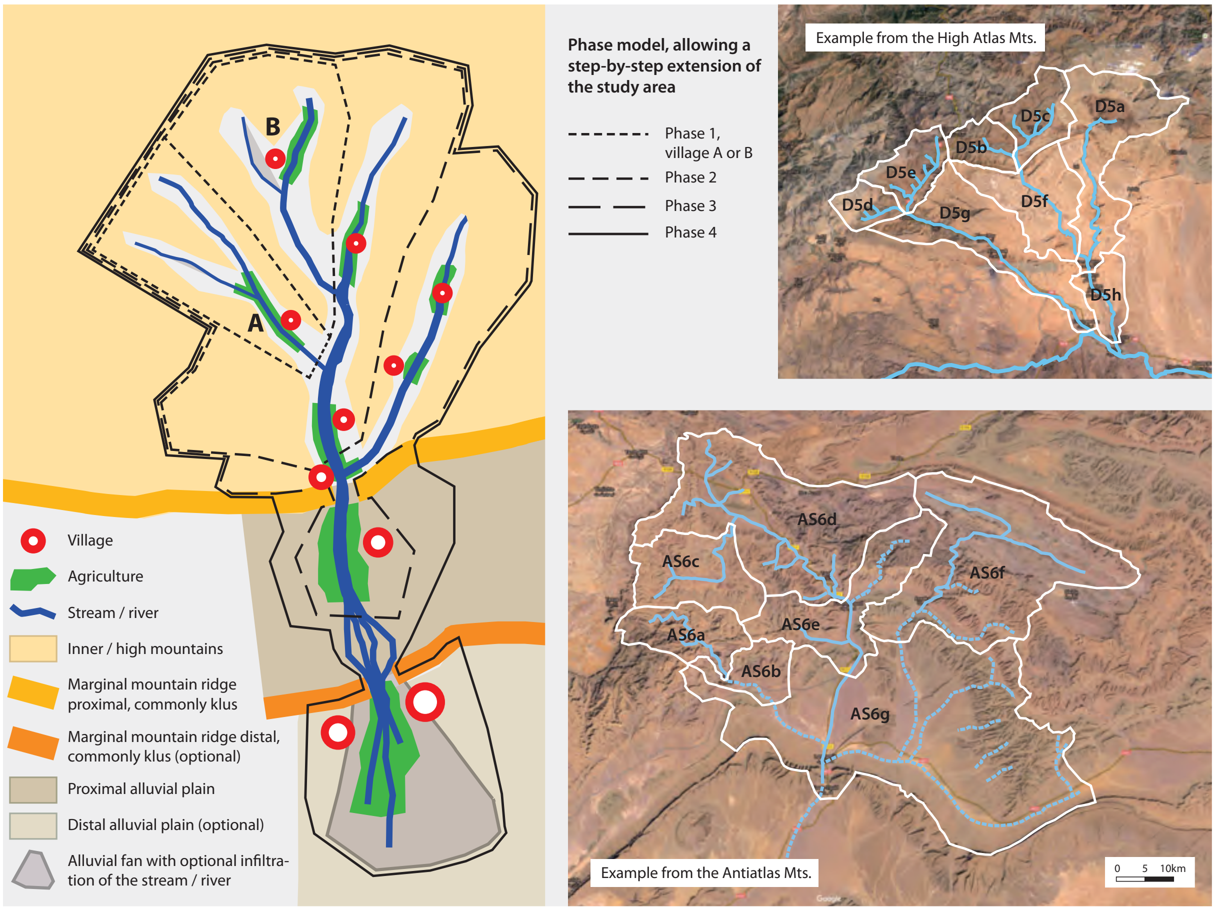


***Fig. 4:** Phase model allowing a step-by-step extension of the selected study areas within a hydrological system or catchment.*
Satellite images: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

3 Morphologies

In the High Atlas Mountains as well as in the Antiatlas Mountains the morphologies of valleys primarily depend on the geological conditions. In addition, climatic conditions such as precipitation rate and the distribution of precipitations over the year play an important role for weathering, erosion and deposition of alluvial material.

Tectonic conditions are completely different in the High Atlas Mountains and in the Antiatlas Mountains and Jebel Saghro respectively, resulting in a different spatial arrangement of geological units (see geological map in annex III). Whereas in the High Atlas Mountains study areas could be found that are as morphologically homogenous as possible, with maximum two different morphologies, most study areas in the Antiatlas Mountains and Jebel Saghro display two or more morphologies.

The morphologies are described in the specific chapters dealing with the High Atlas Mountains (part IV, chapter 1) and the Antiatlas Mountains, respectively (part V, chapter 1). To enable a general overview, all potential study areas and their corresponding morphologies are introduced below (tables 1 and 2). The shortcuts correspond to fig. 2.

Tab. 1: *Potential study areas in the High Atlas Mountains.*

Potential study areas		Principal morphology, as defined in part IV, pages 57 - 68	Part IV, pages
High Atlas Mountains, northern slope			
Shortcut	**Name of the area**		
Oued Tensift catchment (T)			
T1 a-g	Tizi N'Tichka northern slope / Oueds Tichka and Tensift	V-shaped valleys	89 - 92
T2	Eastern tributary of Oued Zad		194 - 195
T3 a, b	Valleys north of Jebel Toubkal		93 - 95
T4 a-d	Oued N'Fis Valley north of Tizi N'Test		96 - 100
T5 a-f	Asif El Mehl area		101 - 103
T6	Foothill valley of Aghbalou	No specific morphology	196 - 197
Oued Oum Er Rbia catchment (O)			
O1 a-c	Ait Bougouemez and Bou Oulli Valleys	V-shaped valleys + trough valleys	110 - 114
O2	Aït M'Hamed with upper Oued Lakhdar	Carbonate plateau	187 - 189
O3 a-f	Upper Assif Melloul / Valley of Imilchil – Agoudal	Trough valleys	152 - 156
O4 a-e	Tighadiouine – Tamaluot – Amelgou – Agheddou – Bouadel	Combination of both trough and V-shaped valleys in one	160 - 163
O5 a-c	Tikhfiste – Toufghine	V-shaped valleys	-- *
O6	Megdaz Valley		105 - 106
O7 a, b	Non river-dependent individual villages around Jebel Til		190 - 192
O8 a			
O8 b	--		-- *
Oued Moulouya catchment (M)			
M1 a, b	Tounfite – Tamazert	Combination of both trough and V-shaped valleys in one	165 - 166
M2 a-e	Tagoudit – Tighermine – Imatchimen – Ait Sidi Bou-moussa		167 - 169
M3 a-c	Eastern High Atlas Mts. north slope		170 - 171
M4, M5	Asdad + Tamslamte		-- *
High Atlas Mountains, southern slope			
Oued Sousse catchment (S)			
S1 a-f	Adar N'Deren – Jebel Toubkal South	V-shaped valleys	72 - 74
S2 a-c	Jebel Siroua West		75 - 77
S3 a-c	Aït Youb – Anzi – Tamsloumte – Imerguene		78 - 80
S4 a, b	Tizi N'Test southern slope		81 - 82
S5, S6, S7, S8, S9	Western High Atlas southern slope		83 - 84
S10 a-e	High Atlas western slope		85 - 88

* Small area of minor interest.

***Tab. 1:** Potential study areas in the High Atlas Mountains, continuation from page 53.*

Potential study areas		Principal morphology, as defined in part IV, pages 57 - 68	Part IV, pages
Oued Drâa catchment (D)			
D1 a-e	Dadès Valley	Trough valleys + canyon-like, stepped foothill valleys	175 - 179
D2 a-d	Jebel Mgoun south flank / Asif Mgoun	V-shaped valleys + canyon-like, stepped foothill valleys	118 - 121
D3 a-3	Valleys north of Toundoute		122 - 124
D4	Ait Touda		-- *
D5 a-h	Asifs Ounila, Mellah and Tamstin / N'Tamnat		125 - 133
D6	Asif Alighane Valley		134 - 136
Oued Rheris catchment (R)			
R1 a-h	Upper Rheris River above Goulmina	Trough valleys	140 - 143
R2	Tamtatouchte (upper Todhra Valley)		144 - 145
Oued Ziz catchment (Z)			
Z1 a-i	Upper Ziz River above Kerrandou ravine	Trough valleys	147 - 150
Oued Guir catchment (G)			
G1 a-c	Western branch of Guir River: Tagrirte – Gourrama – Tazougart	Trough valleys + wide lower mountain valleys / plains	183 - 185
G2 a-c	Eastern branch of Guir River: Ait Aissa ou Ali – Talsint – Beni Tajite – Bouanane		
High Atlas Mountains, westernmost slope towards the Atlantic Ocean			
“Westernmost Atlas” (WA)			
WA1	Western carbonate plateau	Carbonate plateau	198 - 204
WA2 a-d	Central carbonate plateau – Imouzzer Ida ou Tanane – Asif Tamri		
WA3 a-c	Aquesri – Talat Mloulen – Vallée du Paradis		
WA4 a, b	Oued of Assaka		

* Small area of minor interest.

***Tab. 2:** Potential study areas in the Antiatlas Mountains and Jebel Saghro.*

Potential study areas		Morphological domains, as defined in part V, pages 205 - 212	Part V, pages
Antiatlas Mountains			
Shortcut	**Name of the area**		
Oued Massa catchment (Ma)			
Ma1 a-c	Tafraoute and the surrounding areas in the westernmost Antiatlas Mountains	A, B	213 - 219
Ma3 a-d			
Ma2	Valley of Biougra – Tahougat	B	220 - 222
Antiatlas northern slope (AN)			
AN1 a,b	Imgoune – Tingarf valley	B, C	223 - 227
AN2	Ossemgane mountains		228
AN3 a-g	Highlands triangle Agadir Tasguent – Aït Abdallah – Madao / Asif Oussaka		229 - 232
AN4 a, b	Granite pan south of Tazenackht	A (subordinately B, C)	233 - 234
AN5	High plain of Aït Saoun	C	235
AN6	Tasla – Ait Semghane – Ourika Tanslifte valley	D	236 - 237

Tab. 2: *Potential study areas in the Antiatlas Mountains and Jebel Saghro, continuation from page 54.*

Potential study areas		Morphological domains, as defined in part V, pages 205 - 212	Part V, pages
Antiatlas southern slope (AS)			
AS1 a-i	Canyonlands of Assif N’Innt (south of Tafraoute)	A, C	238 - 245
AS2	Canyonlands of Amtoudi	C	246 - 247
AS3 a-i	Upper course of Oued Akka	B, C	248 - 251
AS4 a-e	Alluvial plain of Akka Ighane – Tissint and adjacent canyons	A, B, C, D	252 - 259
AS5	Akka Iguirene	C	260
AS6 a-g	Oued El Koubia / Oued Zguid	B, C (subordinately D)	261 - 263
Jebel Saghro (JS)			
JS1 a-d	Alluvial plain of Nekob and adjacent canyons	B, C	267 - 273
JS2	Canyon of Imi N'Ouzrou – Tazelaft		274
JS3	Ait Ouallal – Outaaoui	B	274 - 275

References:

Atlas du Maroc N°4a, Précipitations annuelles, 1958.

Schulz, O. and Judex, M. (ed.), 2008: IMPETUS Atlas Morocco, Research Results 2002-2007, 3rd edition, Department of Geography, University of Bonn, Germany.

Part IV Potential study areas in the High Atlas Mountains

1 Morphological types

Four main morphological types of valleys are distinguished in the High Atlas Mountains, displaying different cross sections and longitudinal sections as well as different hydrological regimes and layouts of agricultural fields, irrigation and settlements (figs. 1, 2 and 4 - 32). These morphologies are the results of different precipitation rates, different distribution of precipitation over time (periodic, episodic), different geological conditions such as rock types, layering and deformation, and different kinds of weathering end erosion rates. The morphological types introduced hereafter are ideal end members, whereas in reality frequently combined forms occur. Their distribution over the High Atlas Mountains corresponds to the geological conditions with an astonishing precision (see fig. 3).

1.1 V-Shaped valleys (type 1)

The morphology of V-shaped valleys is very close to that of valleys in the crystalline Alps, e.g. in the Swiss Valais. V-shaped valleys usually occur in the high mountains and display steep gradients and slopes. They mostly develop in magmatic rocks and in Precambrian to Triassic, folded or unfolded, low-grade metamorphic, low carbonate clastic sedimentary rocks with weak stratification and cleavage, as they are typical for the western and central High Atlas Mountains. In addition, abundant and evenly distributed precipitation is another important prerequisite.

Streams and rivers in V-shaped valleys usually follow the line of biggest slope with no or only little detours due to differences in erosion resistance of the rocks or to fault zones. This results in an arrangement of valleys more or less perpendicular to the main mountain ridge with numerous bifurcations under angles mostly between 40° and 60° (fig. 1).

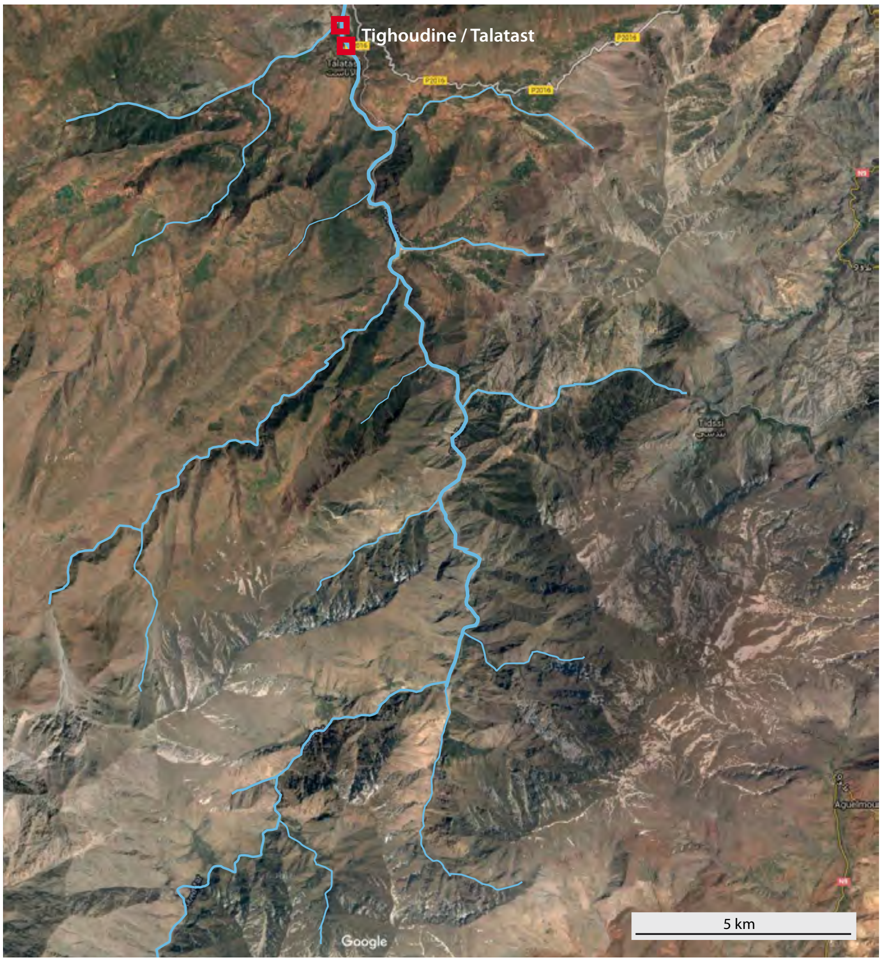


Fig. 1: *Characteristic V-shaped valley (Oued Zad valley west of Tizi N'Tichka).*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

Villages in V-shaped valleys are usually built on the slopes above the main stream. The reason for this is not that the main streams are particularly dangerous during flooding, but that the valley bottoms are too narrow to built villages there. On the slopes, villages are always built on stony ground beyond the most fertile soils. Fertile soils are usually to be found on old debris cones, alluvial cones or even paleo-moraines that are used to create terraced fields (figs. 4-8). Irrigation operates through channels leading water from lateral valleys on higher levels and parallel to the contour lines onto the fields. Irrigated fields on alluvial soil along the streams or on small gravel islands also occur, but they are rather rare as the streambeds are mostly narrow (figs. 7, 9).

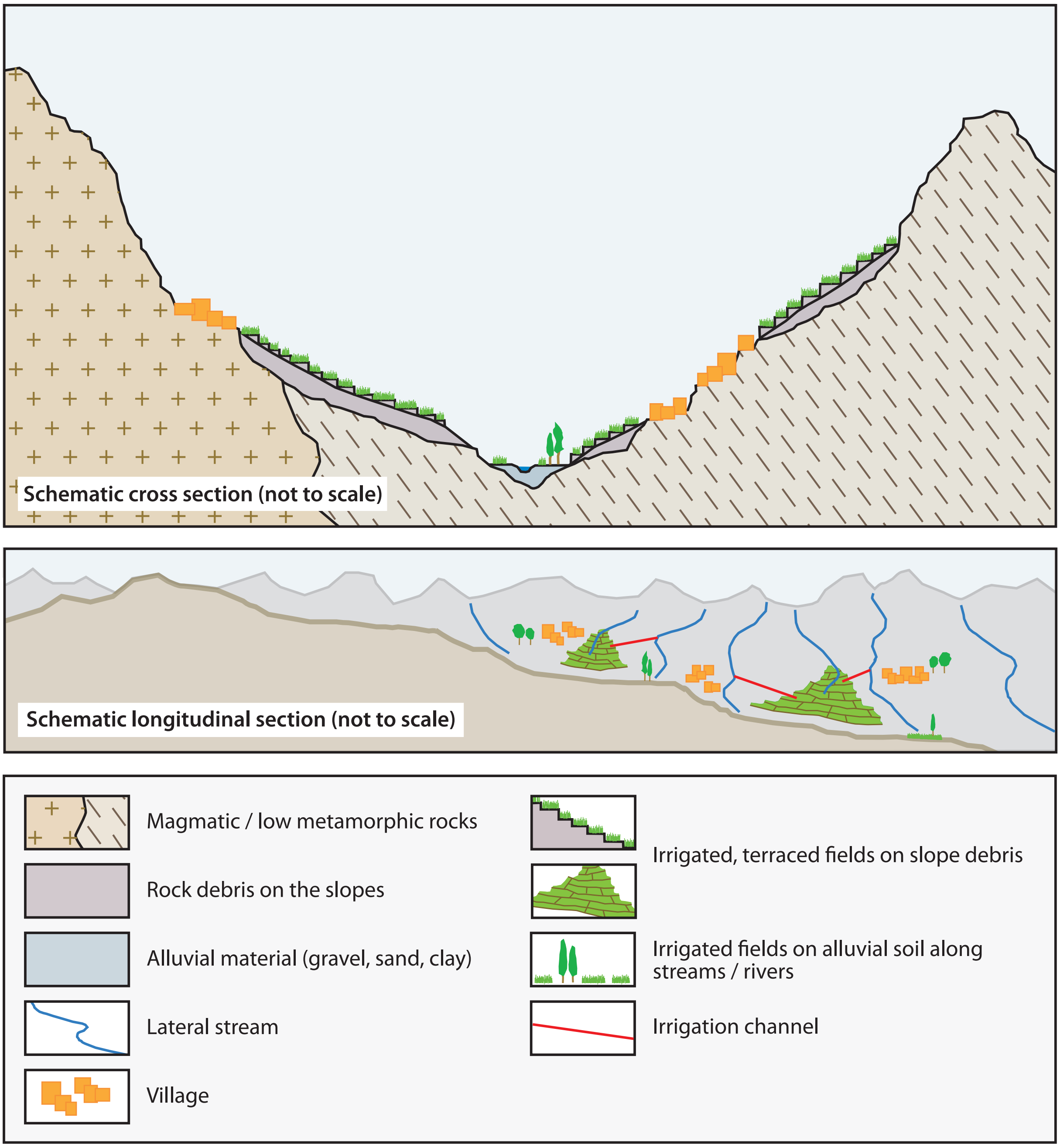
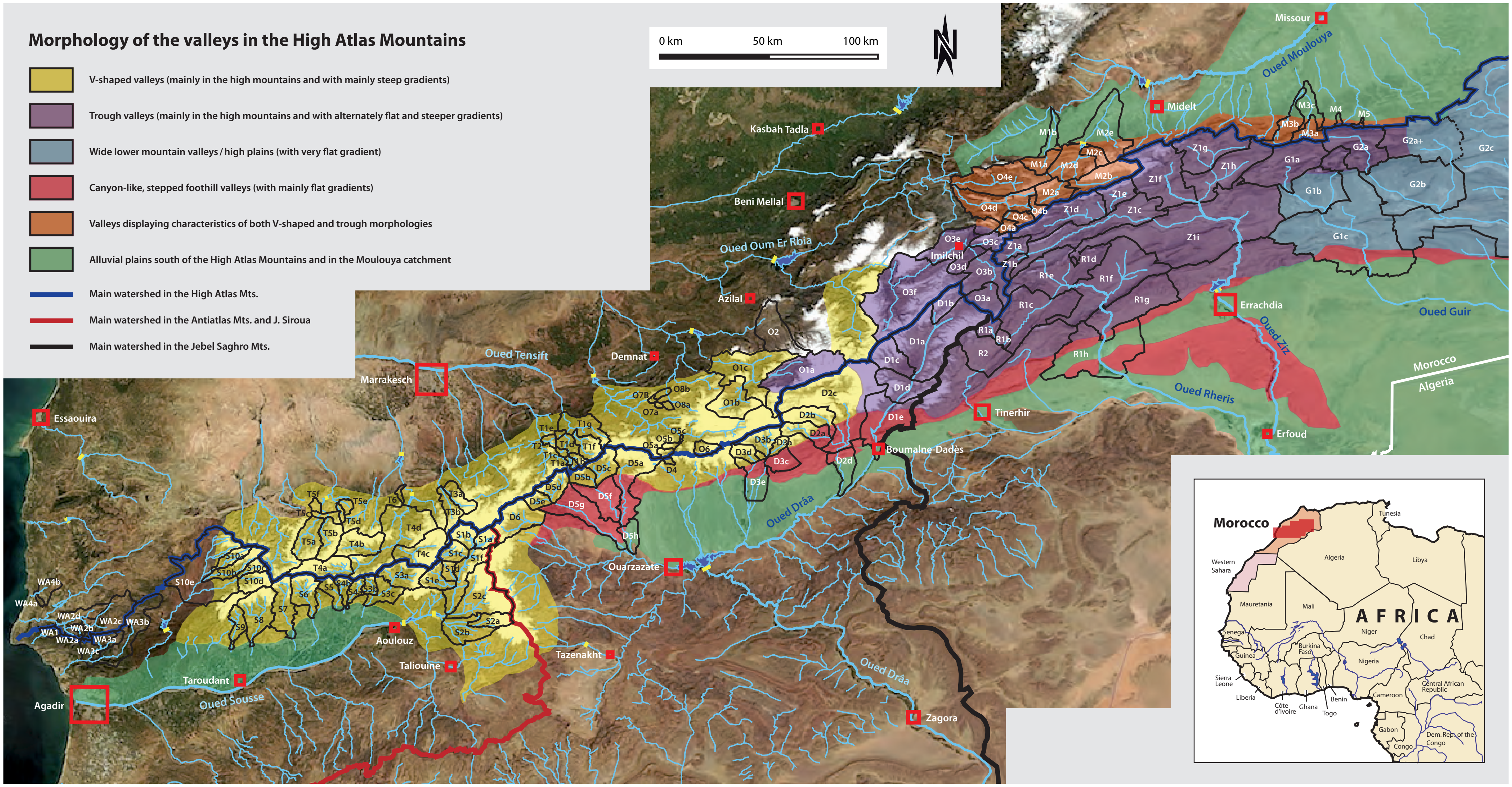


Fig. 2: *Schematic cross and longitudinal sections of a V-shaped valley with characteristic steep gradient, steep slopes, terraced fields and villages on the slopes above the main stream. The fields are irrigated by means of irrigation channels leading water from lateral valleys on higher levels and parallel to the contour lines to the main valley.*

Fig. 3, fold-out plate: *Comparison between a satellite image and a geological map showing a striking correlation between the main morphologies of the High Atlas valleys and the geological conditions.*


Morphology of the valleys in the High Atlas Mountains
V-shaped valleys (mainly in the high mountains and with mainly steep gradients)
Trough valleys (mainly in the high mountains and with alternately flat and steeper gradients)
Wide lower mountain valleys / high plains (with very flat gradient)
Canyon-like, stepped foothill valleys (with mainly flat gradients)
Valleys displaying characteristics of both V-shaped and trough morphologies
Alluvial plains south of the High Atlas Mountains and in the Moulouya catchment
Main watershed in the High Atlas Mts.
Main watershed in the Antiatlas Mts. and J. Siroua
Main watershed in the Jebel Saghro Mts.
0 km
50 km
100 km
N
Missour
Oued Moulouya
Midelt
Kasbah Tadla
Beni Mellal
Oued Oum Er Rbia
Azilal
Imilchil
Errachdia
Oued Ziz
Oued Guir
Morocco
Algeria
Demnat
Oued Tensift
Marrakesch
Essaouira
Tinerhir
Oued Rheris
Erfoud
Boumaine-Dadès
Oued Drâa
Ouarzazate
Aoulouz
Taliouine
Tazenakht
Taroudant
Oued Sousse
Agadir
Zagora
Morocco
AFRICA

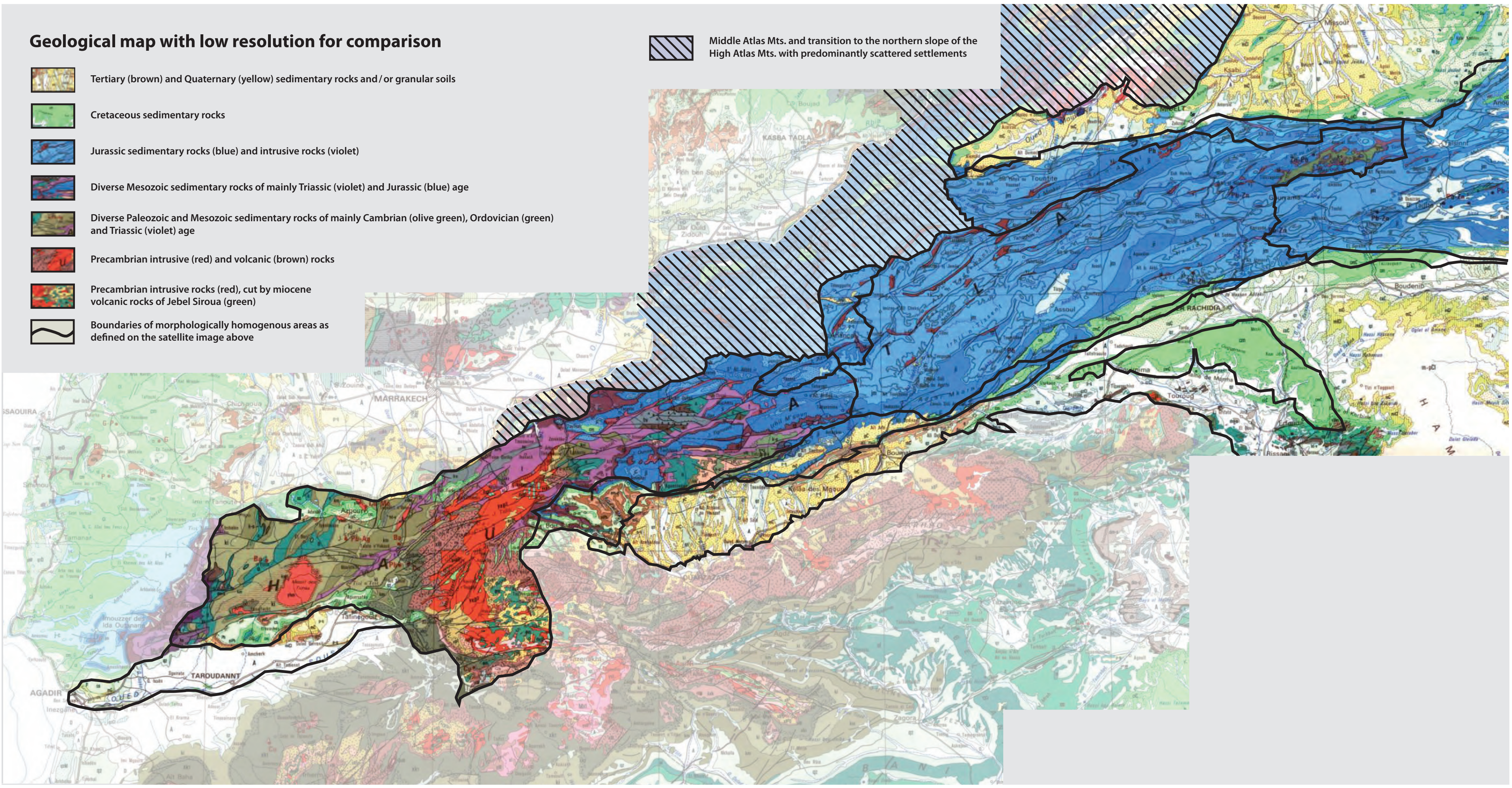

Geological map with low resolution for comparison
Tertiary (brown) and Quaternary (yellow) sedimentary rocks and / or granular soils
Cretaceous sedimentary rocks
Jurassic sedimentary rocks (blue) and intrusive rocks (violet)
Diverse Mesozoic sedimentary rocks of mainly Triassic (violet) and Jurassic (blue) age
Diverse Paleozoic and Mesozoic sedimentary rocks of mainly Cambrian (olive green), Ordovician (green) and Triassic (violet) age
Precambrian intrusive (red) and volcanic (brown) rocks
Precambrian intrusive rocks (red), cut by miocene volcanic rocks of Jebel Siroua (green)
Boundaries of morphologically homogenous areas as defined on the satellite image above
Middle Atlas Mts. and transition to the northern slope of the High Atlas Mts. with predominantly scattered settlements
MARRAKECH
TAROUDANNT
AGADIR

Fig. 4: *V-shaped valley with villages and terraced fields near Chafarni, main ridge of the High Atlas Mountains with Tizi N'Test pass road. Area S4b, autumn 2015.*

Fig. 5: *Outstanding concentration of terraced fields on a mighty accumulation of debris in a V-shaped valley near Aït Moussa, the origin of which may be alluvial or glacial (paleo-moraine). Area T1e, autumn 2015.*

Fig. 6: *Village and terraced fields in a V-shaped valley near Aït Moussa, area T1e, autumn 2015.*

Fig. 7: *V-shaped Lac d'Ifni valley with terraced fields at the valley flank and additional fields at the river level. Area S1b, autumn 2015.*

Fig. 8: *Village Aït Ammar on the steep slope of the V-shaped Tichka Valley. Area T1d, autumn 2015.*

Fig. 9: *Temporary fields that can be washed away at any time on alluvial deposits in the streambed north of Imlil. View up the V-shaped valley towards the Jebel Toubkal range. Area T3b, spring 2015.*

1.2 Trough valleys (type 2)

The morphology of open trough valleys with rather flat gradient, broad bottoms and interjacent, long mountain ridges, as they occur in the High Atlas Mountains, is unique in the European – Mediterranean realm. In the Alps, where the morphology was highly influenced by ice age glaciers, trough valleys are interpreted to be the results of glacial erosion. In the High Atlas Mountains, however, glaciers did not play a central role as a forming element.

The trough valleys are all situated on high altitudes within the gently folded and faulted Jurassic sedimentary rocks of the eastern High Atlas Mountains, indicating that these specific geological conditions constitute the central prerequisite for the development of this morphology. Under conditions of a moderate precipitation rate, interbeddings of moderately hard limestones with marls and weak argillaceous rocks displaying open syn- and anticlines with thrust faults are apparently eroded to such open valleys with broad bottoms.

Most of the trough valleys in the eastern High Atlas run parallel to the main axis of the mountain range (fig. 10). To reach the southern rim of the mountain range nontheless, rivers cross the interjacent and the peripheral mountain chains in ravines (kluses). This indicates that fault zones and broken synclines and anticlines, respectively, that run parallel to the main axis of the mountain range, may have played a central role as weak zones for water erosion, which is not a surprise considering the flat gradients in the eastern High Atlas. This is in great contrast to the western and central High Atlas Mountains, where V-shaped valleys run mainly in perpendicular direction to the axis of the mountain range due to higher precipitation rates and steeper gradients. This may also suggest that the tectonic uplift of the eastern High Atlas was slower than the uplift of the western and central High Atlas.

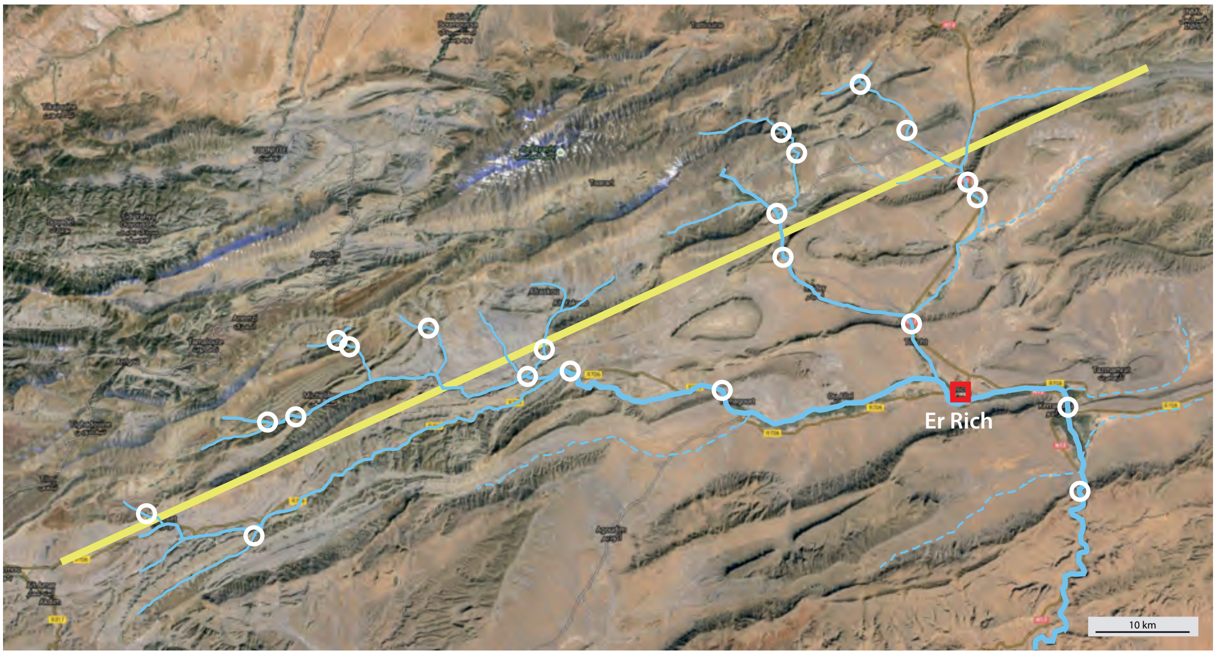


Fig. 10: *Characteristic trough valleys (Oued Ziz catchment west and north of Er Rich in the eastern High Atlas Mountains). The yellow line indicates the direction of the general axis of the mountain range, white circles are ravines (kluses), where streams / rivers cut through one of the mountain ridges that are oriented parallel to the mountain axis.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

Villages in trough valleys are usually built on debris or alluvial cones on the slopes, but still close enough to the main streams to benefit from their surface- and groundwater. The valley bottoms are broad enough and provide enough space for both, villages and fields (figs. 11-15). In main valleys with flat gradients fields are usually not terraced and lie only between half a meter and two meters above the normal low water level. During high water events, they are often affected by flooding and thus eroded, if they are situated on the concave bank or covered with thick layers of sediment if situated on the convex bank. In valleys with steeper gradients also a slight terracing of the fields occurs (fig. 16), or the fields may also spread over flat alluvial or debris cones. Irrigation operates through channels leading water from the main rivers parallel to the contour lines onto the fields.

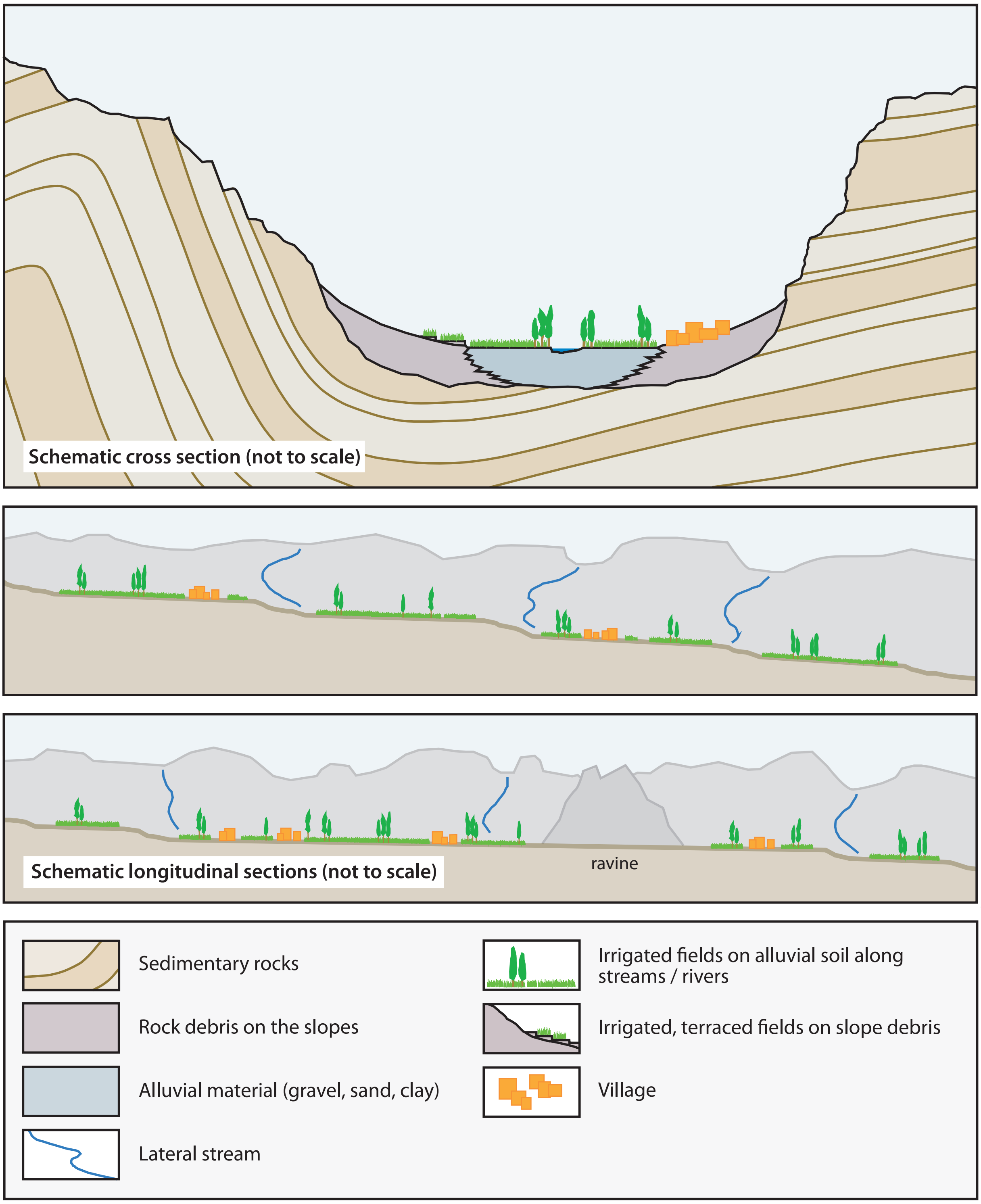


Fig. 11: *Schematic cross and longitudinal sections of a trough valley with characteristic alternating flat and steeper gradients and irrigated fields on both sides of the stream. The sections with steeper gradients are irregularly distributed and usually not inhabited. The valleys are interrupted by ravines (kluses), where the streams / rivers cut through mountain ridges.*

Fig. 12: *Village Akdim with irrigated fields and apple trees on alluvial land at stream level in a trough valley (oued Dadès). Area O3b, spring 2015.*

Fig. 13: *Village Aït Toukshine with irrigated fields and fruit trees on alluvial land in a trough valley along Oued Dadès, view up the valley. Area D1a, spring 2015.*

Fig. 14: *Village Aït Toukshine with irrigated fields and fruit trees on alluvial land in a trough valley along Oued Dadès; irrigation channel in the foreground. Area D1a, spring 2015.*

Fig. 15: *Irrigated fields on alluvial land in a trough valley along Asif Meloul. View up the valley, area O3b, autumn 2015.*

Fig. 16: *Village Oudeddi with irrigated fields in the upper Rheris Gorge that is similar to a trough valley. Area R1e, spring 2015.*

1.3 Wide lower mountain valleys / high plains (type 3)

The wide lower mountain valleys are more like a series of high plains separated from one another by narrow, but long, interjacent, isolated mountain chains oriented southwest – northeast, looking out of the plains like rows of teeth or backs of crocodiles (figs. 17, 19). From the geological point of view, this morphology is the logical continuation of the trough valley morphology towards east, where the High Atlas Mountains dissolve into isolated chains that submerge gently under the Oriental High Plain before they emerge again in Algeria.

In spite of a hardly perceptible gradient, these valleys are flown trough by streams. In the lower parts, where the streams dry out under normal hydrological conditions, the streambeds are often vague, indicating that they can change direction or form shallow lakes with changing water levels during flooding. Despite of a moderate precipitation rate, individual rainfall events can be heavy. This results in a strong erosion of the mountain chains, filling valleys up with huge quantities of quaternary sediments such as clay, sand and gravel, displaying the nearly flat surface of typical alluvial plains.

Fig. 17: *Wide lower mountain valleys in the Oued Guir catchment in the easternmost High Atlas, where the mountain ridges submerge under the Oriental High Plain. White circles are ravines (kluses), where streams / rivers cut through one of the mountain ridges; milky areas do not belong the wide lower mountain valleys / high plains.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

Villages in wide lower mountain valleys / high plains are very rare. They are usually built on the alluvial plain before or directly after a ravine, where the stream or riverbeds are more braided and where the water disperses and infiltrates on a large area in case of flooding. Fields are always irrigated and set up directly beneath the streams or rivers. Irrigation operates through channels leading water from the rivers onto the fields (figs. 18, 20-22).

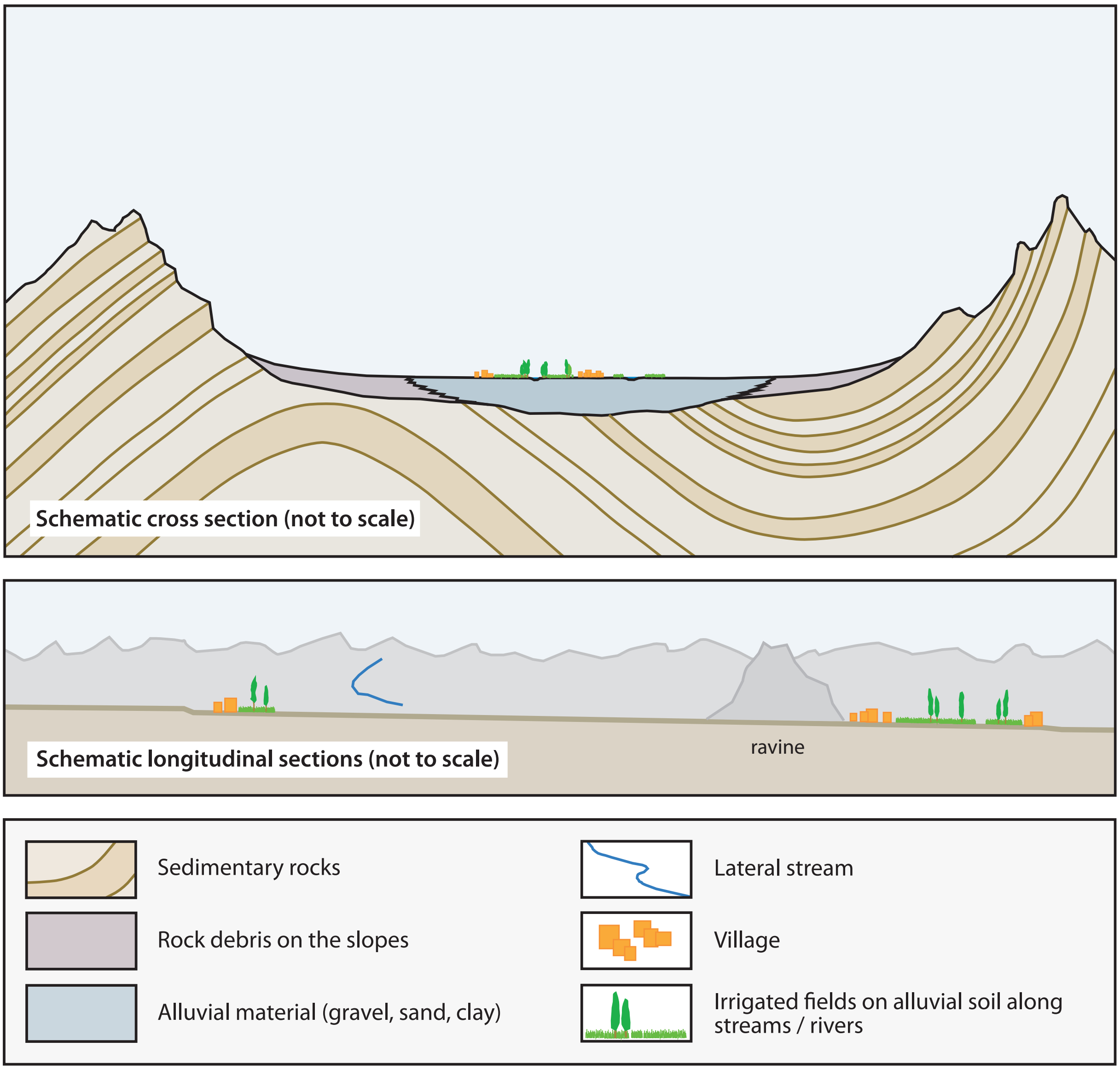


Fig. 18: *Schematic cross and longitudinal sections of a wide lower mountain valley, interrupted by ravines (kluses), where the streams / rivers cut through mountain ridges.*

Fig. 19: *River valley northwest of Beni Tajite that opens up to a high plain bordered by long, but narrow, isolated mountain ranges. Area G2b, autumn 2015.*

Fig. 20: *Irrigated fields in wide valley along a stream near Ait Ouahi and Ait Ouzzoug. Area G2b, autumn 2015.*

Fig. 21: *Village Ait Ouzzoug in wide valley northwest of Beni Tajite. Area G2b, autumn 2015.*

Fig. 22: *Oued Ait Aissa passing through village Ait Ahmed Ohaddou in a wide valley. Area G2b, autumn 2015.*

1.4 Canyon-like, stepped foothill valleys (type 4)

The morphology of canyon-like valleys with stepped slopes is restricted to the southern foothills of the High Atlas Mountains that are traversed by the northern tributaries of the upper Oued Drâa (fig. 23). These rivers rise from the highest peaks of the high Atlas Mountains and are thus permanently provided with water. The canyon-like valleys with stepped slopes develop in areas with rather low precipitation but a temporarily high flow rate, as it is given on the foot of a high mountain range with a humid microclimate in a generally semi-arid or arid greater region. Cretaceous and Tertiary sedimentary rocks with strong stratification and large differences in erosion resistance between harder and weak beds accentuate the development of this morphology.

Fig. 23: *Canyon-like foothill valleys in the Oued Drâa catchment on the southern slope of the High Atlas. The rivers first flow through V-shaped or trough valleys (outside the image), then through canyon-like foothill valleys with numerous ravines (kluses) and finally through the Ouarzazate – Boumalne du Dadès alluvial plain. White circles are ravines (kluses), where streams / rivers cut through one of the external mountain ridges.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

Number and spatial arrangement of streams or rivers forming this type of valleys in the foothills strictly depend on the number and spatial arrangement of the perennial streams / rivers flowing out of the inner mountains into the foothills. Under normal hydrological conditions their volume of water is determined by the drainage of the high mountain region, and thus also depends on the thickness and the duration of the snow cover. Once arrived in the foothills, the streams / rivers follow the line of greatest slope, searching their way through the external mountain ridges that are oriented parallel to the main axis of the High Atlas by cutting ravines (kluses). At low gradients, a slight meandering can be observed.

Tributaries rising within the foothills that form between the external ridges are usually ephemeral and contribute to the total water volume only after local rainfalls. Their beds can thus be broad, but they are hardly as deeply eroded as the perennial main canyons.

Villages are built on the slopes of the canyons, high enough to be safe in case of flooding. Due to limited space, most of them are quite compact. In most of the canyons, the fields are situated in the valley bottom along the streams / rivers, only between half a meter and two meters above the normal low water level (figs. 24-32). To compensate uneven ground, some of them are slightly terraced. During high water events, they are often affected

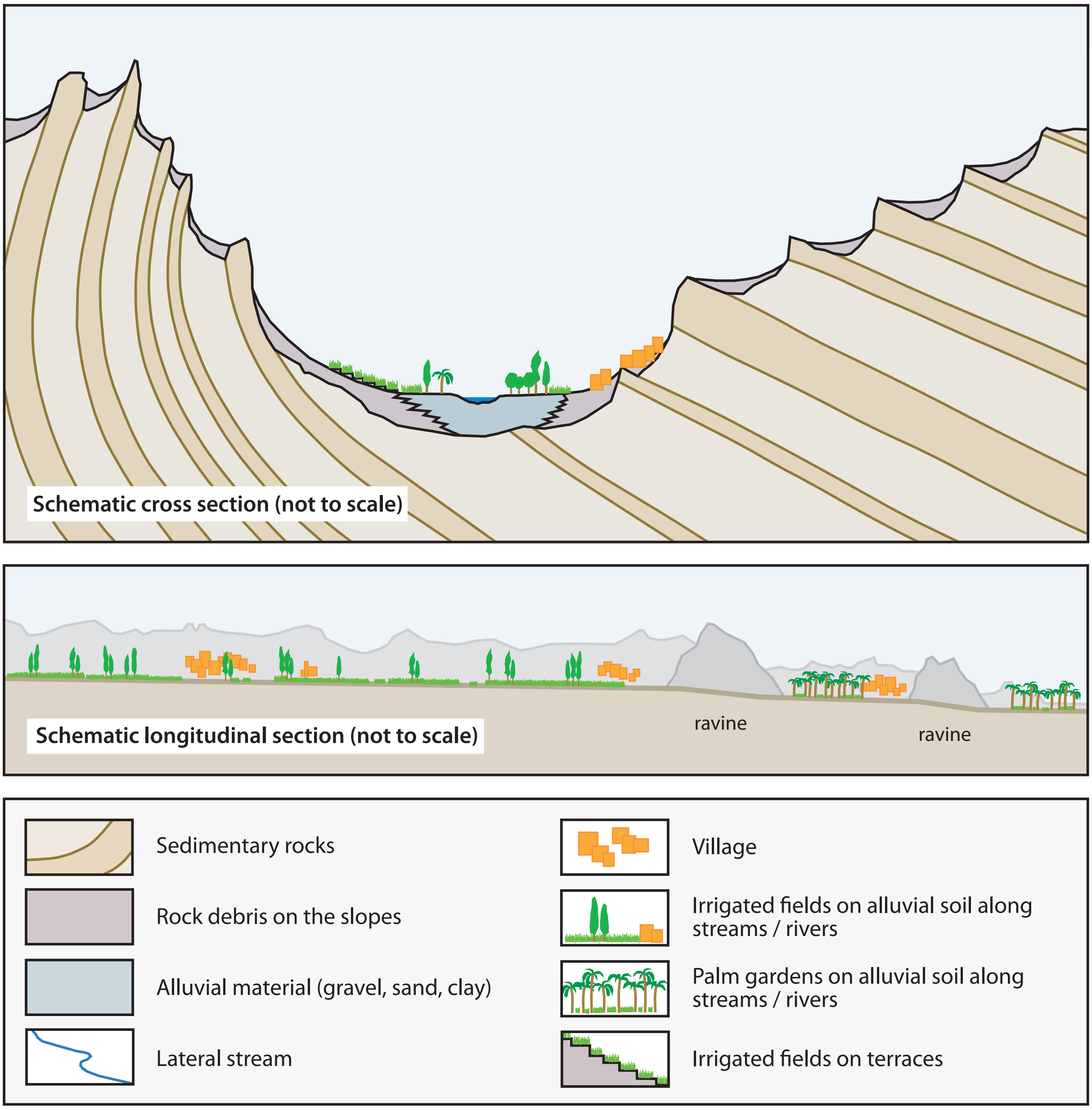


Fig. 24: *Schematic cross and longitudinal sections of a wide lower mountain valley, interrupted by ravines (kluses), where the streams / rivers cut through mountain ridges.*

by flooding and are thus eroded, if they are situated on the concave bank, or covered with thick layers of sediment if situated on the convex bank. In narrow canyons, fields can also be situated on natural terraces above the valley bottom (fig. 29). Irrigation operates through channels leading water from the main rivers parallel to the contour lines onto the fields.

Fig. 25: *Upper Asif Ounila, a typical foothill canyon cutting through Cretaceous and Tertiary carbonaceous sediments, view up the valley near Assaka. Area D5a, autumn 2015.*

Fig. 26: *Village Taguendouchte with irrigated fields, walnut and olive trees in the foothill canyon of upper Asif Ounila (Cretaceous and Tertiary carbonaceous sediments). View up the valley, area D5a, autumn 2015.*

Fig. 27: *Villages near Taguendouchte with irrigated fields, walnut and olive trees in the upper Asif Ounila Valley. If only weak rocks occur, foothill canyons may also show smooth slopes. View up the valley, area D5a, autumn 2015.*

Fig. 28: *Village Tamakouchte at the entrance to the middle Asif Ounila Canyon, cutting through Cretaceous and Tertiary carbonaceous sediments. View up the valley. Area D5a, autumn 2015.*

Fig. 29: *Village Assaka with irrigated fields on stream level and on terraces above in the foothill canyon of upper Asif Ounila, cutting through Cretaceous and Tertiary carbonaceous sediments. View up the valley, area D5a, autumn 2015.*

Fig. 30: *Village Tajeguite in the foothill canyon of upper Asif Ounila cutting through Cretaceous and Tertiary carbonaceous sediments. View down the valley. Area D5a, spring 2015.*

Fig. 31: *Villages Tourbiste, Aït Said and Touzrighte on the lower course of Asif Mgoun in a typical foothill canyon, cutting through Cretaceous and Tertiary carbonaceous sediments. Area D2c, autumn 2015.*

Fig. 32: *Village Maarouf with irrigated fields in the foothill canyon of upper Asif Ounila (Cretaceous and Tertiary carbonaceous sediments). Area D5a, autumn 2015*

2 Potential study areas with predominantly V-shaped valleys (type 1)

2.1 Geographic distribution and geological conditions

All potential study areas that predominantly display V-shaped valleys are situated on the northern, western and southern slope of the western and central High Atlas Mountains, distributed over three catchment areas: Oued Oum Er-Rbia and Oued Tensift on the northern slope and Oued Souss on the southern slope. All three rivers collect enough water in their catchments to reach the Atlantic Ocean, providing irrigation for intensive agricultural use of extensive areas along their lower courses and drinking water for numerous villages and towns. Nowadays, the rate of flow of the Oueds Oum Er-Rbia and Sousse can be allocated over the year to the needs due to several dams.

V-shaped valleys mostly develop in areas with abundant and evenly distributed precipitation combined with weakly structured rocks and rocks with weak stratification, represented here by magmatic and sedimentary rocks of different age. The V-shaped valleys mainly run in perpendicular direction to the axis of the mountain range. This is one of the most important contrasts to the trough valleys occurring in the eastern High Atlas (chapter 5) that mainly run parallel to the axis of the mountain range.

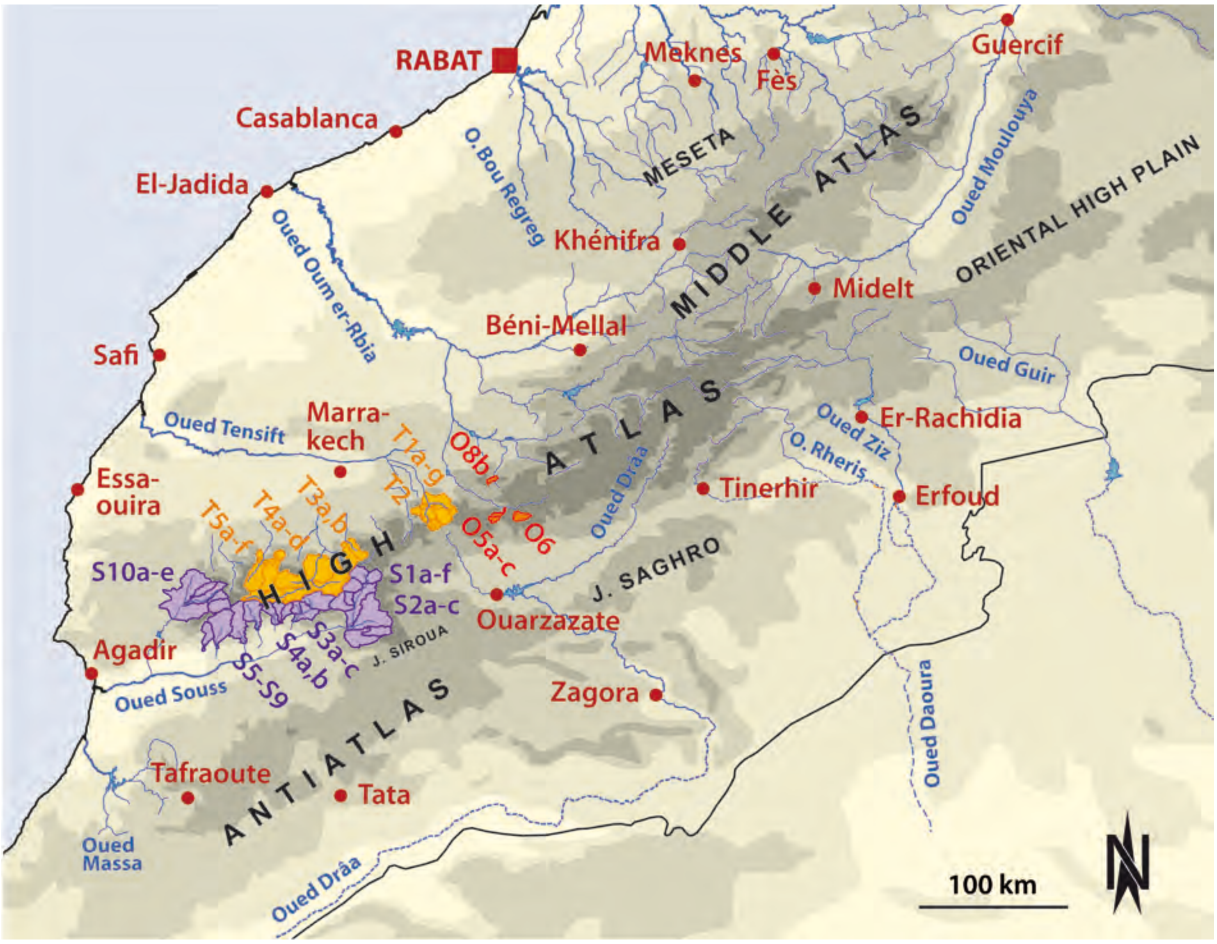


Fig. 33: *Simplified map of the Atlas Mountains showing potential study areas with predominantly V-shaped valleys (type 1).*

Nine combined areas (S1a-f, S2a-c, S3a-c, S4a,b, S10a-e, T1a-g, T3a,b, T4a-d, T5a-f) and six single areas (S5, S6, S7, S8, S9, O6) are introduced below. The single area T2 with additional dry farming is introduced under 'miscellaneous study areas' in chapter 9.2.1. The combined area O5a-c as well as the single area O8b are of minor importance, and are therefore not introduced specifically.

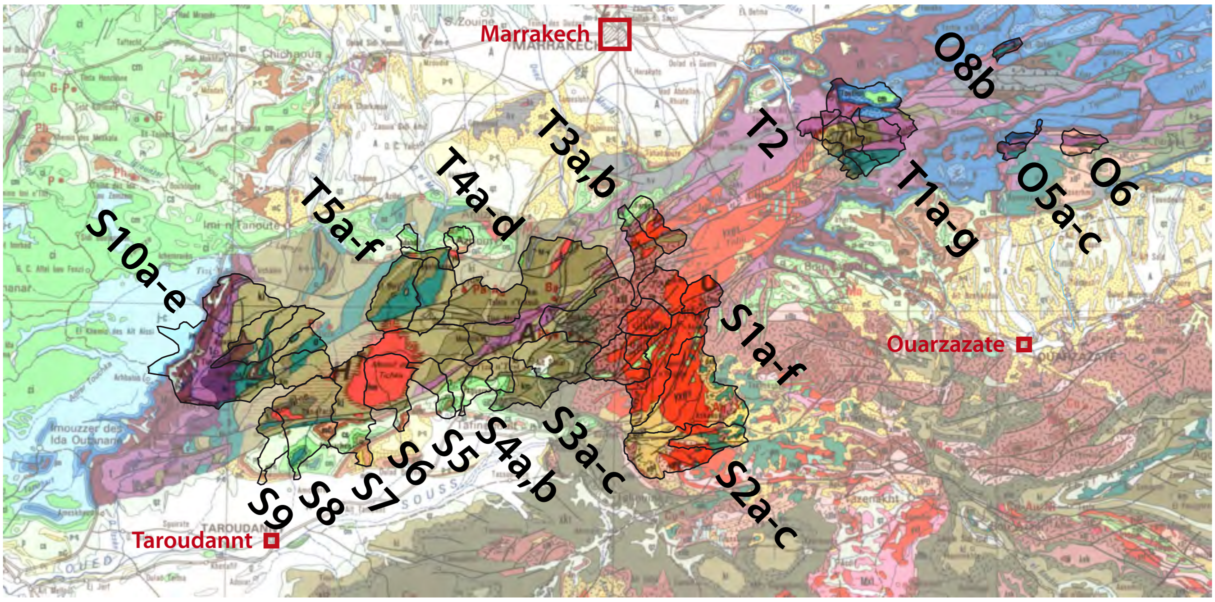


Fig. 34: *Geological map of the western and central High Atlas Mountains showing potential study areas with predominantly V-shaped valleys (type 1); modified after Saadi, M. et al., 1985, Carte Géologique du Maroc 1:1'000'000, Editions du Service Géologique du Maroc, see also annex III.*

Abbreviations for rock types forming V-shaped valleys:

yxII^3: Precambrian intrusive rocks (granites and granitoids) of the 'massif du Taoubkal'

yhm: Granites and granitoids of probably Devonian age of the 'massif du Tichka'

ρxII^3, yxIII: Precambrian volcanic rocks (ignimbrites, rhyolites, andesites) of the 'massif du Toubkal'

φm: Volcanic rocks (phonolites) of Miocene age (10.5-6.5 M.y.) of the 'Jebel Siroua'

xII^2, xII^3: Slates, sandstones (flyschs) and conglomerates of Precambrian age

xk1, xk2: Sandstones and dolomites of uppermost Precambrian age

ki, km: Cambrian sedimentary rocks (predominantly shales), partially low grade metamorphic

o: Ordovician sedimentary rocks (predominantly shales), partially low grade metamorphic

hs: Uppermost Carboniferous sedimentary rocks (predominantly shales, dolomites), partially low grade metamorphic

hr: Permian sedimentary rocks (predominantly red argillaceous rocks and sandstones)

t, tβ: Tertiary sedimentary rocks (predominantly red argillaceous rocks), partially with melaphyr dykes

jc: Upper Jurassic sedimentary rocks (predominantly red marls and argillaceous rocks)

Abbreviations for rock types occurring at the edges:

ci, ciC, cm, cs: Cretaceous sedimentary rocks (limestones, marls, argillaceous rocks)

esC, ei: Eocene (Tertiary) sedimentary rocks (limestones, marls, argillaceous rocks)

mC: Miocene (Tertiary) sedimentary rocks (argillaceous rocks, weakly consolidated sandstones and conglomerates)

2.2 Oued Sousse catchment

Concerning types of valleys, the northeastern part of the Oued Sousse catchment on the steep southern slope of the High Atlas Mountains and the western slope of Jebel Siroua are quite homogenous as predominantly V-shaped valleys occur with some minor morphological deviations towards high plains in the higher mountain areas, followed directly by alluvial plains on the foot of the mountains.

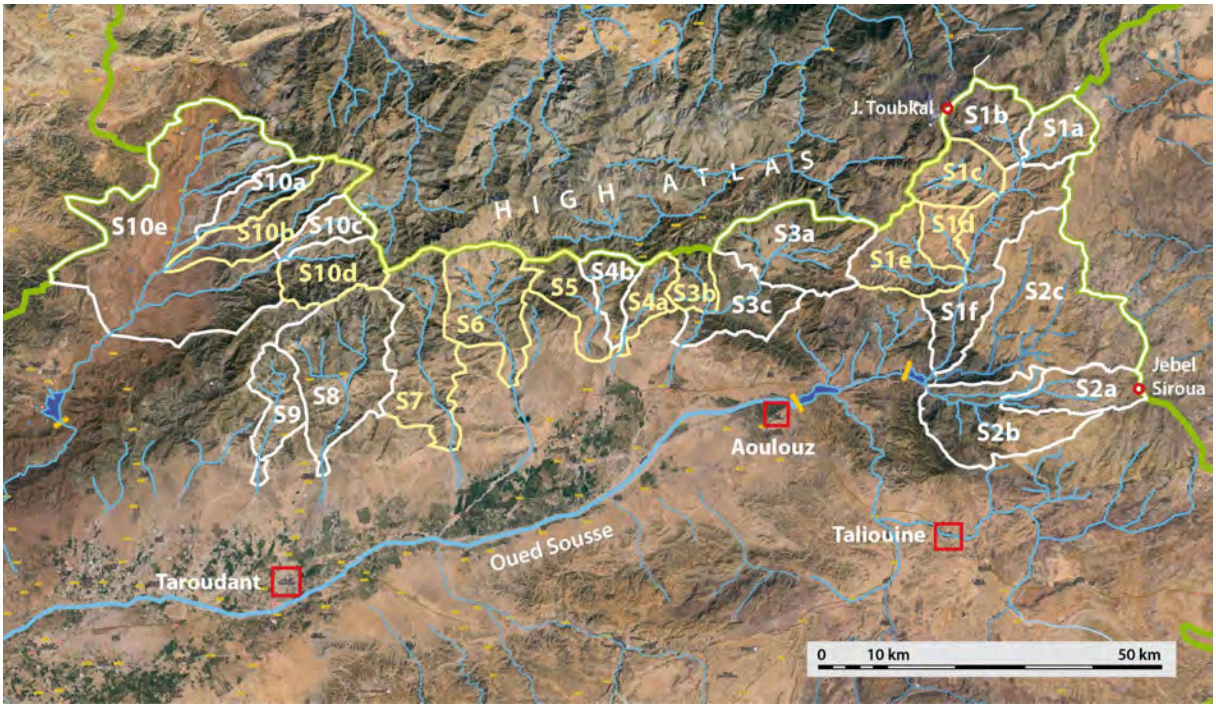


Fig. 35: *Satellite image of potential study areas in the Oued Sousse catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

2.2.1 Area S1 a-f
Adar N'Deren – Jebel Toubkal South

The Adar N'Deren – Jebel Toubkal South area is a valley that runs northeast – southwest between the steeply rising High Atlas Mountains to the north and the more gentle Jebel Siroua to the south. In its uppermost parts the valley is very broad, whereas in the lower parts also gorges occur.

Tab. 1: Key attributes of area S1 a-f.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valleys with alternating flat and steeper gradients, rather large opening angles and partly gorges.
Morphological type of the lower / outer mountain / foot-hill / alluvial plain areas:	---
Predominant rock types:	Granites, ignimbrites, shales.
Geological / tectonic units / geological periods:	See fig. 34, page 70.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Difficult to estimate
Form of settlement:	Compact villages
Density of settlement:	Middle – high
Predominant form of agriculture:	Irrigated farming on terraces at the flanks of V-shaped valleys and on alluvial fans.
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Higher altitudes: Cultivation of grain, vegetables, saffron and cattle fodder crops. Lower altitudes: Additional walnuts, fruit, olives, almonds.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	No tourist infrastructure (exception: Lac Ifni valley).
Degree of documentation:	Lower mountains and foothills: Good High Mountains: No documentation.

***Fig. 36:** Villages near Larba, terraced grain and vegetable fields at the valley flank. V-shaped high mountain valley, area S1a, autumn 2015.*

***Fig. 37:** Village near Larba, terraced fields at the valley flank. V-shaped high mountain valley, area S1a, autumn 2015.*

***Fig. 38:** Village near Larba, terraced grain and vegetable fields at the valley flank. V-shaped high mountain valley, area S1a, autumn 2015.*

***Fig. 39:** Saffron fields near Azrou N'Toubkal. V-shaped high mountain valley, area S1a, autumn 2015.*

***Fig. 40:** Village Azrou N'Toubkal with terraced fields at the valley flank. V-shaped high mountain valley, area S1a, autumn 2015.*

***Fig. 41:** Lac d'Ifni valley with terraced fields at the valley flank and additional fields at the river level. V-shaped valley, valley, area S1b, autumn 2015.*

Fig. 42: *Village near Ctre. Commune Toubkal, slightly terraced fields for the cultivation of grain, vegetables, fodder crops and walnut trees on the valley floor. Broad V-shaped valley, area S1b, autumn 2015.*

Fig. 43: *Asif Tifnoute, gorge between Tizoughine and Imourek-hessane, open cistern for the irrigation of young olive trees. Area S1f, autumn 2015.*

Fig. 44: *Village near Aghela, terraced fields with saffron and almond trees. V-shaped valley, area S1f, autumn 2015.*

Fig. 45: *Village Tamsoulte, slightly terraced fields for the cultivation of grain, vegetables, fodder crops and walnut trees on the valley floor. Broad V-shaped valley, area S1b, autumn 2015.*

2.2.2 Area S2 a-c
Jebel Siroua West

The area west of Jebel Siroua is characterized by high plains below the summit area of the Jebel Siroua volcano and subsequent, long V-shaped valleys running towards west.

Tab. 2: Key attributes of area S2 a-c.

Morphological type of the higher / inner mountain areas:	Primarily high mountain V-shaped valleys with steep gradients. Secondarily high plains crossed by branched streams below the summit of Jebel Siroua
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	Granites, ignimbrites, andesites, phonolites, slates, shales, sandstones, argillaceous rocks.
Geological / tectonic units / geological periods:	See fig. 34, page 70.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks, argan trees.
Density of natural vegetation:	Low – high
Degradation of natural vegetation:	Limited to the surroundings of villages, difficult to estimate on the high plain below J. Siroua summit.
Form of settlement:	Loose and compact villages
Density of settlement:	Low - middle
Predominant form of agriculture:	Irrigated farming on terraces at the flanks of V-shaped valleys and on alluvial fans, subordinate dry farming on high plains.
Irrigation:	Irrigation channels draining streams / sources in lateral valleys
Crops:	Higher altitudes: Cultivation of grain, vegetables, saffron and cattle fodder crops. Lower altitudes: Additional almonds.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	No tourist infrastructure existing.
Degree of documentation:	Lower mountains and foothills: Good High Mountains: Not all areas documented.

Fig. 46: *Village and terraced fields on a ridge southeast of Askaoun. Area S2a, autumn 2015.*

Fig. 47: *Villages Assagour und Tamaloute, terraced fields on Miocene volcanic deposits of Jebel Siroua (Rhyolites). Area S2a, autumn 2015.*

Fig. 48: *Village Agrd Nu Drar, terraced fields at the flank of a V-shaped high mountain valley. Area S2a, autumn 2015.*

Fig. 49: *Terraced fields for saffron and vegetables south of Agrd Nu Drar. V-shaped high mountain valley, area S2a, autumn 2015.*

Fig. 50: *Village, terraced fields and almond trees above Asif Oumarrgh in a V-shaped valley. Area S2b, autumn 2015.*

Fig. 51: *Village and almond trees in a dry lateral valley of Asif Oumarrgh. Area S2b, autumn 2015.*

Fig. 52: *Vegetation consisting mainly of conifers in the Asif Oumarrgh valley. Area S2b, autumn 2015.*

Fig. 53: *Villages Ifri and Id Wayskoute near Askaoun, Jebel Toubkal (4167 m) in the background. Area S2c, autumn 2015.*

2.2.3 Area S3 a-c
Aït Youb – Anzi – Tamsloumte – Imerguene

The Aït Youb – Anzi – Tamsloumte – Imerguene area is characterised by a high plain in the Tamsloumte area and long V-shaped valleys running towards west.

Tab. 3: Key attributes of area S3 a-c.

Morphological type of the higher/inner mountain areas:	Primarily high mountain V-shaped valleys with different, rather large opening angles and steep gradients. Secondarily high plain in the Tamsloumte area.
Morphological type of the lower/outer mountain/foothill /alluvial plain areas:	---
Predominant rock types:	Slates, shales, marls, limestones, argillaceous rocks.
Geological/tectonic units/geological periods:	See fig. 34, page 70.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks, argan trees.
Density of natural vegetation:	Middle - high
Degradation of natural vegetation:	Limited to the surroundings of villages.
Form of settlement:	Compact villages
Density of settlement:	Low – middle
Predominant form of agriculture:	Irrigated farming on terraces at the flanks of V-shaped valleys and on alluvial fans.
Irrigation:	Irrigation channels draining the main river and streams/sources in lateral valleys.
Crops:	Cultivation of grain, vegetables, cattle fodder crops and olives. Argan trees grow outside the agricultural area.
Accessibility/development of road infrastructure:	Lower mountains/main valleys: Easy to access on paved roads. High mountains/lateral valleys: Partially difficult to access on mud roads.
Future prospects/risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	No tourist infrastructure existing.
Degree of documentation:	Lower mountains and foothills: Good High Mountains: Not all areas documented.

Fig. 54: *Village Anzi, olive trees, view up the valley. Area S3a, autumn 2015.*

Fig. 55: *Village Tagadirt, terraced fields, olive trees, view up the valley towards the high plain of Tamsloumte. Area S3a, autumn 2015.*

Fig. 56: *Village Tamsloumte, main ridge of the High Atlas Mts., high plain of Tamsloumte. Area S3a, autumn 2015.*

Fig. 57: *View up the main valley with its permanent stream. Area S3c, autumn 2015.*

Fig. 58: *View up the main valley (with a newly paved road) towards Jebel Toubkal. Area S3c, autumn 2015.*

Fig. 59: *View down the main valley (with a newly paved road) towards the Oued Sousse alluvial plain. Area S3c, autumn 2015.*

Fig. 60: *Village Tasguint with the main streambed. Area S3c, autumn 2015.*

Fig. 61: *Village Tasguint with the main streambed and terraced fields. Area S3c, autumn 2015.*

Fig. 62: *High plain of Tamsloumte, area S3a, autumn 2015.*

2.2.4 Area S4 a, b
Tizi N'Test southern slope

The southern slope of Tizi N'Test (Tizi = pass) raises steeply out of the Oued Sousse alluvial plain. It is thus characterised by steep valleys that run towards south and end in an alluvial plain.

Tab. 4: Key attributes of area S4 a, b.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valleys with steep gradient.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Wide alluvial plain
Predominant rock types:	High Atlas Mts.: Slates, shales, argillaceous rocks. Foothills: Limestones, marls, argillaceous rocks.
Geological / tectonic units / geological periods:	See fig. 34, page 70.
Stream / river:	Periodic
Predominant natural vegetation:	Higher altitudes: Perennials, dwarf palms. Lower altitudes: Conifers, evergreen oaks, argan trees.
Density of natural vegetation:	Middle – high
Degradation of natural vegetation:	High, deforestation almost up to the main mountain crest, small reforestations with non-indigenous pines in lower areas.
Form of settlement:	Compact villages
Density of settlement:	Middle - high
Predominant form of agriculture:	Irrigated farming on terraces at the flanks of V-shaped valleys
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Cultivation of grain, vegetables, olives and cattle fodder crops. Argan trees grow outside the agricultural area.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	Broadening of the pass road with remarkable impact on the natural environment in progress. Tourist infrastructure only in Taroudant and on top of the pass.
Degree of documentation:	In general good.

Fig. 63: *Argan trees with a almost complete destruction of the ground cover due to overgrazing by goats. Foothills of area S4b, spring 2015.*

Fig. 64: *Village Tajgalte with argan trees. Foothills of area S4b, spring 2015.*

Fig. 65: *Villages near Chafarni, main ridge of the High Atlas Mountains with Tizi N'Test pass road and deforestation right up to the pass. Area S4b, autumn 2015.*

Fig. 66: *Villages near Chafarni, view down the valley from Tizi N'Test pass road. Area S4b, spring 2015.*

Fig. 67: *Tizi N'Test pass road, view over the Oued Sousse plain. Areas S4a, b, autumn 2015.*

Fig. 68: *View down the valley of area S4a from Tizi N'Test pass road on to the Oued Sousse plain, autumn 2015.*

2.2.5 Areas S5 – S9 Western High Atlas southern slope

All valleys on the steep southern slope of the western High Atlas Mountains run towards south and end in the Oued Sousse alluvial plain, similar to the Tizi N'Test area S4. Some of them show a kind of high terrace in their uppermost parts with villages beaded parallel to the mountain range.

Tab. 5: Key attributes of areas S5 - S9.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valleys with steep gradient, partially displaying wide high terraces in the uppermost parts.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Wide alluvial plain.
Predominant rock types:	High Atlas Mts.: Granites, slates, shales, slightly metamorphic rocks. Foothills, alluvial plains: Limestones, marls, argillaceous rocks, weakly consolidated conglomerates, sandstones.
Geological / tectonic units / geological periods:	See fig. 34, page 70.
Stream / river:	Periodic
Predominant natural vegetation:	Higher altitudes: Perennials, dwarf palms. Lower altitudes: Conifers, evergreen oaks, argan trees.
Density of natural vegetation:	Middle – high
Degradation of natural vegetation:	Difficult to estimate.
Form of settlement:	Loose and compact villages
Density of settlement:	Middle - high
Predominant form of agriculture:	Irrigated farming on terraces at the flanks of V-shaped valleys
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Cultivation of grain, vegetables, olives and cattle fodder crops. Argan trees grow outside the agricultural area.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	Strikingly many large new houses. No tourist infrastructure existing (with the exception of Taroudant).
Degree of documentation:	Not all areas documented.

Fig. 69: *Irrigation channel (arrow), main ridge of the High Atlas Mountains. Area S8, autumn 2015.*

Fig. 70: *Villages near Tafraouten with terraced fields. Area S9, autumn 2015.*

Fig. 71: *Detail enlargement of fig. 70, area S9, autumn 2015.*

Fig. 72: *Villages near Tafraouten with terraced fields. Area S9, autumn 2015.*

Fig. 73: *Highest villages on a high terrace in the areas S8 and S9, directly below the main ridge of the High Atlas Mountains. View towards east, autumn 2015.*

Fig. 74: *Highest villages on a high terrace in the areas S8 and S9, directly below the main ridge of the High Atlas Mountains. Vew towards east, autumn 2015.*

2.2.6 Area S10 a - e High Atlas western slope

The western slope of the High Atlas Mountains is characterised by several long, parallel valleys that are situated close to each other, ending in the alluvial plain of the Assif N'Aït Messaoud.

Tab. 6: Key attributes of area S10 a-e.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valleys with different opening angles and alternating flat and steeper gradients, partly gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Wide lower mountain valley with very flat gradient / alluvial plain
Predominant rock types:	High Atlas Mts.: Unmetamorphic and low-grade metamorphic carbonate rocks, granites, slates, shales. Foothills, alluvial plains: Conglomerates, sandstones and clays.
Geological / tectonic units / geological periods:	See fig. 34, page 70.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks, argan trees.
Density of natural vegetation:	Low - middle
Degradation of natural vegetation:	In the valleys: Low On the western flank of the High Atlas Mts.: Difficult to estimate, eventually high.
Form of settlement:	Compact villages
Density of settlement:	Low
Predominant form of agriculture:	Primarily irrigated farming on terraces near the streams in V-shaped valleys, additional steep fields for dry farming
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Cultivation of grain, vegetables, cattle fodder crops, almonds and olives.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	Little arable land with regard to the settlements → additional nomadic cattle breeding in high altitudes? No tourist infrastructure existing.
Degree of documentation:	Not all areas documented.

Fig. 75: *Village Ameslane with terraced fields. Area S10a, autumn 2015.*

Fig. 76: *Village Imalalene (end of the road) with terraced fields. Area S10a, autumn 2015.*

Fig. 77: *Village Imalalene at the end of the road. Area S10a, autumn 2015.*

Fig. 78: *Steep fields prepared for dry farming and almond trees (see arrow). Area S10, autumn 2015.*

Fig. 79: *Villages in the very open highest part of the valley. Area S10c, view towards northeast, autumn 2015.*

Fig. 80: *Small terraced fields near Tanout with almond trees. Area S10c, autumn 2015.*

Fig. 81: *Village and terraced fields in the highest part of the valley. Area S10c, autumn 2015.*

Fig. 82: *Gorge and village Imi Meggount with large, very steep, cleared allotments (arrows), the use of which is not obvious. Areas S10c, d, autumn 2015.*

Fig. 83: *Village Tiwona with olive trees. Area S10e, autumn 2015.*

Fig. 84: *Village Souk Sept Talmakant in the lower part of the valley with olive trees. View up-valley (towards northeast), area S10e, autumn 2015.*

Fig. 85: *Foothills with a stream cutting through weak dark read clastic sediments of Carboniferous age. View towards south-east, area S1b, autumn 2015.*

Fig. 86: *Foothills with weak dark read clastic sediments of Car-boniferous age in the dusty air of a windy day. View towards southeast, area S1e, autumn 2015.*

Fig. 87: *Western High Atlas Mountains on a windy day with dusty air east of the alluvial plain of Assif n'Aït Messaoud valley with its characteristic red clastic sediments of Carboniferous to Triassic age. Area S10e, autumn 2015.*

2.3 Oued Tensift catchment

Similar to the northeastern part of the Oued Sousse catchment, the Oued Tensift catchment is also quite homogenous, as all valleys occurring are V-shaped valleys in the higher mountain areas. The foothills in contrast are dominated by marginal mountain ridges with alluvial plains in between that are cut by ravines (kluses). These areas, however, are densely populated and used for intensive farming, or their natural hydrological systems are disturbed by dams. They are therefore not appropriate for the intended case studies. An exception is area T6 that does not match with the four basic valley types of the High Atlas Mountains as defined in chapter 1 and that will be discussed under ‘miscellaneous study areas’ in chapter 9.2.2.

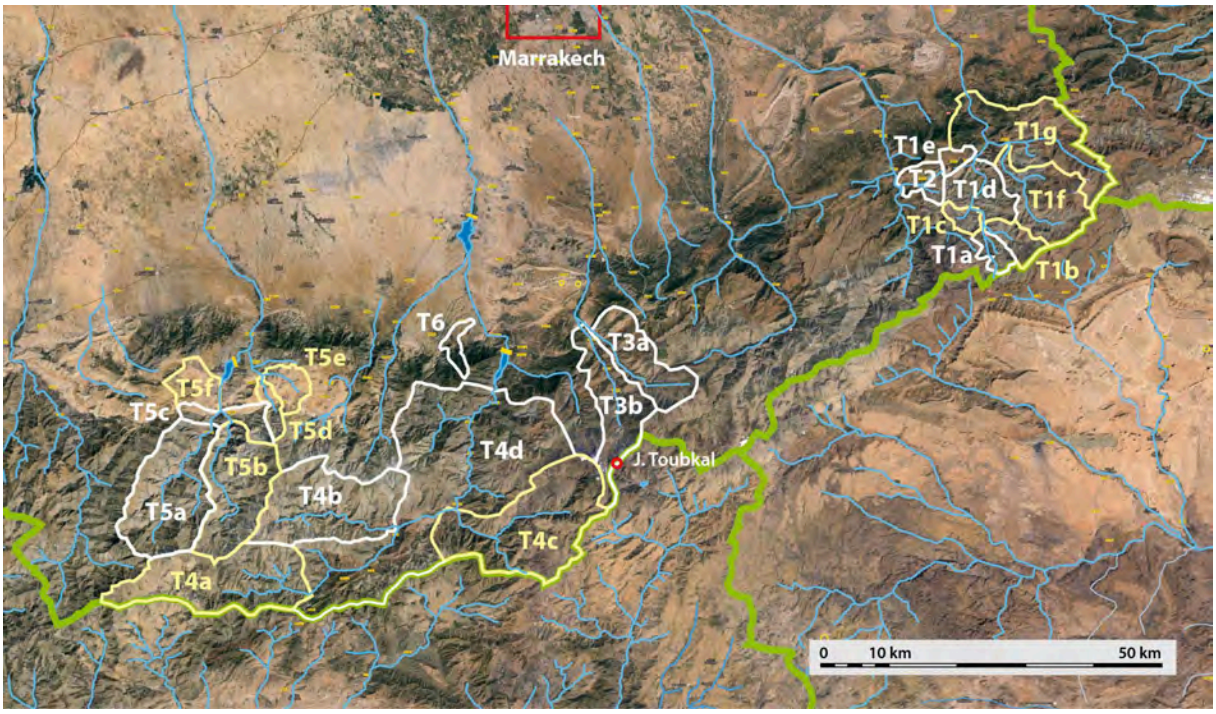


Fig. 88: *Satellite image of potential study areas in the Oued Tensift catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

2.3.1 Area T1 a-g
Tizi N'Tichka northern slope / Oueds Tichka and Tensift

In contrast to the southern slope of the High Atlas Mountains with steep, short valleys, its northern slope is flatter with longer valleys. Due to the strongly branched Oueds Tichka and Tensift with many tributaries, the northern slope of Tizi N'Tichka (Tizi = pass) is characterised by numerous inhabited valleys.

Tab. 7: Key attributes of area T1 a-g.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valleys with steep gradients, partly gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	Slates, shales, marls, limestones.
Geological / tectonic units / geological periods:	See fig. 34, page 70.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Low - middle
Degradation of natural vegetation:	Presumably strong. Small, moderately successful reforestations with non-indigenous conifers.
Form of settlement:	Compact villages
Density of settlement:	Middle – high
Predominant form of agriculture:	Primarily irrigated farming on terraces at the flanks of V-shaped valleys and on small alluvial fans. Secondarily dry farming, mostly along the lower course of Oued Tichka.
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Higher altitudes: Cultivation of grain, vegetables and cattle fodder crops. Lower altitudes: Additional walnuts and olives.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	Broadening of the pass road with remarkable impact on the natural environment in progress. Little tourist infrastructure.
Degree of documentation:	Lower mountains and foothills: Good High Mountains: Not all areas documented.

Fig. 89: *Villages in the uppermost Oued Tichka Valley with slightly terraced fields along the stream and dry farming on the shoulder to the left at the top. Area T1a, spring 2015.*

Fig. 90: *Reforestation with non-indigenous pines in the uppermost Oued Tichka Valley. Area T1a, spring 2015.*

Fig. 91: *Road construction site (broadening of the pass road). Area T1a, autumn 2015.*

Fig. 92: *Road construction site, new breakthrough with remarkable impact on the natural environment in progress (arrow). Area T1a, spring 2015.*

Fig. 93: *Village Aït Ammar in spring with water-filled Oued Tichka and a concrete irrigation channel (to the right at the bottom). Area T1d, spring 2015.*

Fig. 94: *Village Aït Ammar in autumn with nearly empty Oued Tichka. Area T1d, autumn 2015.*

Fig. 95: *Village in the middle part of Oued Tichka Valley. Area T1d, spring 2015.*

Fig. 96: *Village with terraced fields on alluvial land in the middle part of Oued Tichka Valley. Area T1d, spring 2015.*

Fig. 97: *Village Tazlida in the lower Oued Tichka Valley with terraced fields. View up the valley (towards south), area T1d, autumn 2015.*

Fig. 98: *Village near Tazlida with water-filled Oued Tichka and terraced fields. View up the valley (towards south), area T1d, spring 2015.*

Fig. 99: *Outstanding concentration of terraced fields on a mighty accumulation of debris near Aït Moussa, the origin of which may be alluvial or glacial (paleo-moraine). Area T1e, autumn 2015.*

Fig. 100: *Terraced fields from fig. 99 seen from a different angle. Area T1e, autumn 2015.*

Fig. 101: *View down the valley from Aït Moussa towards the Oued Tichka Valley (eastwards). Area T1e, autumn 2015.*

Fig. 102: *Village and terraced fields near Aït Moussa. Area T1e, autumn 2015.*

Fig. 103: *Lower course of Oued Tensift after the confluence with Oued Tichka. Villages and slightly terraced fields for dry farming are situated above the river. View down the valley, area T1g, spring 2015. See also fig. 104.*

Fig. 104: *Lower course of Oued Tensift after the confluence with Oued Tichka. Villages and slightly terraced fields for dry farming are situated above the river. Note the erosional trenches in the foreground. Area T1g. spring 2015. See also fig. 103.*

Fig. 105: *Lower course of Oued Tensift after the confluence with Oued Tichka, view up the valley towards the main ridge of the High Atlas Mountains. Area S1a, spring 2015.*

2.3.2 Area T3 a, b
Valleys north of Jebel Toubkal

The Jebel Toubkal range is one of the most visited regions by foreign mountaineers and hikers. On days with good weather several hundred people are on their way. Accordingly, the tourist infrastructure on its northern slope that can be reched in two hours from the international airport of Marrakech is well developed and endangers the natural environment. The neighbouring Ourika Valley to the east is a popular weekend getaway destination for residents of Marrakech and also hosts the Oukaimeden ski resort.

Tab. 8: Key attributes of area T3 a, b.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valleys with steep gradient, partly gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	High Atlas Mts.: Magmatic rocks, predominantly andesites and granites. Foothills: carbonate rocks (limestones, marls, argillaceous rocks).
Geological / tectonic units / geological periods:	See fig. 34, page 70.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Presumably strong, reforestation with cedars and non-indigenous pines in higher altitudes.
Form of settlement:	Compact villages
Density of settlement:	Low - middle
Predominant form of agriculture:	Primarily irrigated farming on terraces at the flanks of V-shaped valleys and on small alluvial fans. Additional temporary fields on alluvial deposits in streambeds.
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Higher altitudes: Cultivation of grain, vegetables and cattle fodder crops. Lower altitudes: Additional walnuts.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access.
Future prospects / risks:	Well-developed tourist infrastructure for Jebel Toubkal trekking tours in Imlil and luxury tourism in the foothills, bearing the risk of overexploitation of natural resources and pollution (solid waste, water pollution).
Remarks:	Critical attitude towards environment issues?
Degree of documentation:	Lower mountains and foothills: Good High Mountains: Not all areas documented.

Fig. 106: *Alluvial plain behind the first range of the foothills (klus). View up the valley towards the Jebel Toubkal range, area T3b, spring 2015.*

Fig. 107: *Temporary fields on alluvial deposits in the streambed. View up the valley towards the Jebel Toubkal range, area T3b, spring 2015.*

Fig. 108: *Streambed, view up the valley towards village Imlil and Jebel Toubkal (Morocco's highest peak, 4167 m). Area T3b, spring 2015.*

Fig. 109: *Reforestation with non-indigenous pines on the northern slope of the Jebel Toubkal range (foreground and middle ground, arrow). Area T3b, spring 2015.*

Fig. 110: *Small village that is only accessible over a dilapidated suspension bridge during high water. Area T3b, spring 2015.*

Fig. 111: *Villages near Tacheddirt with terraced fields. Area T3a, spring 2015.*

Fig. 112: *Terraced fields at 2400 m above sea level (arrow) with direct irrigation by a lateral stream on the northern slope of Jebel Toubkal range. Area T3a, spring 2015*

Fig. 113: *Mountain farmer working on terraced fields on the northern slope of Jebel Toubkal range. Area T3a, spring 2015.*

2.3.3 Area T4 a-d
Oued N'Fis Valley north of Tizi N'Test

The Oued N'Fis valley running from southwest to northeast is the only V-shaped valley on the northern slope that is not oriented perpendicularly to the mountain range.

Tab. 9: Key attributes of area T4 a-d.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valleys with different opening angles and alternating flat and steeper gradients, partly gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	Slates, shales, marls, dolomites.
Geological / tectonic units / geological periods:	See fig. 34, page 70.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Low – high
Degradation of natural vegetation:	Difficult to estimate, generally rather low with exceptions.
Form of settlement:	Compact villages
Density of settlement:	Middle - high
Predominant form of agriculture:	Primarily irrigated farming on terraces at the flanks of V-shaped valleys and on small alluvial fans.
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Higher altitudes: cultivation of grain, vegetables and cattle fodder crops. Lower altitudes: Additional walnuts, olives and almonds.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access (mud / paved roads).
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	Little tourist infrastructure existing. 'Natural reserve' on Tizi N'Test and 'Moufflon hunting reserve' for trophy hunters north of Tizi N'Test. Barrage Ouirgane north of area T4d.
Degree of documentation:	Lower mountains and foothills: Good High Mountains: Not all areas documented.

Fig. 114: *Villages near Aghbare on the very steep flank of the uppermost Oued N'Fis Valley. View up the valley, area T4a, autumn 2015.*

Fig. 115: *Village with terraced fields in the uppermost Oued N'Fis Valley. Area T4a, autumn 2015.*

Fig. 116: *Village with terraced fields on the very steep flank of the uppermost Oued N'Fis Valley. Area T4a, autumn 2015.*

Fig. 117: *Main road of Aghbare, a typical souk village at the end of the motorable road. Area T4a, autumn 2015.*

Fig. 118: *Village Aghbare with a garbage heap (arrow); souk villages at the end of motarable roads are always situated "at the end of the modern world", suffering from its remnants that do not rot. Area T4a, autumn 2015.*

Fig. 119: *Walnut Trees along a small lateral stream of Oued N'Fis. Area T4a, autumn 2015.*

Fig. 120: *Natural vegetation consisting of conifers (cypresses) and evergreen oaks without any ground covering shrubs north of Tizi N'Test. View towards north, area T4d, spring 2015.*

Fig. 121: *Source in the shady and humid northern flank of Tizi N'Test. Area T4d, autumn 2015.*

Fig. 122: *Oued N'Fis Valley with Tizi N'Test pass road and snow-covered Jebel Toubkal in the background. View down the valley towards northeast, area T4d, autumn 2015.*

Fig. 123: *Village near Mouldikht with terraced fields and almond trees. Area T4d, autumn 2015.*

Fig. 124: *Villages of Mouldikht in the middle, more open part of Oued N'Fis valley. View up the valley. Area T4d, autumn 2015.*

Fig. 125: *Villages south of Tinmel in the middle, more open part of Oued N'Fis valley. View up the valley. Area T4d, autumn 2015.*

***Fig. 126:** Mosque of Tin Mal (Tinmel) in Oued N'Fis Valley, built in the 12[th] century and nucleus of the Almohad realm. Area T4d, spring 2015.*

***Fig. 127:** Oued N'Fis with lateral fields, 2 km below Tinmel. View down the valley, area T4d, spring 2015.*

***Fig. 128:** Villages near Ijoukak in the Oued N'Fis Valley. View down the valley, area T4d, spring 2015.*

***Fig. 129:** Gorge of Oued N'Fis at the lower end of the more open part of the valley. Area T4d, spring 2015.*

***Fig. 130:** Village and Oued N'Fis between Ijoukak and Toug el Khair. Area T4d, autumn 2015.*

***Fig. 131:** Fruit plantation and Oued N'Fis between Imidal und Barrage Ouirgane. View up the valley, area T4d, spring 2015.*

Fig. 132: *Villages on a mountain ridge in the Ighil Valley (lateral valley of Oued N'Fis) with terraced fields. Area T4b, autumn 2015.*

Fig. 133: *Small village in the Ighil Valley that is acessible only over a frightening mud road (arrow). Area T4b, autumn 2015.*

Fig. 134: *Village Ighil at the end of the motorable road with terraced fields. Area T4b, autumn 2015.*

Fig. 135: *Village Ighil at the end of the motorable road. Area T4b, autumn 2015.*

Fig. 136: *View down the valley from Ighil. Area T4b, autumn 2015.*

Fig. 137: *Local famers near village Tijiricht riding on their donkeys with saddlebags full of cattle fodder crops. Area T4c, autumn 2015.*

2.3.4 Area T5 a-f
Asif El Mehl area

The core zone of the Asif El Mehl area consists of two parallel high mountain valleys running towards north through Paleozoic sediments. In Addition, the area is extended over the inherent foothills above Barrage Abi El Abbess Septi that are composed of Mesozoic and Cenozoic sediments.

Tab. 10: Key attributes of area T5 a-f.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valleys with different opening angles and alternating flat and steeper gradients, partly gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	High plains and V-shaped valleys
Predominant rock types:	High Atlas Mts: Slates, shales. Foothills: carbonate rocks (limestones, marls, argillaceous rocks, gypsum)
Geological / tectonic units / geological periods:	See fig. 34, page 70.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Partially strong
Form of settlement:	Compact villages
Density of settlement:	Low - middle
Predominant form of agriculture:	Primarily irrigated farming on terraces at the flanks of V-shaped valleys and on small alluvial fans.
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Higher altitudes: cCultivation of grain, vegetables and cattle fodder crops. Lower altitudes: Additional walnuts, olives and almonds.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible, but not to expect as the landscape is not particularly attractive.
Remarks:	No tourist infrastructure existing. Barrage Abi El Abbess Septi north of area T5 supplying irrigation systems in the alluvial plain at the northern foot of the High Atlas Mts.
Degree of documentation:	Lower mountains and foothills: Good High Mountains: Not all areas documented.

Fig. 138: *Villages Imindounit / Taounghast at the end of the motorable road in the Asif El Mehl Valley. View up the valley (towards south), area T5a, autumn 2015.*

Fig. 139: *Gorge of the Asif El Mehl with a new mud road. On the left hand side relics of terraced fields and of an old mule trail (arrows). View down the valley, area T5a, autumn 2015.*

Figs. 140 and 141: *Details of the old terraced fields from fig. 139 with relics of dry retaining walls and a nomad cave, suggesting that the fields were terraced in the midst of this hostile environment by nomads far from the settlements of the permanent population. Seeds of the old cereal are still spreading and growing. Area T5a, autumn 2015.*

Fig. 142: *Part of the village Adassil. View down the valley towards north, area T5c, autumn 2015.*

Fig. 143: *Part of the village Adassil, area T5c, autumn 2015.*

Fig. 144: *Villages on the high plain west of the Asif El Mehl Valley (arrow). Area T5f, autumn 2015.*

Fig. 145: *Villages from fig. 144 on the high plain west of the Asif El Mehl Valley (arrow) from another perspective. Area T5f, autumn 2015.*

Fig. 146: *Villages on both sides of Asif El Mehl. The shine on the hills is due to weak, slaty, cambro-ordoviacian rock debris, deposited mostly parallel to the surface. Below Barrage Abi El Abbess Septi, north of area T5, autumn 2015.*

Fig. 147: *Villages above Asif El Mehl, view down the valley. Below Barrage Abi El Abbess Septi, north of area T5, autumn 2015.*

Fig. 148: *Natural vegetation northwest of area T5e, autumn 2015.*

2.4 Oued Oum Er-Rbia catchment

The Oued Oum Er-Rbia catchment on the northern slope of the High Atlas Mountains comprises numereous valleys of different types that will be in the focus of the later chapters 3.2, 5.4, 6.2 and 9.1. However, the small, single area O6 is the most interesting V-shaped valley in the catchment and deserves closer attention here. The other V-shaped valleys are the combined area O5a-c and in the single area O8b that are of minor importance and that will therefore not be introduced specifically.

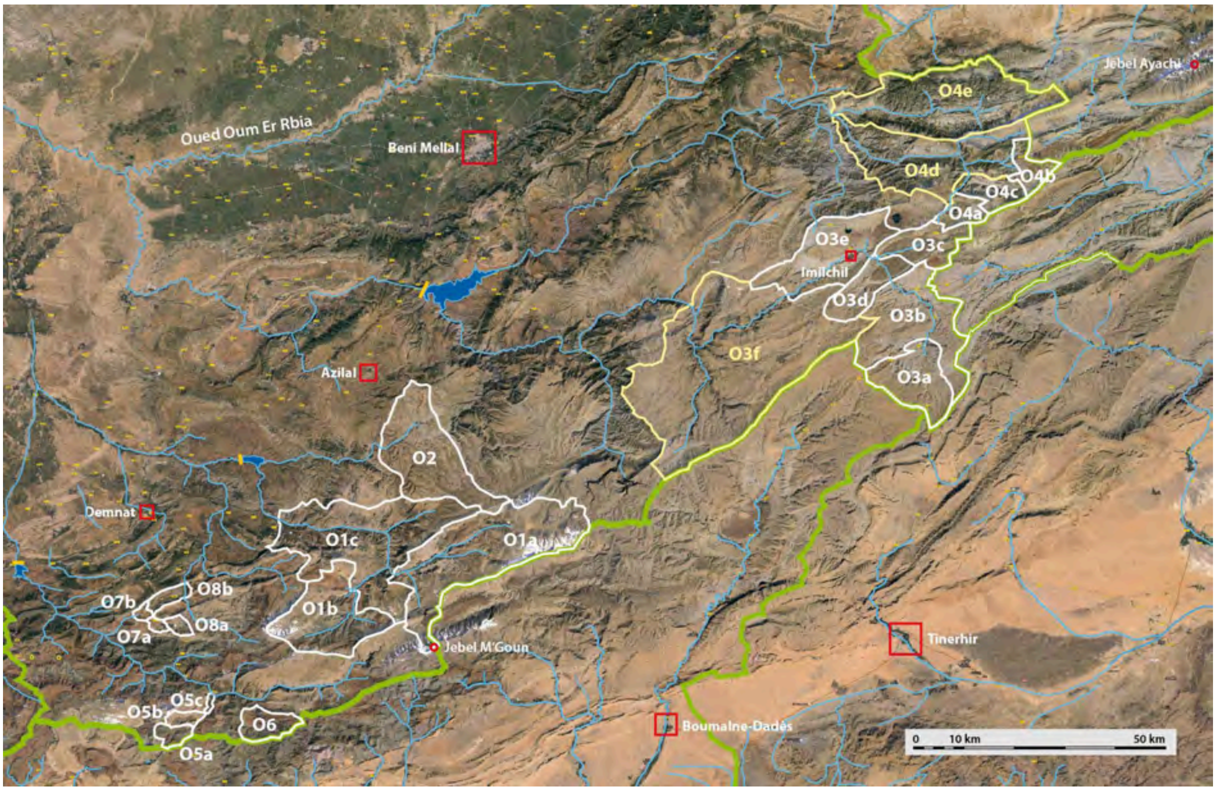


Fig. 149: *Satellite image of potential study areas in the Oued Oum Er-Rbia catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

2.4.1 Area O6
Megdaz Valley

Area O6 in the Megdaz valley is situated in one of the least accessible regions on the northern slope of the High Atlas Mountains. That is why the area is not combined with other areas in the surroundings. Most valleys in this region are in some way accessible, however, as the rivers often flow through nearly inaccessible gorges, the mud roads were built high up in the mountains, which makes them long and dangerous, especially in wintertime.

Two years ago, Megdaz was only accessible on a mule track. Today it is one of the few villages in this region that has been connected to the paved road network. The Megdaz valley and the neighbouring valleys have mostly very steep slopes, often also with rock faces, where carbonaceous rocks occur. This may be the reason why they are less densely populated and why agriculture does not play a very important role, suggesting that other income generating activities like animal husbandry are more important. These valleys catch the eye through the authenticity of their villages where most houses are well maintained and built with traditional natural building material. Also modern civilisation in the form of litter did not yet arrive in the valley.

Tab. 11: Key attributes of area O6.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valley with close opening angles and flat gradient, partly gorge.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	Limestones, marls, slates, shales.
Geological / tectonic units / geological periods:	See fig. 34, page 70.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Strong, partially very strong.
Form of settlement:	Compact villages
Density of settlement:	Low
Predominant form of agriculture:	Little irrigated farming on terraces at the flanks of V-shaped valleys and in riverbeds. Presumably mayor animal husbandry.
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Cultivation of grain, vegetables, cattle fodder crops (?) and walnuts.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on long and exposed mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible
Remarks:	No tourist infrastructure (except in Toufghine / Aït Alla outside area D6).
Degree of documentation:	Not the whole area documented.

Fig. 150: *Stream near Megdaz with walnut trees. Area O6, autumn 2015.*

Fig. 151: *Village Megdaz, area O6, autumn 2015.*

Fig. 152: *Village Imizilen in the Megdaz Valley with walnut trees. Area O6, autumn 2015.*

Fig. 153: *Village Imizilen in the Megdaz Valley. Area O6, autumn 2015.*

Fig. 154: *Goats in the Megdaz valley. Area O6, autumn 2015.*

3 Potential study areas with V-shaped valleys (type 1) and trough valleys (type 2)

3.1 Geographic distribution and geological conditions

A combination of V-shaped valleys and trough valleys occurs at the boundary between the western / central High Atlas Mountains that are dominated by magmatic and sedimentary rocks of different ages, and the eastern High Atlas Mountains that are predominantly built of Jurassic limestones and marls. This is not a coincidence, since the morphology of the western and the central High Atlas Mountains is dominated by V-shaped valleys in the upper high mountain parts, whereas in the eastern High Atlas Mountains mainly trough valleys occur. Characteristics of V-shaped valleys and trough valleys are described in the chapters 1.1 (page 57) and 1.2 (page 60), respectively.

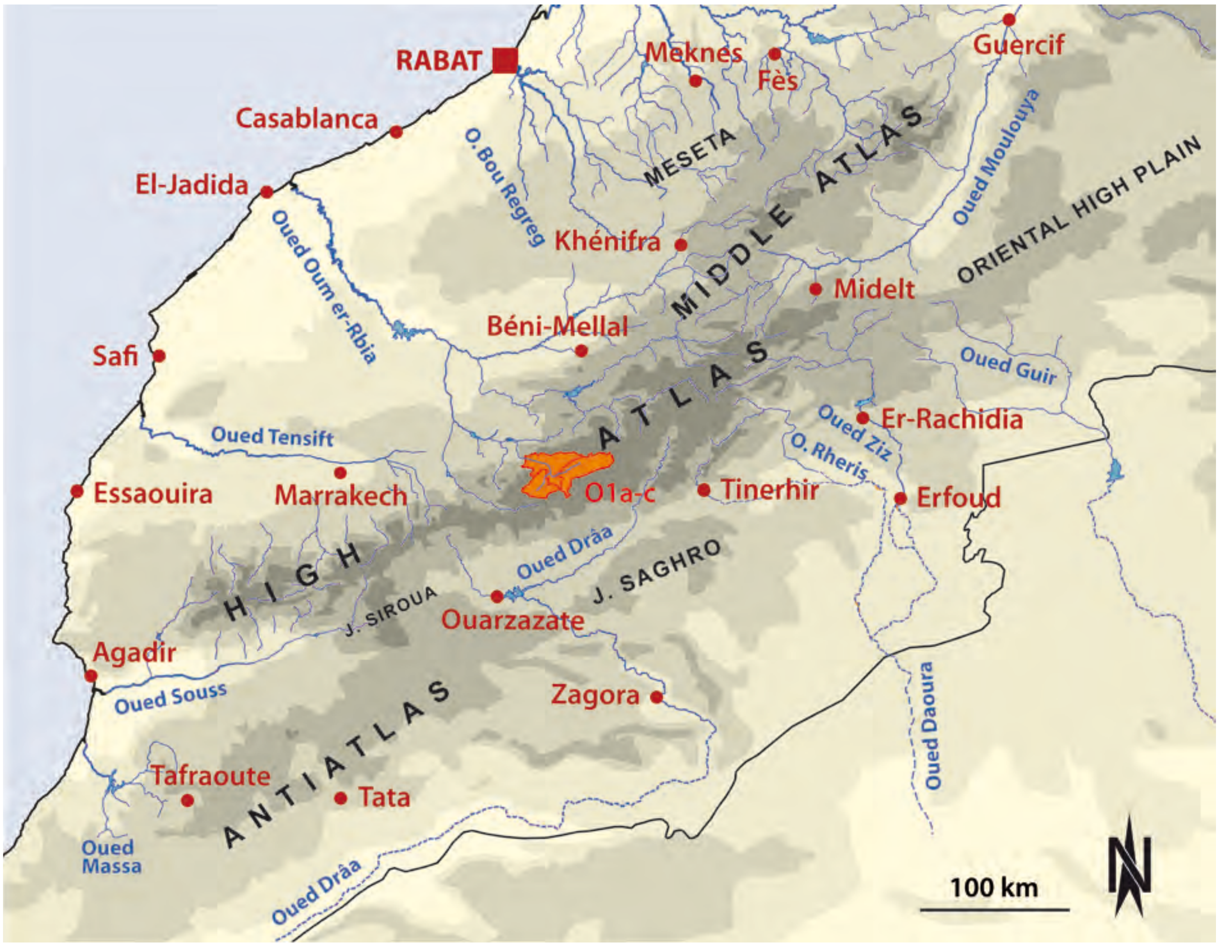


Fig. 155: Simplified map of the Atlas Mountains showing the potential study area O1 that is a combination of V-shaped valleys (type 1) and trough valleys (type 2).

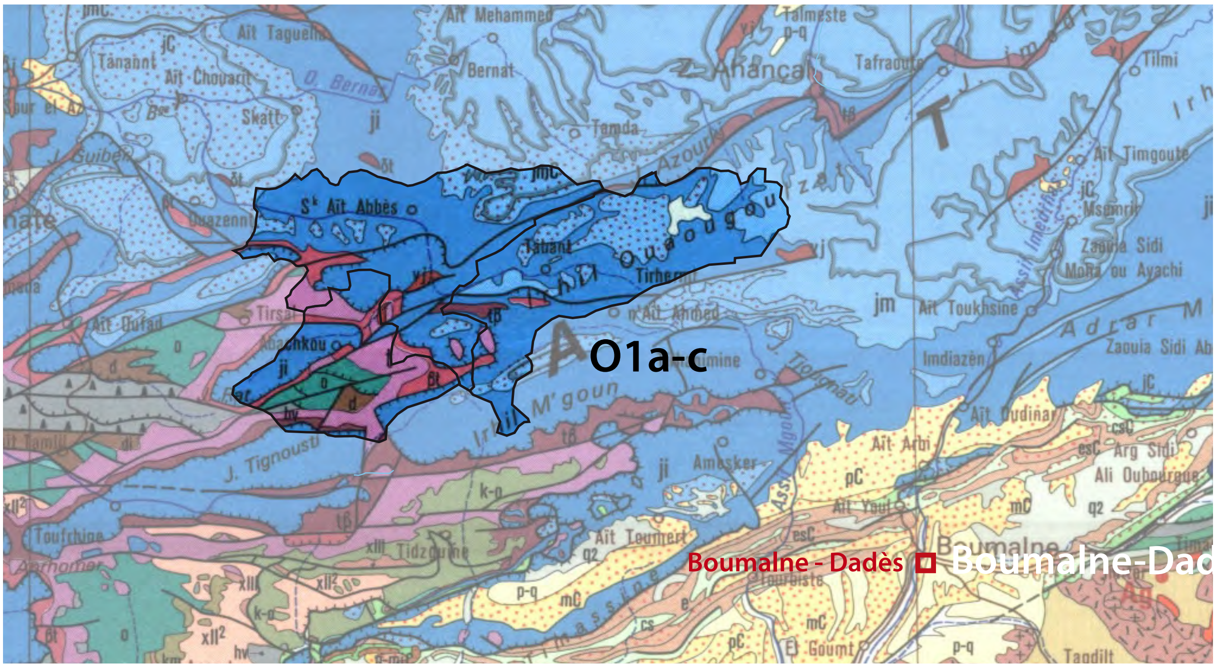


Fig. 156: *Geological map of the central High Atlas Mountains showing potential study area O1 that is a combination of V-shaped valleys (type 1) and trough valleys (type 2); modified after Saadi, M. et al., 1985, Carte Géologique du Maroc 1:1'000'000, Editions du Service Géologique du Maroc, see also annex III.*

Abbreviations for rock types forming predominantly V-shaped valleys (violet, green, brown:

o: Ordovician sedimentary rocks (predominantly shales)

d: Devonian sedimentary rocks (predominantly shales)

hv: Cambrian sedimentary rocks (predominantly shales)

t, tβ: Tertiary sedimentary rocks (predominantly red argillaceous rocks), partially with melaphyr dykes

Abbreviations for rock types forming predominantly trough valleys (blue):

ji: Liassic (Jurassic) sedimentary rocks (grey limestones, marls, argillaceous rocks)

jm: Middle Jurassic sedimentary rocks (grey limestones, marls, argillaceous rocks)

jmC: Upper Jurassic) sedimentary rocks (red marls, argillaceous rocks)

3.2 Oued Oum Er-Rbia catchment

The Oued Oum Er-Rbia catchment on the northern slope of the High Atlas Mountains comprises valleys of different types. A combination of V-shaped valleys and trough valleys occurs in area O1 (this chapter). Area O2 is dominated by a carbonate plateau with scattered farmsteads and dry farming, whereas in area O3 predominantly trough valleys occur. Area O4 valleys display characteristics of both V-shaped and trough valleys in the same place, and pure V-shaped valleys occur in the areas O5, O6 and O8b. Non river-dependent individual villages occur in the areas O7 and O8a. Areas O2 to O4 and O7 / O8a will be discussed in the chapters 5.4, 6.2, and 9.1.

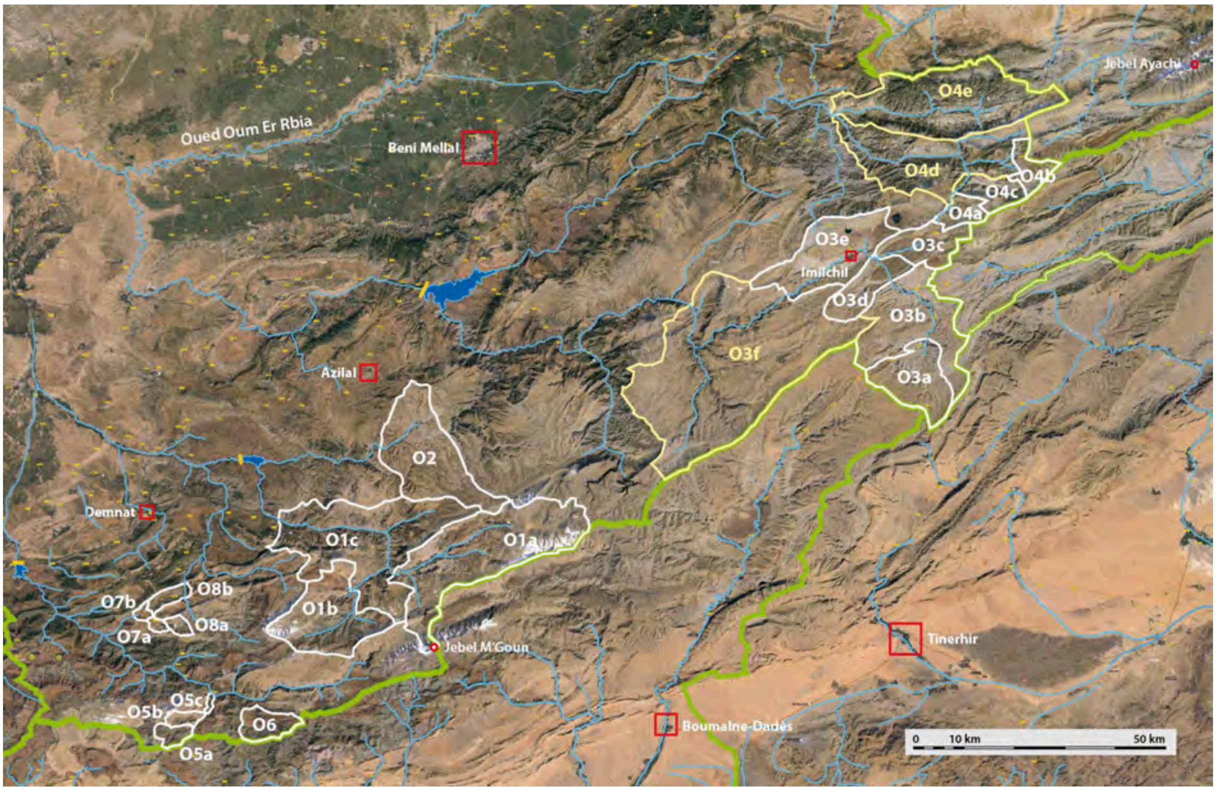


Fig. 157: *Satellite image of potential study areas in the Oued Oum Er-Rbia catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

3.2.1 Area O1 a-c
Aït Bougouemez and Bou Oulli Valleys

Area O1 is located on the border between those parts of the High Atlas Mountains that are built of various, mostly Precambrian to Paleozoic rocks to the west and Jurassic carbonaceous sediments to the east. It is therefore not surprising that the western part of the area is dominated by V-shaped valleys, whereas trough valleys occur in the eastern part.

Tab. 12: Key attributes of area O1 a-c.

Morphological type of the higher / inner mountain areas:	Area O1a: High mountain trough valley with flat gradient. Areas O1b, c: High mountain V-shaped valleys with different opening angles and alternating flat and steeper gradients, partly gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant natural vegetation:	Area O1a: Limestones and marls Areas O1b, c: Slates, shales, limestones, marls, argillaceous rocks
Geological / tectonic units / geological periods:	See fig. 156, page 108.
Stream / river:	Permanent
Natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks, pines.
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Difficult to estimate, presumably partially strong, small successful local reforestations with pines.
Form of settlement:	Primarily compact villages; additional scattered farmsteads in the northern part of area O1c.
Density of settlement:	Middle - high
Predominant form of agriculture:	Primarily irrigated farming on terraces at the flanks of V-shaped valleys and along rivers / streams in trough valleys; additional dry farming in the northern part of area O1c.
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Higher altitudes: Cultivation of grain, vegetables, cattle fodder crops and apples. Lower altitudes: Additional olives, almonds and walnuts.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, tourist infrastructure already well developed.
Remarks:	Tourist infrastructure in area O1a for Jebel Mgoun trekking.
Degree of documentation:	Not all areas documented.

Fig. 158: *View to the south over the farthest Aït Bougouemez trough valley. The forests consist of conifers (cypresses) and strongly over-exploiteted evergreen oaks. Area O1a, autumn 2015.*

Fig. 159: *Villages Iglaouane, Ighririne, and Zawyat Oulmzi with irrigated fields and apple plantations on alluvial deposits in the farthest Aït Bougouemez trough valley. Poplar trees are used for construction purposes. Area O1a, autumn 2015.*

Fig. 160: *Irrigated fields on alluvial deposits between Ikhf N'Ighir and Aït Ouanougdal in the Aït Bougouemez trough valley. Area O1a, autumn 2015.*

Fig. 161: *Extensiverly used grassland on alluvial deposits in the Aït Bougouemez trough valley. View up the valley, area O1a, autumn 2015.*

Fig. 162: *Village with irrigated fields on alluvial deposits between Ikhf N'Ighir and Aït Ouanougdal in the Aït Bougouemez trough valley. Area O1a, autumn 2015.*

Fig. 163: *Village with irrigated fields on alluvial deposits between Ikhf N'Ighir and Aït Ouanougdal in the Aït Bougouemez trough valley. Reforestation with pine trees in the background. Area O1a, autumn 2015.*

Fig. 164: *Village with slightly terraced irrigated fields and apple plantation between Aït Ouanougdal und Aghbalou. Aït Bougouemez trough valley, area O1a, autumn 2015.*

Fig. 165: *Village Aït Ouanougdal in the Aït Bougouemez trough valley, area O1a, autumn 2015.*

Fig. 166: *Village near Aghbalou with an apple plantation in the Aït Bougouemez trough valley. Area O1a, autumn 2015.*

Fig. 167: *Gorges on the southern flank of the Aït Bougouemez trough valley between Aït Ouanougdal and Aghbalou. Area O1a, autumn 2015.*

Fig. 168: *Remnants of a severely degraded forest on the southern flank of the Aït Bougouemez trough valley between Aït Ouanougdal and Aghbalou. Area O1a, autumn 2015.*

Fig. 169: *Village between Ikhf N'Ighir und Aït Ouanougdal in the Aït Bougouemez trough valley. Area O1a, autumn 2015.*

Fig. 170: Hand plough as it is common in the whole High Atlas Mountains. Aït Bougouemez valley, area O1a, autumn 2015.

Fig. 171: Villages and irrigated, terraced fields in the V-shaped Bou Oulli Valley. The red earth results from weathering of weak, red, Triassic argillaceous rocks. View down the valley, area O1b, autumn 2015.

Fig. 172: Village north of Aït Bou Oulli with Walnut trees. V-shaped Bou Oulli Valley, area O1b, autumn 2015.

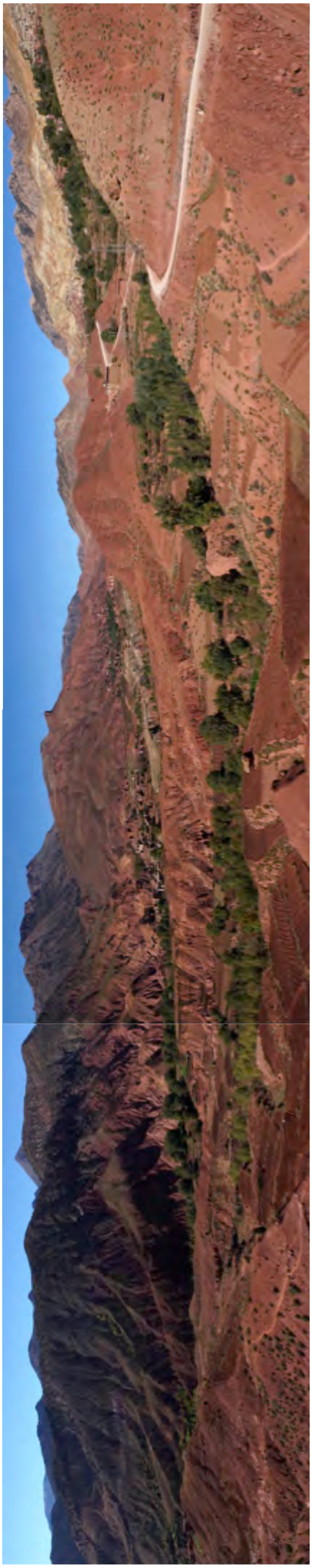


Fig. 173: Villages and irrigated, terraced fields in the V-shaped Bou Oulli Valley. The red earth results from weathering of weak, red, Triassic argillaceous rocks. View down the valley, area O1b, autumn 2015.

Fig. 174: *Sources escaping from Triassic melaphyrs, forming small cascades (arrows). Area O1c, autumn 2015.*

Fig. 175: *View from the southern rim of the carbonate plateau over area O1c towards snow-covered Jebel Mgoun, with scattered farmsteads and terraced fields for dry cultivation of grain; autumn 2015.*

Fig. 176: *View from below the southern rim of the carbonate plateau over area O1c towards snow-covered Jebel Mgoun, with dry cultivation of olive and almond trees; autumn 2015.*

Fig. 177: *Fields in the riverbed south of village Aït Abbas. View up the valley towards south, area O1c, autumn 2015.*

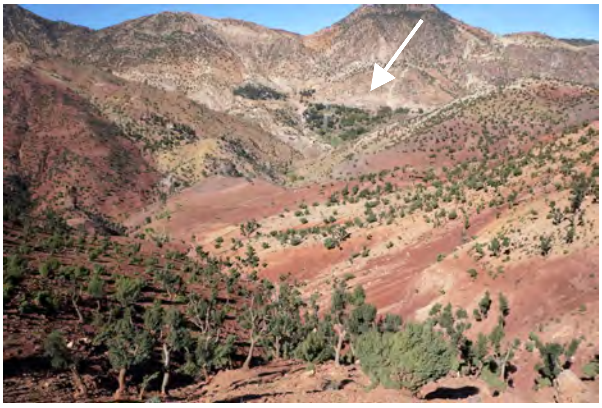


Fig. 178: *Severely degraded forest (evergreen oaks) and a village with irrigated, terraced fields in the background (arrow). Northwest of the "red pass", area O1c, autumn 2015.*

Fig. 179: *Village with terraced fields in the steep valley northwest of the "red pass". Area O1c, autumn 2015.*

4 Potential study areas with of V-shaped valleys (type 1) and canyon-like, stepped foothill valleys (type 4)

4.1 Geographic distribution and geological conditions

All areas that are combinations of V-shaped valleys in the upper high mountain parts and canyon-like, stepped foothill valleys in the lower parts are situated on the southern slope of the central High Atlas Mountains, facing towards the upper Drâa Valley that forms a vast high plain between the High Atlas Mountains to the north and Jebel Saghro to the south. As a consequence, they are all part oft the upper Oued Drâa catchment above the El Mansour Eddahbi dam east of Ouarzazate, where the river provides irrigation for numerous oasis and drinking water for the city of Ouarzazate.

After passing the dam and the almost uninhabited gorge below, Oued Drâa enables the existence of a continuous river oasis with millions of date palms between Agdz and Zagora. South of Zagora, under normal hydrological conditions, the remaining water infiltrates into the alluvial plains and the riverbed dries out. Nowadays, the rate of flow of the Oued Drâa can be allocated over the year to the needs of the oases due to the El Mansour Eddahbi dam.

Tree combined areas (D2a-d, D3a-e and D5a-h) and one single area (D6) are introduced below. The single area D4 that is of minor importance is not introduced specifically.

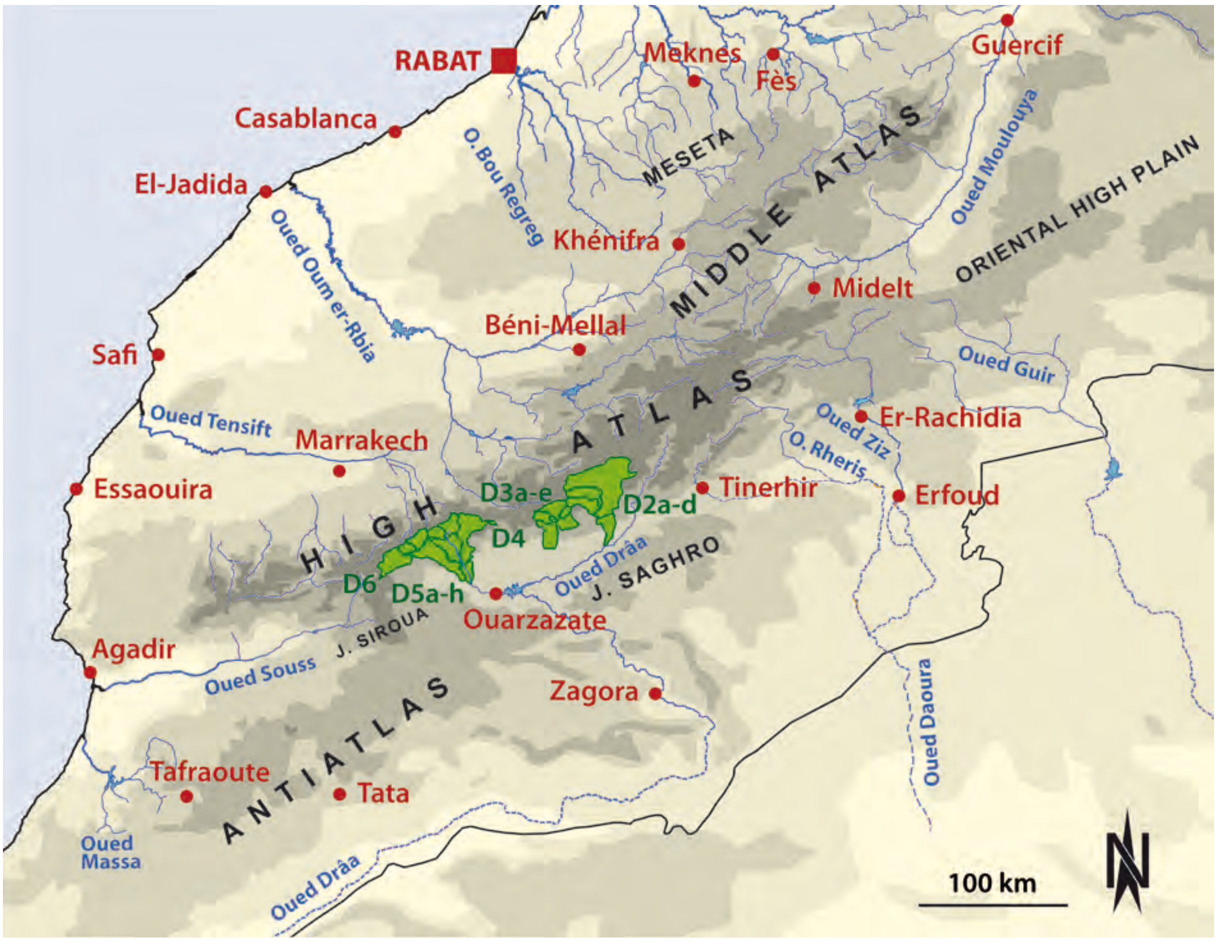


Fig. 180: *Simplified map of the Atlas Mountains showing potential study areas that are combinations of V-shaped valleys (type 1) and open, stepped foothill valleys (type 4).*

The morphology with V-shaped valleys in the inner / higher mountains and rather small, open canyons with stepped slopes forming the outer valleys that cross the foothills and reach into the alluvial plains represents the geological conditions. V-shaped valleys mostly develop in areas with abundant and evenly distributed precipitation combined with weakly structured rocks and rocks with weak stratification, represented here by magmatic rocks as well as sedimentary rocks of Ordovician, Triassic and Jurassic age. Canyon-like valleys with stepped slopes on the other hand develop in areas with rather low precipitation but a temporarily high flow rate, as it is given on the foot of a high mountain range with a humid microclimate in a generally semi-arid or arid greater region. Weak, but strongly stratified sedimentary rocks accentuate their development additionally.

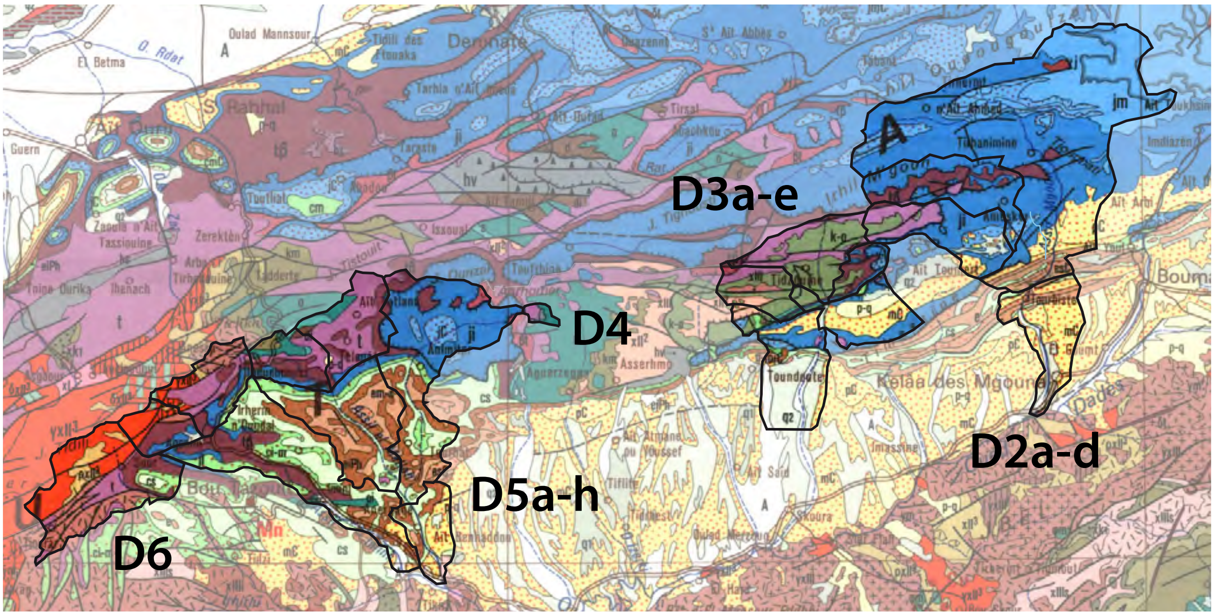


Fig. 181: *Geological map of the southern slope of the central High Atlas Mountains showing potential study areas that are combinations of V-shaped valleys (type 1) and canyon-like, stepped foothill valleys (type 4); modified after Saadi, M. et al., 1985, Carte Géologique du Maroc 1:1'000'000, Editions du Service Géologique du Maroc, see also annex III.*

Abbreviations for rock types forming V-shaped valleys:

$yxII^3$: Precambrian intrusive rocks (granites and granitoids)

ρxII^3, yxIII: Precambrian volcanic rocks (ignimbrites, rhyolites, andesites)

km: Cambrian sedimentary rocks (predominantly shales)

o: Ordovician sedimentary rocks (predominantly shales)

t, tβ: Triassic sedimentary rocks (predominantly red argillaceous rocks), partially with melaphyr dykes

ji: Liassic (Jurassic) sedimentary rocks (limestones, marls)

Abbreviations for rock types forming canyon-like, stepped foothill valleys:

cs, ci: Cretaceous sedimentary rocks (limestones, marls, argillaceous rocks)

em, ei: Eocene (Tertiary) sedimentary rocks (limestones, marls, argillaceous rocks)

mC: Miocene (Tertiary) sedimentary rocks (argillaceous rocks, weakly consolidated sandstones and conglomerates)

pC: Pliocene (Tertiary) sedimentary rocks (argillaceous rocks, weakly consolidated sandstones and conglomerates)

4.2 Oued Drâa catchment

The northern part of the Oued Drâa catchment on the steep southern slope of the High Atlas Mountains comprises V-shaped valleys in the western and trough valleys in the eastern part of the higher mountain regions. The foothills in contrast, are all dominated by similar canyon-like, stepped valleys. The combination of V-shaped valleys and canyon-like, stepped foothill valleys in the areas D2, D3 and D6 is introduced in this chapter. The combination of trough valleys and canyon-like, stepped foothill valleys as found in area D1 will be introduced in chapter 7.2.

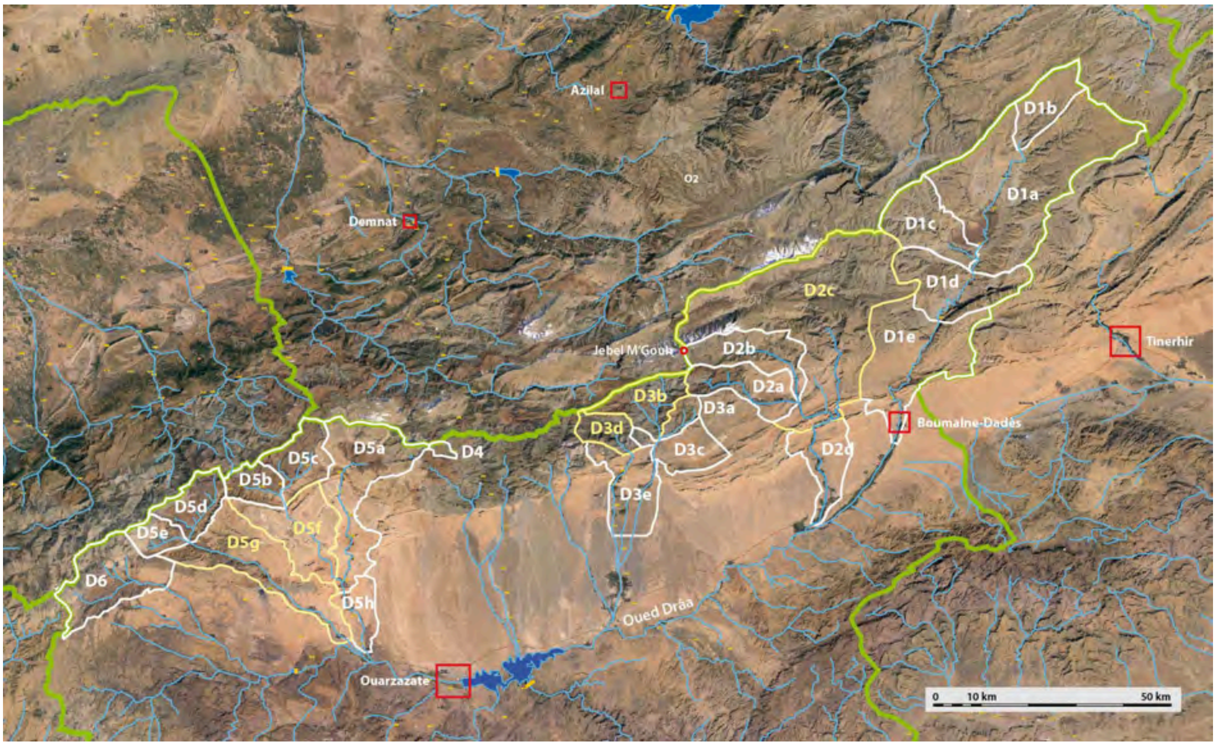


Fig. 182: *Satellite image of potential study areas on the southern slope of the High Atlas Mts. in the upper Oued Drâa catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

4.2.1 Area D2 a-d
Jebel Mgoun south flank / Asif Mgoun

The south flank of Jebel Mgoun is the least accessible region on the southern flank of the High Atlas Mountains. As the rivers often flow through nearly inaccessible gorges, the mud roads were built high up in the mountains, which makes them long and dangerous, especially in wintertime. The higher parts of the area have therefore not been investigated, their isolated nature, however, may be of interest for the intended project as the influence of modern civilisation is supposed to be very limited.

Tab. 13: Key attributes of area D2 a-d.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valleys with different opening angles and alternating flat and steeper gradients, partly gorges. Area D2a is a very open trough valley parallel to the mountain range, that is more like a high plain.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Open, canyon-like, stepped foothill valley with ravines.
Predominant rock types:	High Atlas Mts.: Predominantly carbonate rocks (limestones, marls, argillaceous rocks). Foothills: Carbonate rocks, sparsely consolidated gravel, sands, clay.
Geological / tectonic units / geological periods:	See fig. 181, page 116.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Low - middle
Degradation of natural vegetation:	Difficult to estimate, presumably partially strong.
Form of settlement:	Compact villages
Density of settlement:	Low – high
Predominant form of agriculture:	High mountains: Irrigated farming on terraces at the flanks of V-shaped valleys and on small alluvial fans. Lower mountains and foothills: Irrigated farming on alluvial land along streambeds.
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Higher altitudes: Cultivation of grain, vegetables and cattle fodder crops. Lower altitudes: Additional olives, almonds and walnuts.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on long and exposed mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	Tourist infrastructure in Bou Thrarar and El Kelâa des Mgouna only.
Degree of documentation:	Lower mountains and foothills: Good High Mountains: Not documented.

Fig. 183: *Village Aït Zekri with irrigated fields. High plain of Alemdoun - Aït Khlifa - Aït Troumert - Aït Zekri, area D2a, autumn 2015.*

Fig. 184: *Village Aït Troumert with irrigated fields and fruit plantations on both sides of the stream, irrigation channel on the right hand side (arrow). High plain of Alemdoun - Aït Khlifa - Aït Troumert - Aït Zekri, area D2a, autumn 2015.*

Fig. 185: *Village Aït Khlifa, irrigation channel crosses the stream on a bridge (arrow). High plain of Alemdoun - Aït Khlifa - Aït Troumert - Aït Zekri, area D2a, autumn 2015.*

Fig. 186: *Tighremt near Aït Khlifa. High plain of Alemdoun - Aït Khlifa - Aït Troumert - Aït Zekri, area D2a, autumn 2015.*

Fig. 187: *School of Irhil N'Oumgoun. High plain of Alemdoun - Aït Khlifa - Aït Troumert - Aït Zekri, area D2a, autumn 2015.*

Fig. 188: *Village Alemdoun with fields on both sides of the river. High plain of Alemdoun - Aït Khlifa - Aït Troumert - Aït Zekri, area D2a, autumn 2015.*

Fig. 189: *Natural vegetation on the high plain of Alemdoun - Aït Khlifa - Aït Troumert - Aït Zekri. Area D2a, autumn 2015.*

Fig. 190: *Village Bou Thaghar (Bou Thrarar) and Asif Mgoun with fields and walnut trees on the island between the two branches. Area D2c, autumn 2015.*

Fig. 191: *Villages Aït Said and Touzrighte on the lower course of Asif Mgoun in a typical canyon-like foothill valley in weak cretaceous and tertiary carbonaceous sediments. Area D2c, autumn 2015.*

Fig. 192: *Village Tourbiste on the lower course of river Mgoun in a typical canyon-like foothill valley in weak cretaceous and tertiary carbonaceous sediments. Area D2c, autumn 2015.*

Fig. 193: *Decaying Khsar north of El Kelâa des Mgouna, situated on a hill above Asif Mgoun. Foothills of the High Atlas Mts. in the background, view towards west. Area D2c, autumn 2015.*

Fig. 194: *Village Aït Troumert with irrigated fields and fruit plantations on both sides of the stream. High plain of Alemdoun - Aït Khlifa - Aït Troumert - Aït Zekri, area D2a, autumn 2015.*

Fig. 195: *Village Aït Khlifa, high plain of Alemdoun - Aït Khlifa - Aït Troumert - Aït Zekri. Area D2a, autumn 2015.*

Fig. 196: *Village Alemdoun with fields on both sides of the river. High plain of Alemdoun - Aït Khlifa - Aït Troumert - Aït Zekri, area D2a, autumn 2015.*

Fig. 197: *Villages Tourbiste, Aït Said and Touzrighte on the lower course of Asif Mgoun in a typical canyon-like foothill valley in weak cretaceous and tertiary carbonaceous sediments. Area D2c, autumn 2015.*

Fig. 198: *Oasis of El Kelâa des Mgouna, with Asif Mgoun. View towards south with the Antiatlas Mountains in the background. Area D2c, autumn 2015.*

4.2.2 Area D3 a-e Valleys north of Toundoute

Similar to the south flank of Jebel Mgoun, the higher valleys of Area D3 have not been investigated. Their accessibility, however, is better than in area D2 and they may be of interest for the intended project due to their secluded location with a limited influence of modern civilisation.

Tab. 14: Key attributes of area D3 a-e.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valleys with different opening angles and alternating flat and steeper gradients, partly gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Open, canyon-like, stepped foothill valleys with ravines. Alluvial fans / plains with very flat gradient and final infiltration of the rivers under normal hydrological conditions.
Predominant rock types:	High Atlas Mts.: Predominantly slates, shales, argillaceous rocks. Foothills: Carbonate rocks, sparsely consolidated gravel, sands, clay.
Geological / tectonic units / geological periods:	See fig. 181, page 116.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Partially strong
Form of settlement:	Compact villages
Density of settlement:	Middle – high
Predominant form of agriculture:	High mountains: Irrigated farming on terraces at the flanks of V-shaped valleys and on small alluvial fans. Lower mountains and foothills: Irrigated farming on alluvial land along and in streambeds.
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Higher altitudes: Cultivation of grain, vegetables and cattle fodder crops. Lower altitudes: Additional olives and almonds.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	No tourist infrastructure existent.
Degree of documentation:	Lower mountains and foothills: Good High Mountains: Not documented.

Fig. 199: *Villages near Asaka Kantoula, view up the valley. The red rocks are Triassic argillaceous rocks. Area D3a, autumn 2015.*

Fig. 200: *Villages near Asaka Kantoula, view down the valley. The red rocks are Triassic argillaceous rocks. Area D3a, autumn 2015.*

Fig. 201: *Terraced fields with almond and olive trees near Asaka Kantoula, view up the valley. The red rocks are Triassic argillaceous rocks. Area D3a, autumn 2015.*

Fig. 202: *Terraced fields with almond and olive trees near Asaka Kantoula, view up the valley. The red rocks are Triassic argillaceous rocks. Area D3a, autumn 2015.*

Fig. 203: *Village Asaka Kantoula, area D3a, autumn 2015.*

Fig. 204: *Villages near Ifrane N'Aït Zaghar with a broad river bed. Area D3c, autumn 2015.*

Fig. 205: *Villages near Ifrane N'Aït Zaghar with a broad river bed, view up the valley, area D3c, autumn 2015.*

Fig. 206: *Fields on alluvial soil in the midst of the broad river bed. Area D3c, autumn 2015.*

Fig. 207: *Ravine (klus) in the proximal marginal mountain ridge. View down the valley (towards south), area D3c, autumn 2015.*

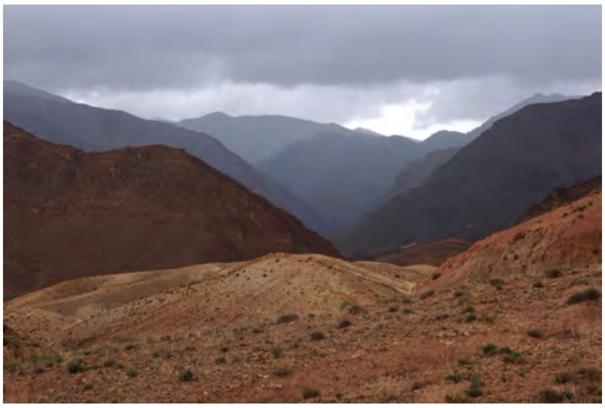


Fig. 208: *View into the narrow V-shaped valley of area D3d, heavy rainfall, autumn 2015.*

Fig. 209: *View from the alluvial plain northwards to the High Atlas Mountains. Area D3e, autumn 2015.*

4.2.3 Area D5 a-h
Asifs Ounila, Mellah and Tamstin / N'Tamnat

In contrast to the other areas on the southern flank of the High Atlas Mountains in the Drâa catchment, the foothills that consist of Mesozoic and Cenozoic rocks play the most important role in area D5 as they cover more than half of it. Particularly the Asif Ounila valley is densely populated despite its location at the edge of the arid high plain of Ouarzazate. This is possible because the river that originates from high areas with wintery rain and snowfall is usually perennial.

Tab. 15: Key attributes of area D5 a-h.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valleys with different opening angles and alternating flat and steeper gradients.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Open, canyon-like, stepped foothill valleys.
Predominant rock types:	High Atlas Mts.: Granites, limestones, marls, slates, shales, argillaceous rocks. Foothills: Limestone, marls, argillaceous rocks.
Geological / tectonic units / geological periods:	See fig. 181, page 116.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Very low – middle
Degradation of natural vegetation:	In the high mountains partially strong, in the foothills difficult to estimate. Several moderately successful reforestations with non-indigenous junipers and pines.
Form of settlement:	Compact villages
Density of settlement:	Middle - high
Predominant form of agriculture:	High mountains: Irrigated farming on terraces at the flanks of V-shaped valleys and on small alluvial fans. Lower mountains and foothills: Irrigated farming on alluvial land along the streambeds.
Irrigation:	Irrigation channels draining primarily the main river.
Crops:	Higher altitudes: Cultivation of grain, vegetables and cattle fodder crops. Lower altitudes: Additional olives, almonds and walnuts (and few dates in area D5h).
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure in the upper valleys is possible.
Remarks:	In the upper valleys a modest tourist infrastructure exists in several villages. In area D5h Aït Ben Haddou is a tourist resort with luxury hotels / swimming pools near the eponymous world heritage.
Degree of documentation:	Lower mountains and foothills: Good, but not all areas documented. High Mountains: Not all areas documented.

Fig. 210: *Severely degraded natural vegetation consisting of dwarf thorn shrubs and conifers (cypress, juniper). V-shaped valleys south of Tizi N'Tichka, area D5b, spring 2015.*

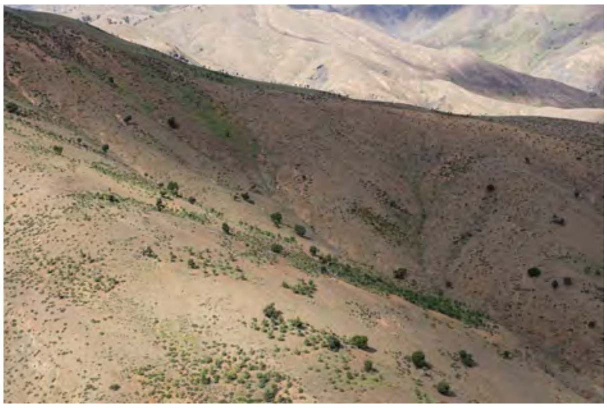


Fig. 211: *Remnants of a conifer forest with moderately successful attempts of reforestation; south of Tizi N'Tichka. Area D5b, autumn 2015.*

Fig. 212: *View from the Tizi N'Tichka road towards southwest over the V-shaped valleys of area D5b with reforestation. Area D5b, spring 2015.*

Fig. 213: *Natural vegetation consisting of conifers (cypress, juniper) and dwarf shrubs. V-shaped valley of area D5b, spring 2015.*

Fig. 214: *Village Argue, view up the V-shaped valley. Area D5b, spring 2015.*

Fig. 215: *Village Argue (left) and single farm, view down the V-shaped valley. Area D5b, spring 2015*

Fig. 216: *Village near Argue, V-shaped valley of area D5b, autumn 2015.*

Fig. 217: *Terraced cereal fields near Argue, view down the valley. Area D5b, spring 2015.*

Fig. 218: *Village Tamesna with irrigated terraced fields along Asif N'Tamnat, view up the V-shaped valley. Area D5d, autumn 2015.*

Fig. 219: *V-shaped Asif N'Tamnat Valley with irrigated terraced fields seen from the Tizi N'Tichka road. The red rocks are Triassic argillaceous rocks. View down the valley towards southwest, area D5d, autumn 2015.*

Fig. 220: *Village Tichkiouine in the Asif Tamstin Valley. View down the V-shaped valley towards east, area D5e, autumn 2015.*

Fig. 221: *Village Ramasinte Tamsinte in the V-shaped Asif Tamstin Valley. The red rocks are triassic argillaceous rocks. Area D5e, autumn 2015.*

Fig. 222: *Open cistern for the purpose of irrigation near village Tichkiouine. Area D5e, autumn 2015.*

Fig. 223: *Villages Iloughmane (left) and Igouadayne (right) in a V-shaped valley. Area D5e, autumn 2015.*

Fig. 224: *Asif Melloul west of Telouet. Broad V-shaped valley that is more like a high plain. View toward east, area D5c, spring 2015.*

Fig. 225: *Cereal fields west of Kasbah Telouet. Broad V-shaped valley that is more like a high plain. Area D5c, spring 2015.*

Fig. 226: *Rural hamlet (douar) as a part of village Telouet. Area D5c, spring 2015.*

Fig. 227: *Rural hamlet (douar) as a part of village Telouet. Area D5c, autumn 2015.*

Fig. 228: *View from Telouet towards south over area D5a, the numerous villages of which are hidden in the Asif Ounila canyon, that cuts through the foothills. Area D5c, autumn 2015.*

Fig. 229: *Saline water flowing out of saltworks, leaving a thick salt crust in a lateral valley of the Asif Ounila canyon. Area D5c, autumn 2015.*

Fig. 230: *Village Anguelez with irrigated fields, walnut and olive trees in the upper Asif Ounila Canyon. Area D5a, autumn 2015.*

Fig. 231: *Village Anemiter in the upper Asif Ounila Canyon. Area D5a, autumn 2015.*

Fig. 232: *Village Tiourassine with irrigated fields, walnut and olive trees in the Asif Ounila Canyon. Area D5a, spring 2015.*

Fig. 233: *Village Maarouf with irrigated fields in the upper Asif Ounila Canyon. Area D5a, autumn 2015.*

Fig. 234: *Village Maarouf with irrigated fields in a bend of Asif Ounila. Asif Ounila Canyon, area D5a, spring 2015.*

Fig. 235: *Village Taguendouchte with irrigated fields, walnut and olive trees in the upper Asif Ounila Canyon. View up the valley, area D5a, autumn 2015.*

Fig. 236: *Villages near Taguendouchte with irrigated fields, walnut and olive trees in the upper Asif Ounila Canyon. View up the valley, area D5a, autumn 2015.*

Fig. 237: *Village Tajeguite in the upper Asif Ounila Canyon. View down the valley, area D5a, spring 2015.*

Fig. 238: *Village Assaka with irrigated fields, walnut and olive trees in the upper Asif Ounila Canyon. Note the irrigated fields on a terrace above the river in the foreground. View up the valley, area D5a, autumn 2015.*

Fig. 239: *Upper Asif Ounila Canyon, view up the valley near Asska. Area D5a, autumn 2015.*

Fig. 240: *Village Tamakouchte in the lower Asif Ounila Canyon. View up the valley, area D5a, autumn 2015.*

Fig. 241: *Village Aït Farse in the lower Asif Ounila Canyon. Area D5a, autumn 2015.*

Fig. 242: *Fields of village Wa-Ou-Nsamt with the neighbouring village at the lower end of the Asif Ounila Canyon. View towards west, area D5a, spring 2015.*

Fig. 243: *Village Wa-Ou-Nsamt with Asif Ounila, area D5a, autumn 2015.*

***Fig. 244**: Irrigation channel with draw well supplying the fields of village Wa-Ou-Nsamt. Area D5a, spring 2015.*

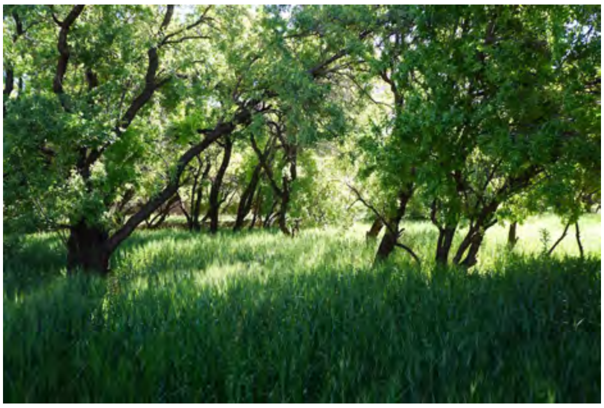


***Fig. 245:** Cereal field with almond trees, village Wa-Ou-Nsamt. Area D5a, spring 2015.*

***Fig. 246:** Khsar Aït Ben Haddou, a rather badly preserved world heritage site and tourist destination with many hotels around it in the lower Asif Ounila Valley. Area D5h, spring 2015.*

***Fig. 247:** Khsar Aït Ben Haddou with Asif Ounila. View to the south, Area D5h, spring 2015.*

***Fig. 248:** Lowest Asif Ounila Valley north of the confluence with Oued Ouarzazate. View to the south, area D5h, spring 2015.*

4.2.4 Area D6 Asif Alighane Valley

The Asif Alighane Valley can be connected to the composed area D5 since Asif Alighane flows into the same river system near Ouarzazate. Asif Alighane, however, is inhabited in its higher areas on the southern slope of the High Atlas Mountains only. It is of special interest for the intended project as it is characterised by a unique morphology with several very open segments within the V-shaped valley that are like high plains.

Tab. 16: Key attributes of area D6.

Morphological type of the higher / inner mountain areas:	Very open high mountain V-shaped valleys / high plains.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	Granites, andesites, shales, argillaceous rocks.
Geological / tectonic units / geological periods:	See fig. 181, page 116.
Stream / river:	Periodic / permanent
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Very low – middle
Degradation of natural vegetation:	Difficult to estimate, may be partially strong.
Form of settlement:	Compact villages
Density of settlement:	Middle
Predominant form of agriculture:	Primarily irrigated farming on terraces at the flanks of V-shaped valleys and on small alluvial fans.
Irrigation:	Irrigation channels draining the main river and streams / sources in lateral valleys.
Crops:	Cultivation of grain, vegetables, cattle fodder crops, olives, almonds and walnuts.
Accessibility / development of road infrastructure:	In general easy to access.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	No tourist infrastructure existent.
Degree of documentation:	In general good.

***Fig. 249:** Villages Ancal and Aguert Nissin, view towards west. Bright ochre areas to the right are granites on the foot of the Jebel Toubkal range that are quite infertile compared to the sedimentary rocks to the left. Area D6, autumn 2015.*

***Fig. 250:** Villages Tagadirte (left) and Noumezoire (right), view towards west. The red rocks above the villages are Triassic argillaceous rocks. The contact towards the bright ochre overlaying granites of the Jebel Toubkal range is a thrust plane. The granites are quite infertile compared to the sedimentary rocks to the left. Area D6, autumn 2015.*

***Fig. 251:** Villages Anfid (left) and Sour (foreground), view towards east. Area D6, autumn 2015.*

***Fig. 252:** Village Tidili with school buildings in the foreground, view towards west. Area D6, autumn 2015.*

***Fig. 253:** Village Imaghouden Adkki with terraced fields, area D6, autumn 2015.*

Fig. 254: *Village Anfid with a broad dry riverbed. View towards the Jebel Toubkal range. Area D6, autumn 2015.*

Fig. 255: *Village Anfid with an irrigation channel in a lateral valley (arrow). View towards the Jebel Toubkal range. Area D6, autumn 2015.*

Fig. 256: *Villages Tizi and Tamaste with terraced fields. Area D6, autumn 2015.*

5 Potential study areas with predominantly trough valleys (type 2)

5.1 Geographic distribution and geological conditions

All potential study areas that predominantly display trough valleys are situated on the northern and southern slope of the eastern High Atlas Mountains, distributed over three catchment areas: Oued Oum Er-Rbia on the northern slope and the Oueds Rheris and Ziz on the southern slope. Whereas the Oued Oum Er-Rbia catchment collects enough water on the humid northern slope of the High Atlas Mountains to reach the Atlantic Ocean, the Oueds Rheris and Ziz rarely flow much further southwards than to the Erfoud or Rissani oases, where the water usually infiltrates in the alluvial plains under normal hydrological conditions. Both rivers provide irrigation and drinking water for numerous oasis and towns. Nowadays, the rate of flow of Oued Ziz can be allocated over the year due to the El Hassan Addakhil dam north of Er Rachidia.

Tree combined areas (O3a-f, R1a-h and Z1a-i) and one single area (R2) are introduced below.

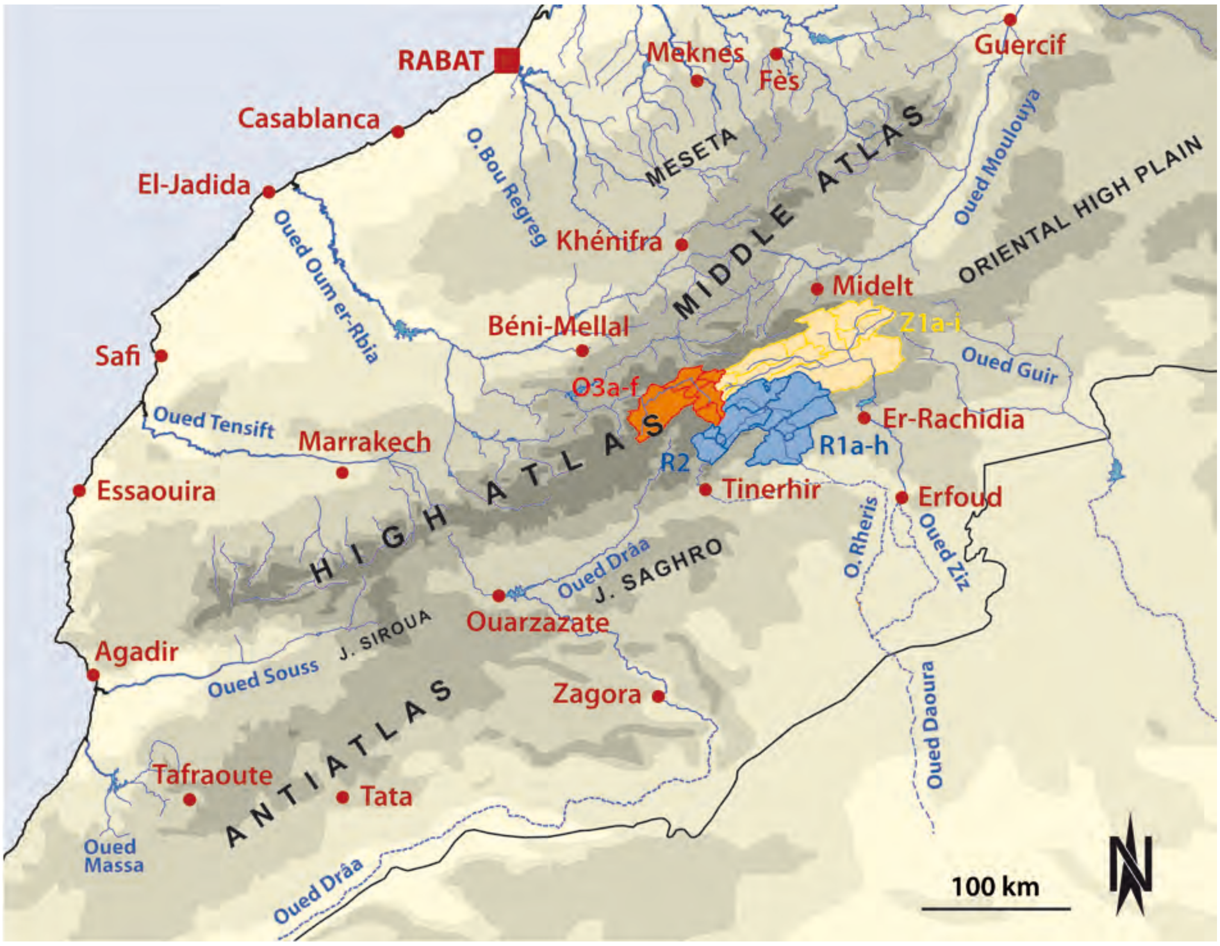


Fig. 257: Simplified map of the Atlas Mountains showing potential study areas with predominantly trough valleys (type 2).

The trough valleys are all situated within the gently folded and faulted Jurassic sedimentary rocks of the eastern High Atlas Mountains, indicating that these specific geological conditions constitute the central prerequisite for the formation of trough valleys in the high Atlas Mountains. In the alpine realm that was dominated by ice age glaciers, trough valleys are interpreted to be the results of glacial erosion. In the eastern High Atlas Mountains, however, glaciers did not play any role as a forming element. Under conditions of a moderate precipitation rate, interbeddings of moderately hard limestones with marls and weak argillaceous rocks displaying open syn- and anticlines with thrust faults are apparently eroded to such open valleys with broad bottoms.

Most of the trough valleys in the eastern High Atlas run parallel to the axis of the mountain range. To reach its southern rim nontheless, rivers cross mountain chains in ravines (kluses). This indicates that fault zones and broken synclines and anticlines respectively may have played a central role as weak zones for water erosion, which is not a surprise considering the flat gradients in the eastern High Atlas. This is in great contrast to the western and central High Atlas where V-shaped valleys run mainly in perpendicular direction to the axis of the mountain range due to higher precipitation rates and steeper gradients (see chapters 2, 3 and 4). This may also suggest that the tectonic uplift of the eastern High Atlas Mountains was slower than the uplift of the western and central High Atlas Mountains.

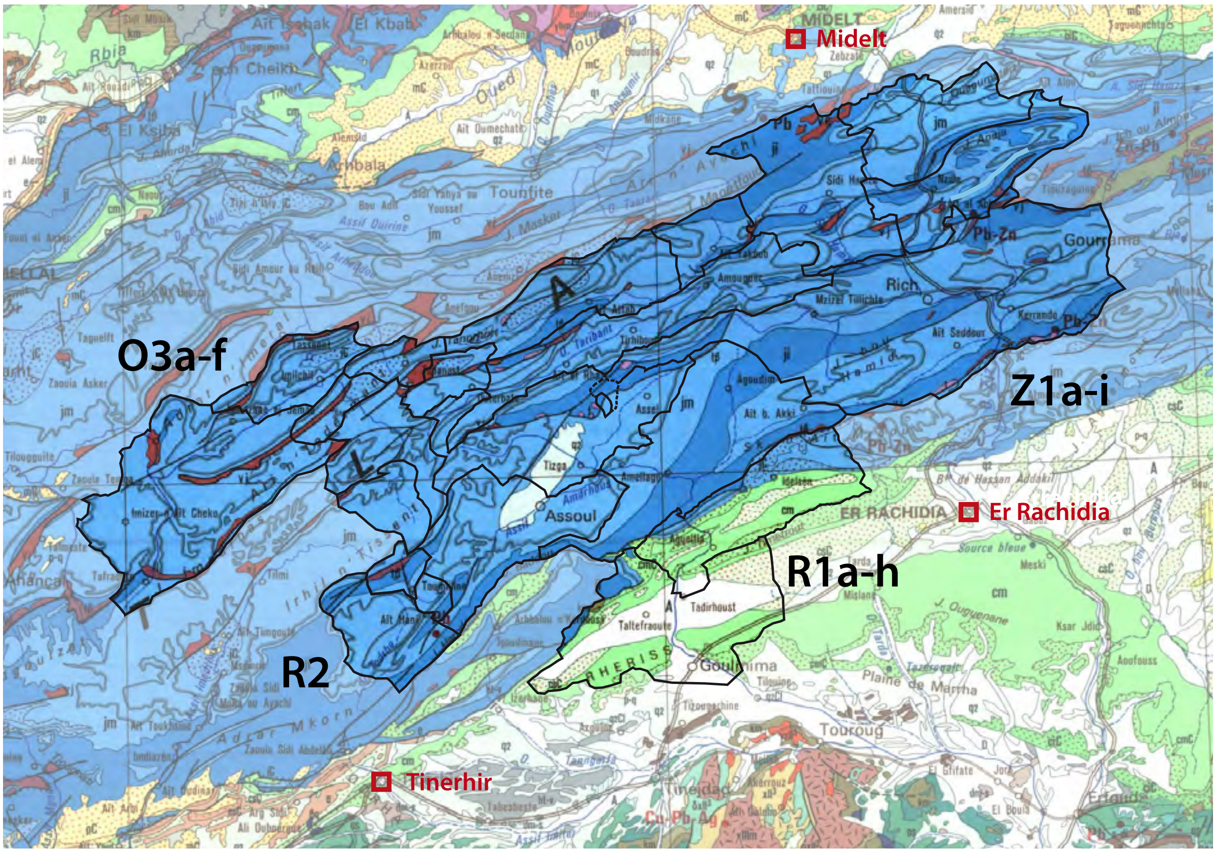


Fig. 258: *Geological map of the eastern High Atlas Mountains showing potential study areas with predominantly trough valleys (type 2); modified after Saadi, M. et al., 1985, Carte Géologique du Maroc 1:1'000'000, Editions du Service Géologique du Maroc, see also annex III.*

The eastern High Atlas Mountains mainly consist of Jurassic sedimentary rocks such as limestones, marls and argillaceous rocks. The southern foothills partly include Cretaceous limestones and marls as well.

Abbreviations for major rock types forming trough valleys (blue):

ji: Liassic (Jurassic) sedimentary rocks (grey limestones, marls, argillaceous rocks)

jm: Middle Jurassic sedimentary rocks (grey limestones, marls, argillaceous rocks)

jc: Upper Jurassic) sedimentary rocks (red marls, argillaceous rocks)

Abbreviations for rock types of minor importance (green, violet):

cm: Middle Cretaceous sedimentary rocks (grey to red limestones, marls, argillaceous rocks)

t, tβ: Tertiary sedimentary rocks (mostly red argillaceous rocks), partially with melaphyr dykes

νj: Episyenites, diorites and gabbros of Mesozoic age

νe: Syenites of Tertiary age

5.2 Oued Rheris catchment

Oued Rheris is one of the three catchments, where predominantly trough valleys occur. After crossing the foothills, the lowermost Rheris Valley passes into the huge alluvial plain south of the High Atlas Mountains. Since both towns in the alluvial plain, Tadighoust and Goulmina, are of a manageable size, these areas may also be of interest for the intended project.

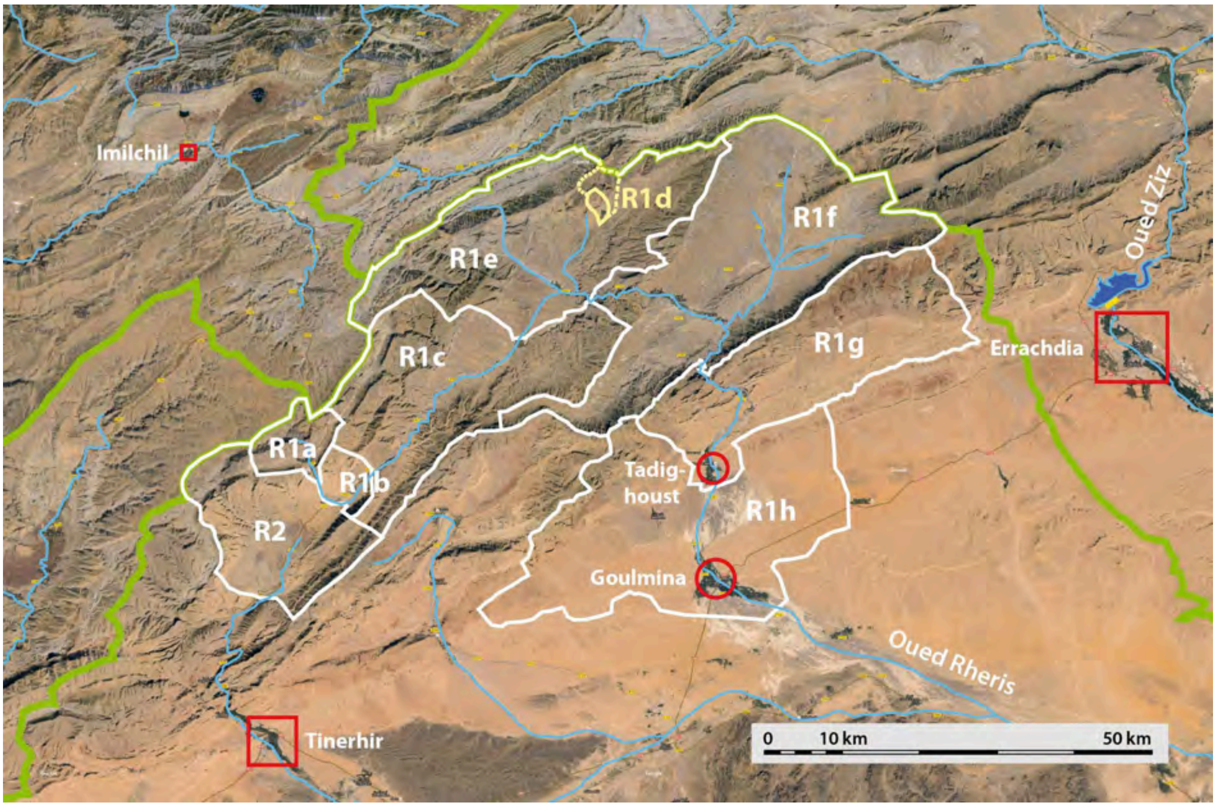


Fig. 259: *Satellite image of potential study areas in the Oued Rheris catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

5.2.1 Area R1 a-h Upper Rheris River above Goulmina

In contrast to the other catchments of the High Atlas Mountains whereof only sections of their uppermost parts are covered by the areas introduced within this report, the upper Oued Rheris catchment is almost completely covered by the areas R1 and R2. Even though the catchments in the eastern High Atlas are large, they do not comprise many valleys since the rivers are only sparsely branched and the valleys cover large areas.

Tab. 17: Key attributes of area R1 a-h.

Morphological type of the higher / inner mountain areas:	High mountain trough valleys with alternately flat and steeper gradient, partly uninhabited or gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Open alluvial plains.
Predominant rock types:	High Atlas Mts.: Predominantly carbonate rocks (limestones, marls) with subordinate igneous rocks (granites, diorites, gabbros). Foothills, alluvial plains: Carbonate rocks, sparsely consolidated gravel, sands, clay.
Geological / tectonic units / geological periods:	See fig. 258 page 138.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials and thorn shrubs. Lower altitudes: Conifers, evergreen oaks, undetermined trees.
Density of natural vegetation:	Very low – low
Degradation of natural vegetation:	Difficult to estimate, presumably strong.
Form of settlement:	Compact villages
Density of settlement:	Low - middle
Predominant form of agriculture:	Primarily irrigated, non terraced or slightly terraced fields on alluvial deposits at the side of streambeds, under normal hydrological conditions 0.5 - 2m higher than the water level, inundated at high water level.
Irrigation:	Irrigation channels draining main rivers / streams.
Crops:	Higher altitudes: Cultivation of grain, vegetables, cattle fodder crops and apples. Lower altitudes: Additional dates (areas R1g, R1h).
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	Tourist infrastructure in Amellagou only.
Degree of documentation:	Not all areas documented.

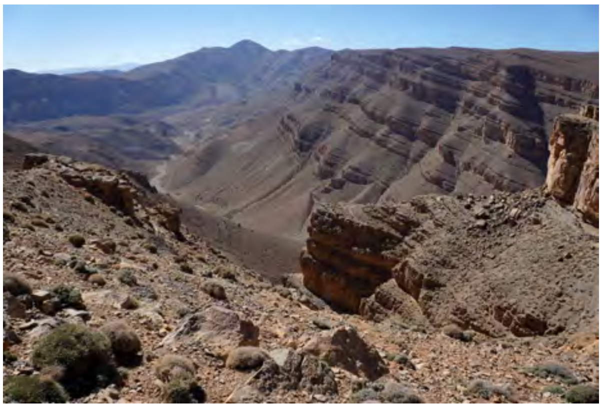


Fig. 260: *Headwater of Oued Rheris, Tizi N'Tirherhouzine, view towards southwest. Area R1a, autumn 2015.*

Fig. 261: *"Bonsai"-vegetation (thorn shrubs), due to overgrazing by goats and sheep. Area R1a, autumn 2015.*

Fig. 262: *Village Aït Daouid in a trough valley with irrigated fields on alluvial land at stream level. Area R1a, autumn 2015.*

Fig. 263: *Villages Toumliline (left) and Aït Daouid (right) in a trough valley with irrigated fields on alluvial land at stream level. Area R1a, autumn 2015.*

Fig. 264: *Village Aït Hani with flooded fields, area R1b, spring 2015.*

Fig. 265: *Cereal fields near Aït Hani. View down the trough valley, area R1b, spring 2015.*

__Fig. 266:__ Segment of the upper Oued Rheris valley without permanent settlement that is nomad's land. Area R1c, spring 2015.

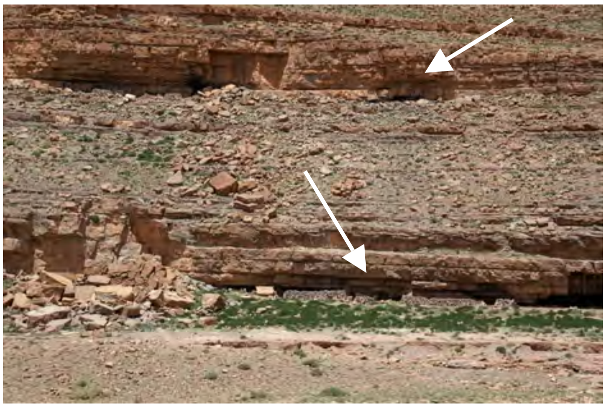


__Fig. 267:__ Nomad caves with protective walls (arrow) in the upper Oued Rheris valley. Area R1c, spring 2015.

__Fig. 268:__ Apple plantation with irrigation channel in the Oued Rheris valley near Assoul. Area R1c, spring 2015.

__Fig. 269:__ Medina of Assoul with irrigated cereal fields on both sides of Oued Rheris and treshing floors at the mountain flank (arrow). Area R1c, spring 2015.

__Fig. 270:__ Village near Taourirt in the upper Rheris Gorge, irrigated cereal fields. Area R1e, spring 2015.

__Fig. 271:__ Irrigated cereal fields with walls against flooding (arrow) near Taourirte in the upper Rheris Gorge. Area R1e, spring 2015.

Fig. 272: *Village Oudeddi with irrigated fields in the upper Rheris Gorge. Area R1e, spring 2015.*

Fig. 273: *Ford in the lower Rheris Gorge. Area R1g, spring 2015*

Fig. 274*: Irrigated cereal fields near Amellagou in a broad trough valley. Area R1f, spring 2015.*

Fig. 275: *Karst source water flowing into Oued Rheris in the lower Rheris Gorge, with local visitors. Area R1g, spring 2015.*

Fig. 276: *Village Tigremt N'Igram with palm gardens and the dry bed of Oued Rheris. Area R1g, spring 2015*

Fig. 277: *Cereal fields in the alluvial plain south of the High Atlas Mts., view towards the foothills. Area R1h, spring 2015.*

Fig. 278: *Soil salinisation in the cereal fields of fig. 277. Area R1h, spring 2015.*

5.2.2 Area R2 Tamtatouchte (upper Todhra Valley)

The upper Todhra Valley is in so far interesting for the intended project as Tamtatouchte, the only village in the area, is developing fast. This is documented by numerous new buildings, most of them Hotels for foreign Tourists with swimming pools. The reason for this may be that the road through the spectacular Todhra Gorge is passable also with larger motor coaches as they are used for non-individual tourism. The valley above Tamtatouchte is more like a high plain and completely uninhabited. The Todra Gorge is uninhabited and the valley below is already part of the northern suburbs of Tinerhir, which makes these areas unsuitable for the intended project.

Tab. 18: Key attributes of area R2.

Morphological type of the higher / inner mountain areas:	High mountain trough valley with flat gradient / high plain.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	Predominantly carbonate rocks (limestones, marls) with subordinate igneous rocks (granites, diorites, gabbros).
Geological / tectonic units / geological periods:	See fig. 258 page 138.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials and thorn shrubs. Lower altitudes: Conifers, evergreen oaks, undetermined trees.
Density of natural vegetation:	Very low – low
Degradation of natural vegetation:	Presumably very strong.
Form of settlement:	Compact village
Density of settlement:	Low
Predominant form of agriculture:	Primarily irrigated, non terraced or slightly terraced fields on alluvial deposits at the side of streambeds, under normal hydrological conditions 0.5 - 2m higher than the water level, inundated at high water level.
Irrigation:	Irrigation channels draining main rivers / streams.
Crops:	Cultivation of grain, vegetables, cattle fodder crops and apples.
Accessibility / development of road infrastructure:	Easy to access.
Future prospects / risks:	The development of the village and in particular of the tourist infrastructure is very (too?) fast.
Remarks:	Several hotels in the village.
Degree of documentation:	In general good.

Fig. 279: *Very broad trough valley forming a high plain northeast of Tamtatouchte with Oued Todhra and the paved road Tamtatouchte – Assoul. View towards southwest, area R2, autumn 2015.*

Fig. 280: *Artemisia herba-alba covering the high plain northeast of Tamtatouchte ('artemisia steppe'). Area R2, aut. 2015.*

Fig. 281: *Mostly abandoned fields along Oued Todhra in the high plain northeast of Tamtatouchte. Area R2, spring 2015.*

Fig. 282: *Village Tamtatouchte. View down the valley, area R2, autumn 2015.*

Fig. 283: *Development of Tamtatouchte with new touristic buildings (arrows). View up the valley, area R2, spring 2015.*

Fig. 284: *Single tree on a mountain crest (arrow) west of Tamtatouchte as an indicator for complete deforestation of the slopes. Area R2, spring 2015.*

5.3 Oued Ziz catchment

Oued Ziz is the easternmost catchment, where predominantly trough valleys occur. After crossing the foothills, the lowermost valley passes into the huge alluvial plain south of the High Atlas Mountains. This area, however, is not appropriate for the intended study as the natural hydrological system is disturbed by the El Hassan Addakhil dam north of Er Rachidia.

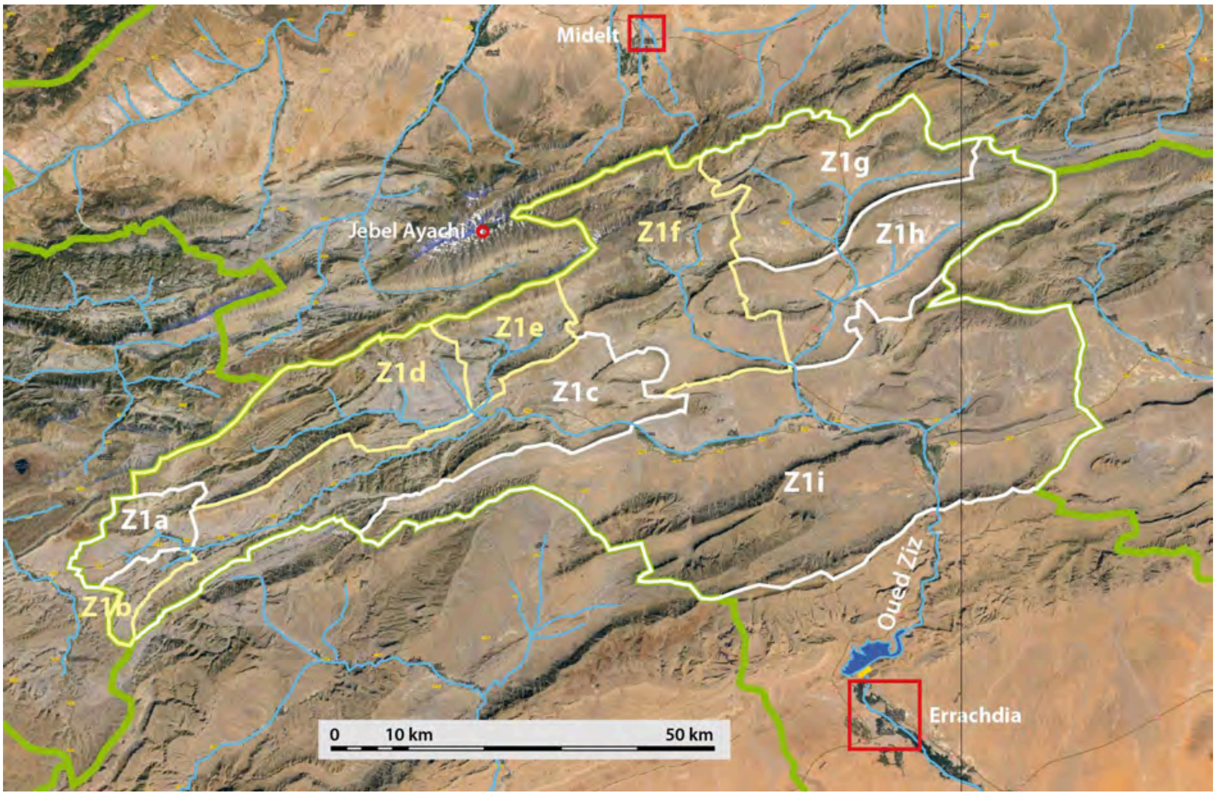


Fig. 285: *Satellite image of potential study areas in the Oued Ziz catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

5.3.1 Area Z1 a-i
Upper Ziz River above Kerrandou ravine

What applies to the Oued Rheris catchment is also valid for the Oued Ziz catchment that is completely covered by the area Z1. Like area R1 it does not comprise many valleys since the rivers are only sparsely branched and the valleys cover large areas.

Tab. 19: Key attributes of area Z1 a-i.

Morphological type of the higher / inner mountain areas:	High mountain trough valleys with alternately flat and steeper gradient, partly uninhabited or gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	High Atlas Mts.: Predominantly carbonate rocks (limestones, marls) with subordinate igneous rocks (granites, diorites, gabbros). Foothills, alluvial plains: Carbonate rocks, sparsely consolidated gravel, sands, clay.
Geological / tectonic units / geological periods:	See fig. 258 page 138.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials and thorn shrubs. Lower altitudes: Conifers, evergreen oaks, undetermined bushes.
Density of natural vegetation:	Very low – low, locally middle
Degradation of natural vegetation:	Presumably strong
Form of settlement:	Compact villages
Density of settlement:	Middle
Predominant form of agriculture:	Primarily irrigated, non terraced or slightly terraced fields on alluvial deposits at the side of streambeds, under normal hydrological conditions 0.5 - 2m higher than the water level, inundated at high water level.
Irrigation:	Irrigation channels draining main rivers / streams.
Crops:	Higher altitudes: Cultivation of grain, vegetables, cattle fodder crops, apples and cherries. Lower altitudes: Additional olives.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	Tourist infrastructure in Er Rich (area Z1i) or Imilchil / Agoudal (area O3b) only.
Degree of documentation:	Not all areas documented.

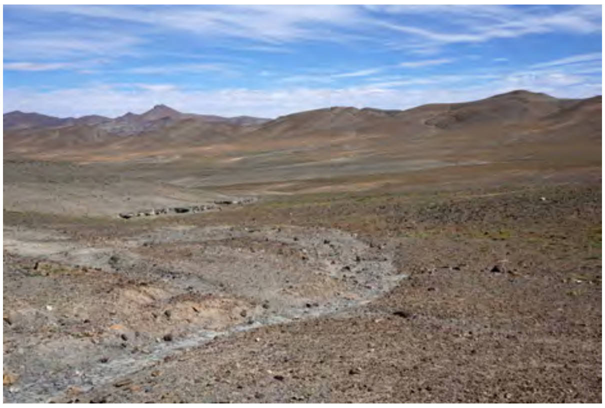


Fig. 286: *Source region of Oued Taribante on the nearly uninhabited high plain west of Outerbate. Area Z1a, spring 2015.*

Fig. 287: *Village Outerbate with irrigated cereal fields and fruit plantations in the Oued Taribante trough valley. Area Z1a, spring 2015.*

Fig. 288: *Irrigated cereal fields and fruit plantations on the bank of Oued Taribante near Outerbate. Poplar wood is used for constructional purposes. Oued Taribante trough valley, area Z1a, spring 2015.*

Fig. 289: *Open citern for the purpose of irrigation at Tamzazerte. Oued Taribante trough valley, area Z1c, spring 2015.*

Fig. 290: *Irrigation channel near village Taribante (arrow) that is derived from Oued Taribante further up. Area Z1c, spring 2015.*

Fig. 291: *Irrigated cereal fields and fruit plantations on the bank of Oued Taribante near village Taribante, representing a typical layout of fields in trough valleys. Area Z1c, spring 2015.*

Fig. 292: *Village Taribante in the Oued Taribante trough valley. Area Z1c, spring 2015.*

Fig. 293: *Village Tabrijate with its pink school building and Oued Taribante. Oued Taribante trough valley, area Z1c, spring 2015.*

Fig. 294: *Gorge of Oued Taribante with small fields and a fruit plantation. Area Z1c, spring 2015.*

Fig. 295: *Gorge of Oued Taribante with a presumably not degraded natural vegetation on the valley flanks. Area Z1c, spring 2015.*

Fig. 296: *Village Igli with Oued Taribante. Oued Taribante trough valley, area Z1c, spring 2015.*

Fig. 297: *Sparse vegetation near village Igli, area Z1c, spring 2015. As almost everywhere in area Z1 the question arises here as to how far the sparseness of the vegetation is of natural or anthropogenic origin.*

Fig. 298: *Lower course of Oued Taribante in a broad trough valley, with the old Kasbah of Tamagourte. View up the valley, area Z1i, spring 2015.*

Fig. 299: *Cherry plantation near Mzizel, view down the broad, lower Taribante trough valley towards Er Rich. Gusty winds arise dust from the dry alluvial soil. Area Z1i, spring 2015.*

Fig. 300: *Olive plantation near Karrandou in the broad middle Ziz trough valley. Area Z1i, spring 2015.*

Fig. 301: *Broad upper Ziz trough valley, the vegetation of which consists of tufts of Halfah Grass (middle ground), referred to as 'halfah grass steppe'. View up the valley towards east, area Z1g, spring 2015.*

5.4 Oued Oum Er-Rbia catchment

Area O3 in the Oued Oum Er-Rbia catchment is one of the three areas, where predominantly trough valleys occur. Asif Melloul, one of the mayor tributaries of Oued Oum Er-Rbia, vanishes in a huge system of gorges after running through area O3. These gorges are almost uninhabited. Below the gorges, the Bin El Ouidane Dam disturbs the natural hydrological system. As a consequence the lower parts of the gorges and the areas influenced by the dam are not appropriate for the intended study.

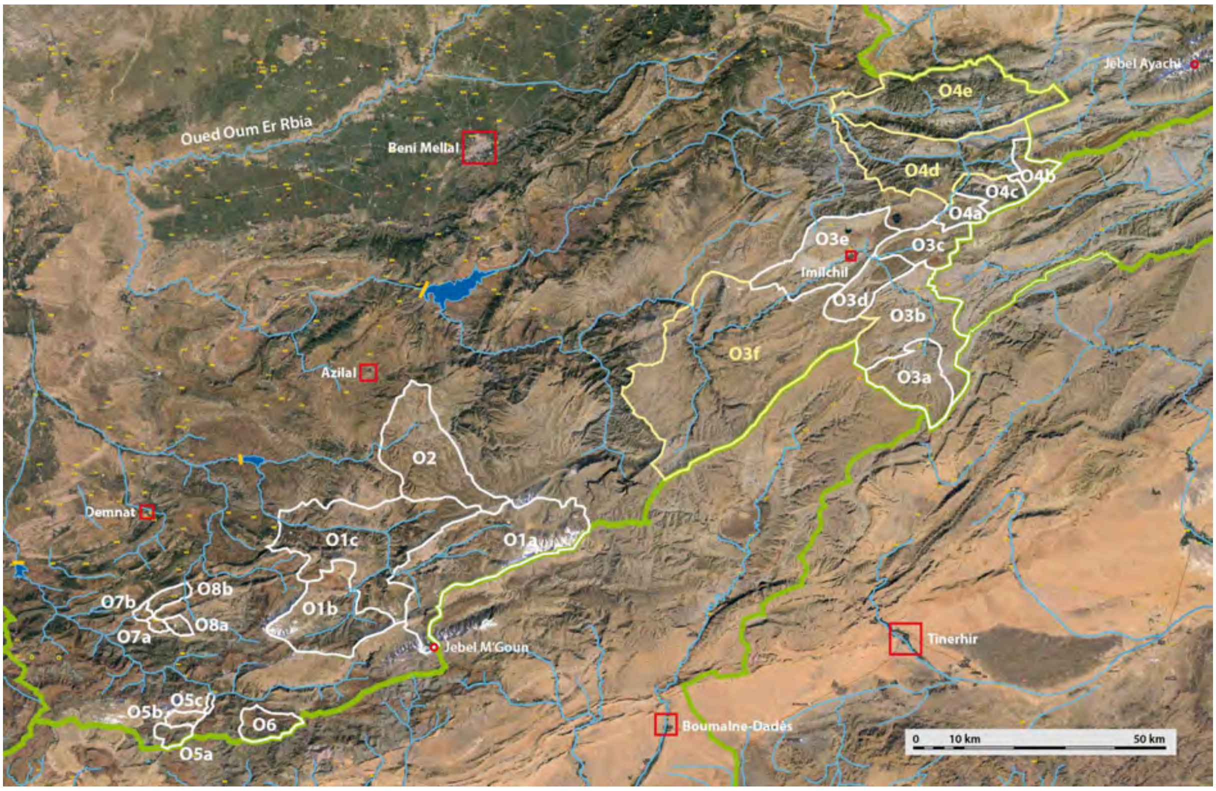


Fig. 302: *Satellite image of potential study areas in the Oued Oum Er-Rbia catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

5.4.1 Area O3 a-f Upper Assif Melloul / Valley of Imilchil - Agoudal

The upper part of Assif Melloul and its uppermost tributaries are densely inhabited and used for agriculture. Its lower part flows through a system of mostly uninhabited gorges. It disposes, however, of an extraordinary large catchment area on a carbonate plateau with some isolated farmsteads that may be of interest for the intended study (area O3f).

Tab. 20: Key attributes of area O3 a-f.

Morphological type of the higher / inner mountain areas:	High mountain trough valleys with alternately flat and steeper gradient, partly gorges. The southwestern part of area O3f consists of V-type valleys.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	Predominantly carbonate rocks (limestones, marls) with subordinate igneous rocks (granites, diorites, gabbros).
Geological / tectonic units / geological periods:	See fig. 258 page 138.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials and thorn shrubs, mostly “bonsayized” by overgrazing. Lower altitudes: Conifers, evergreen oaks, undetermined bushes.
Density of natural vegetation:	Very low – low
Degradation of natural vegetation:	Very strong, as documented by statements of locals.
Form of settlement:	Compact villages
Density of settlement:	Middle - High
Predominant form of agriculture:	Primarily irrigated, non terraced or slightly terraced fields on alluvial deposits at the side of streambeds, under normal hydrological conditions 0.5 - 2m higher than the water level, inundated at high water level.
Irrigation:	Irrigation channels draining main rivers / streams.
Crops:	Cultivation of grain, vegetables, cattle fodder crops and fruit (apples, cherries).
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, further development of tourist infrastructure is possible.
Remarks:	Tourist infrastructure in Imilchil and Agoudal.
Degree of documentation:	Lower mountains and foothills: Good, area O3f not documented. High Mountains: Not all areas documented.

Fig. 303: *Natural vegetation: spherical shrubs that are limited in growth due to overgrazing by goat and sheep. Area O3a, autumn 2015.*

Fig. 304: *Shrubs are pulled out together with their roots in a huge quantity and used for firewood. Area O3a, autumn 2015.*

Fig. 305: *Village Agoudal in spring, with irrigated fields on alluvial land at stream level in a typical trough valley. According to statements made by locals the mountains in the background are called "Green Mountain" as they were forested in former times. A chronology of deforestation, however, does not exist in the local awareness. Area O3a, spring 2015.*

Fig. 306: *Village Agoudal in autumn, with irrigated fields on alluvial land at stream level. Area O3a, autumn 2015.*

Fig. 307: *Ploughing by mules is the most common form in the mountains all over Morocco. Near Agoudal, area O3a, 2015.*

Fig. 308: *Irrigation channel, Assif Melloul and irrigated fields at stream level near Agoudal, area O3b, spring 2015.*

***Fig. 309:** Irrigated fields on alluvial land at stream level in the Asif Melloul trough valley. Area O3b, autumn 2015.*

***Fig. 310:** Irrigated fields on alluvial land at stream level with village Timarirhyne in the background. Asif Melloul trough valley, area O3b, spring 2015.*

***Fig. 311**: Slightly karsted limestone with high water retention capacity. Asif Melloul trough valley, area O3b, spring 2015.*

***Fig. 312:** Village Tissila in the Asif Melloul trough valley. Area O3b, spring 2015.*

***Fig. 313:** Village Akdim with irrigated fields and apple trees on alluvial land at stream level. Asif Melloul trough valley, area O3b, spring 2015.*

Fig. 314: *Damming of Assif Melloul to supply irrigation channels on both sides near village Tissila. Asif Melloul trough valley, areas O3b, and O3d, autumn 2015.*

Fig. 315: *Sheep southwest of Tizi N'Inouzane, near Aït Yekkou. Area O3c, autumn 2015.*

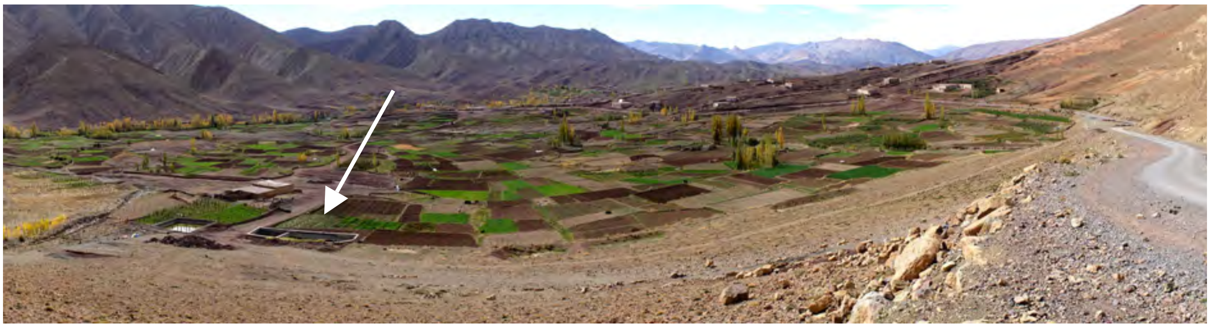


Fig. 316: *Villages Aït Yekkou and Tilmi with irrigated fields and open cistern (arrow) in a trough valley. Area O3c, autumn 2015.*

Fig. 317: *Village Taghighachte with **i**rrigated fields on alluvial land at stream level in a trough valley. Area O3c, autumn 2015.*

Fig. 318: *Village Sountate with irrigated fields and apple trees on alluvial land at stream level in the Asif Melloul trough valley. Area O3d, spring 2015.*

***Fig. 319**: Irrigated fields and poplar trees on alluvial land at stream level. Asif Melloul trough valley, area O3d, autumn 2015. The poplar trees are used for construction purposes (intermediate floors, roofs).*

***Fig. 320:** Village Tighramt Nihoudine in the Asif Melloul trough valley. Area O3d, autumn 2015.*

***Fig. 321:** Main raod in the town of Imilchil. Asif Melloul trough valley, area O3e, autumn 2015.*

***Fig. 322:** Lac de Tislit near Imilchil. Area O3e, spring 2015.*

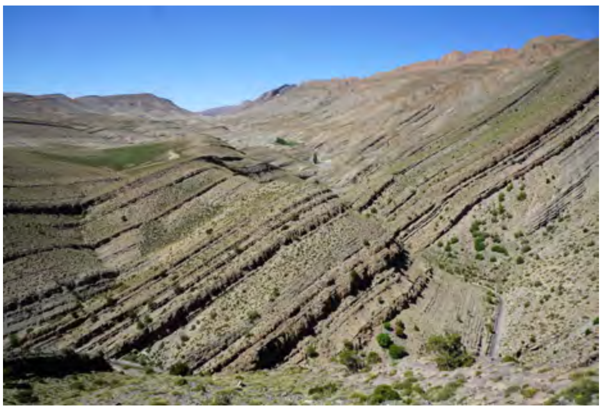


***Fig. 323:** Uninhabited valley northwest of Imilchil with alternating limestones (more resistant to erosion) and marls, which is typical for the Jurassic sediments in this region. Area O3e, spring 2015.*

6 Potential study areas combining characteristics of both trough and V-shaped valleys (types 1 and 2) altogether

6.1 Geographic distribution and geological conditions

All potential study areas combining characteristics of both trough- and V-shaped valleys within the same valley are situated within gently folded and faulted Jurassic sedimentary rocks on the northern slope of the eastern High Atlas Mountains, distributed over the Oued Oum Er-Rbia catchment and the Oued Moulouya catchment. The difference to the pure trough valleys of type 2 lies not so much in the geomorphology than in the distribution of the irrigated fields, that are not restricted to the bottom only, but partially are also set up along the valley flanks. Thus, the geologic preconditions are similar to the pure trough valleys.

In the western Moulouya catchment that is under influence of a humid mountain climate most valleys descending from the High Atlas Mountains continue into the adjacent alluvial Moulouya high plain as broad, rather flat depressions with fertile soils. Some of these soils are intensely used for mechanized agriculture such as cereal farming and fruit plantations. The well defined outlines of these farming areas without confusingly rampant fields makes these depressions interesting for the intended studies, since they represent the only areas with mechanized agriculture selected for this report.

The combined Area O4a-e is restricted to the inner Atlas Mountains only, whereas the combined areas M1a, b, M2a-e and M3a-c also include parts of the Moulouya alluvial plain. Areas M4 and M5 are small single areas of minor importance that are not introduced specifically.

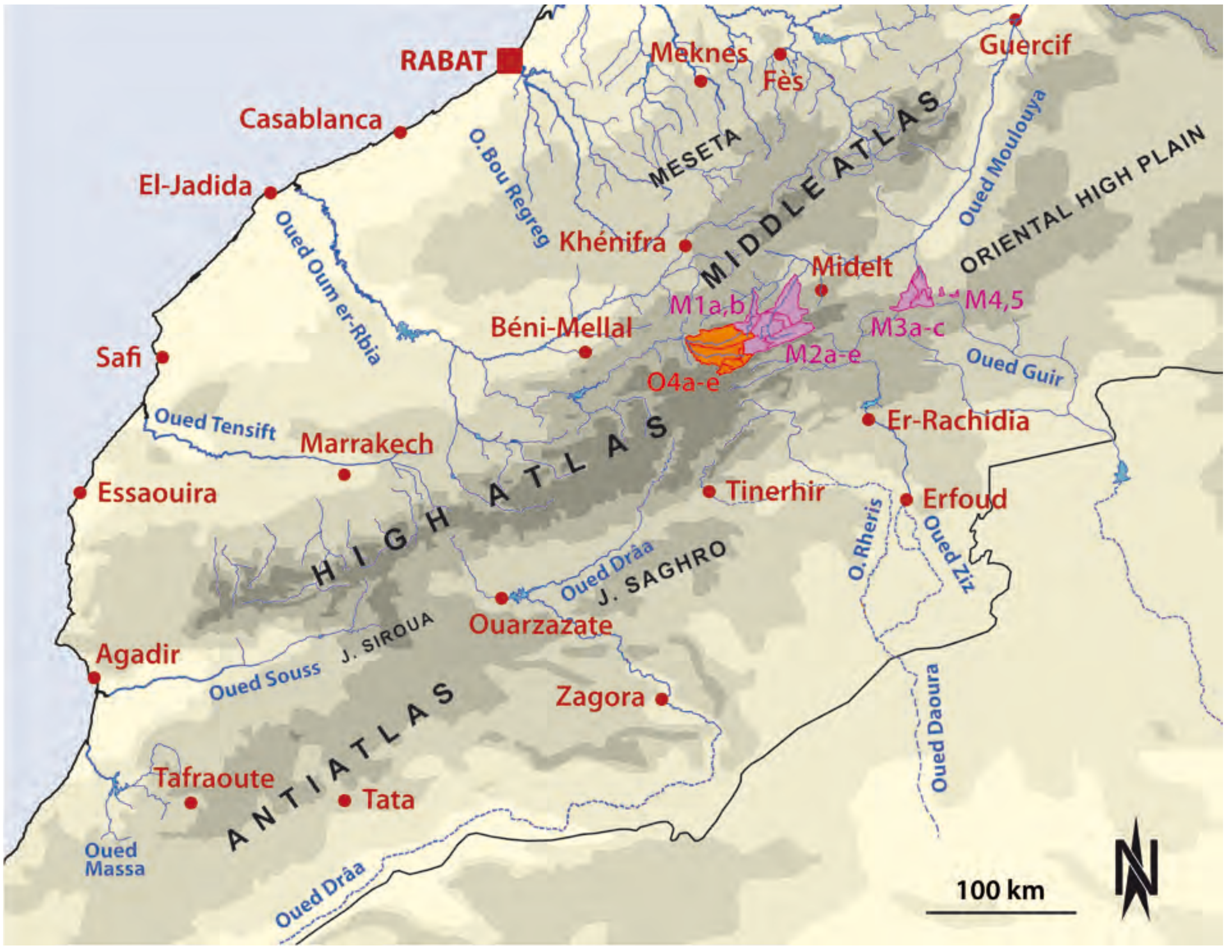


Fig. 324: *Simplified map of the Atlas Mountains showing potential study areas displaying characteristics of both trough valleys and V-shaped valleys (types 1 and 2) altogether.*

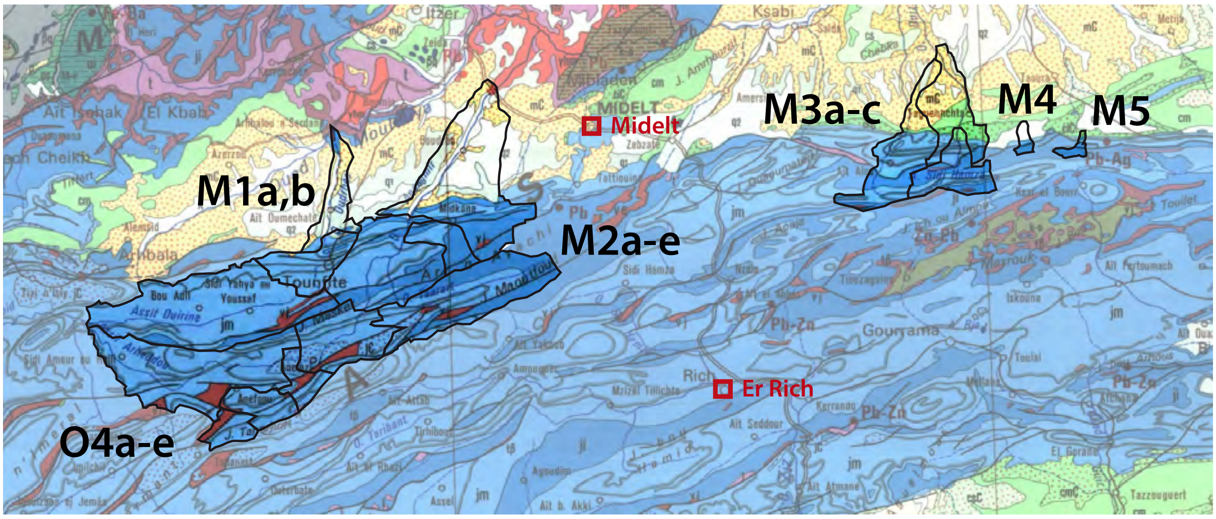


Fig. 325: *Geological map of the eastern High Atlas Mountains showing potential study areas with characteristics of both trough valleys and V-shaped valleys (types 1 and 2) altogether; modified after Saadi, M. et al., 1985, Carte Géologique du Maroc 1:1'000'000, Editions du Service Géologique du Maroc, see also annex III.*

The eastern High Atlas Mountains mainly consist of Jurassic sedimentary rocks such as limestones, marls and argillaceous rocks. The adjacent Moulouya high plain is dominated by Tertiary sediments, but partly includes Cretaceous limestones and marls as well.

Abbreviations for major rock types forming trough valleys (blue):

ji: Liassic (Jurassic) sedimentary rocks (grey limestones, marls, argillaceous rocks)

jm: Middle Jurassic sedimentary rocks (grey limestones, marls, argillaceous rocks)

jc: Upper Jurassic) sedimentary rocks (red marls, argillaceous rocks)

Abbreviations for rock types of minor importance (violet):

t, tβ: Triassic sedimentary rocks (mostly red argillaceous rocks), partially with melaphyr dykes

νj: Episyenites, diorites and gabbros of Mesozoic age

νe: Syenites of Tertiary age

Abbreviations for rock types in the Moulouya high plain (green, yellow, white):

cm: Middle Cretaceous sedimentary rocks (grey to red limestones, marls, argillaceous rocks)

mC: Miocene (Tertiary) sedimentary rocks (argillaceous rocks, weakly consolidated sandstones and conglomerates)

q2: Pleistocene (Quaternary) sediments (silt, sand, gravel)

6.2 Oum Er-Rbia catchment

Apart from pure V-shaped valleys in the areas O1b/c, O5, O6 and O8b, trough valleys in the areas O1a and O3a-e, carbonate plateaus with scattered farmsteads and dry farming in the areas O2 and O3f, and non river-dependent individual villages in the areas O7 and O8a, the scenically very diversified Oued Oum Er-Rbia catchment also contains valleys that combine the characteristics of both trough and V-shaped valleys in the same place in area O4.

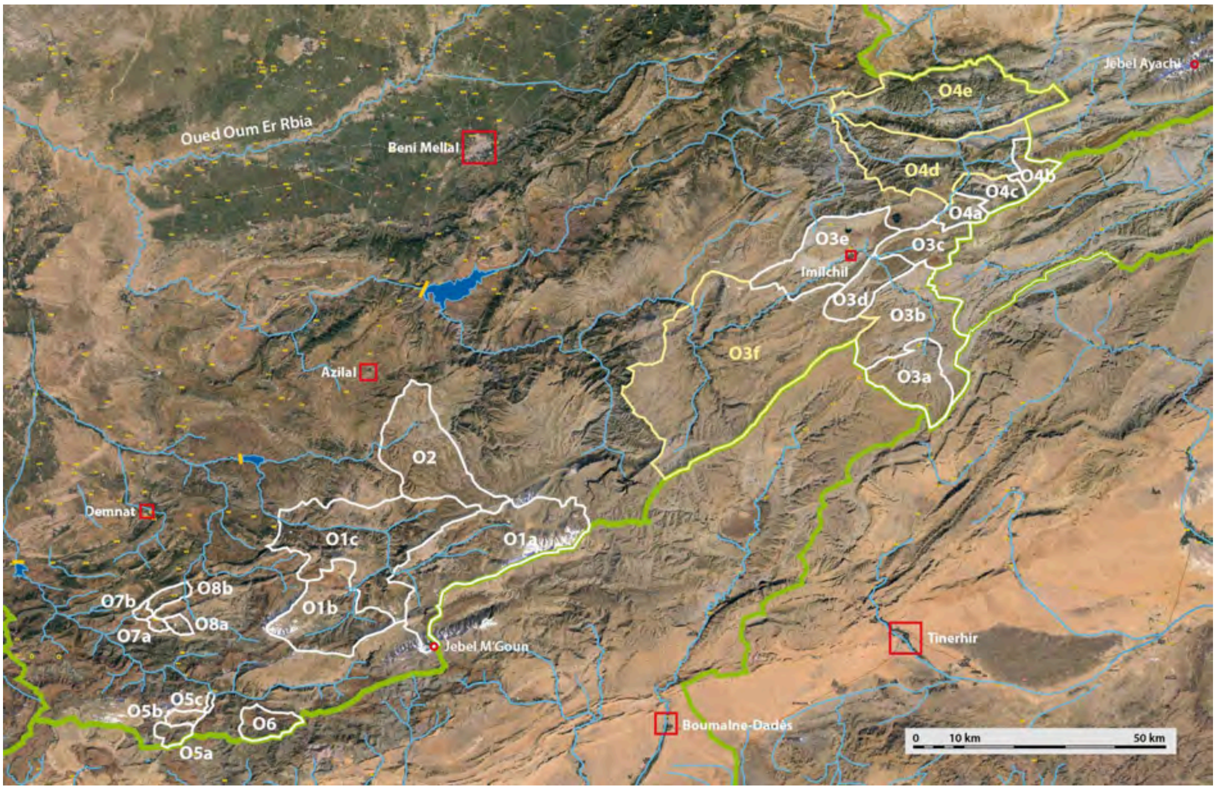


Fig. 326: *Satellite image of potential study areas in the Oued Oum Er-Rbia catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

6.2.1 Area O4 a-e Tighadiouine - Tamaluot - Amelgou - Agheddou - Bouadel

The lower, sparsely populated parts of area O4 (O4d and O4e) have not been investigated due to poor accessibility. The upper parts O4a, b and c are characterized by vast cedar forests that are unlikely to occur anywhere else in the High Atlas Mountains. Unfortunately these cedar forests are in a very poor condition due to persisting overuse, often leading to complete deforestation.

Tab. 21: Key attributes of area O4 a-e.

Morphological type of the higher / inner mountain areas:	High mountain valleys with alternately flat and steeper gradient, combining characteristics of both trough and V-shaped valleys. They are partly uninhabited or gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	Predominantly carbonate rocks (limestones, marls) with subordinate igneous rocks (granites, diorites, gabbros).
Geological / tectonic units / geological periods:	See fig. 325, page 158.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials and thorn shrubs. Lower altitudes: Conifers, evergreen oaks, cedars.
Density of natural vegetation:	Middle – high
Degradation of natural vegetation:	Very strong and obvious deforestation particularly of the cedar forests.
Form of settlement:	Compact villages
Density of settlement:	Low - middle
Predominant form of agriculture:	Primarily irrigated, non terraced or slightly terraced fields on alluvial deposits at the side of streambeds, secondarily slightly terraced irrigated fields at the valley flanks.
Irrigation:	Irrigation channels draining main and lateral streams.
Crops:	Cultivation of grain, vegetables, cattle fodder crops and few apples.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible.
Remarks:	Very simple tourist infrastructure in Amelgou and Tighadiouine. Outside area O4 in Tagoudit/Agoudim (area M2a).
Degree of documentation:	Not all areas documented.

Fig. 327: *Village Tamalout, with slightly terraced fields. Area O4b, autumn 2015.*

Fig. 328: *Village Tamalout, seen from the deforested area to the south. Area O4b, autumn 2015.*

Fig. 329: *Almost completely deforested cedar forest south of village Tamalout. Area O4b, autumn 2015.*

Fig. 330: *Completely deforested cedar forest south of village Tamalout. Area O4b, autumn 2015.*

Fig. 331: *Last tree stumps in a completely deforested cedar and oak forest southwest of village Tamalout. Area O4b, autumn 2015.*

Fig. 332: *Village Amelgou with irrigated cereal, potato and vegetable fields on the bank of the stream. Area O4c, autumn 2015.*

Fig. 333: *Loading of mules with simple hand ploughs. Village Amelgou. Area O4c, autumn 2015.*

Fig. 334: *Women on the way to their fields. Village Amelgou. Area O4c, autumn 2015.*

Fig. 335: *Irrigated and slightly terraced fields near village Amelgou. Area O4c, autumn 2015.*

Fig. 336: *Corn harvest near village Amelgou. Area O4c, autumn 2015.*

Fig. 337: *Ploughing by mules is the most common form in the mountains all over Morocco. Near Amelgou, area O4c, autumn 2015.*

Fig. 338: *Dead and dying cedars (yellow arrow) due to repeated cutting of the branches to feed animals in wintertime, whereas oaks (red arrow) are not or even less affected by this treatment. Near Amelgou, area O4c, autumn 2015.*

***Fig. 339**: Dead and dying cedars due to repeated cutting of the branches to feed animals in wintertime. Near Amelgou, area O4c, autumn 2015.*

***Fig. 340:** Remnants of a at once dense cedar forest. Near Amelgou, area O4c, autumn 2015.*

***Fig. 341:** Remnants of a at once dense cedar forest. Soil erosion in the foreground due to exposition of the soil to rainfall. Near Amelgou, area O4c, autumn 2015.*

***Fig. 342:** Village Tigadhiouine with irrigated terraced cereal fields and fruit trees. Poplar trees are used for construction purpose. Area O4a, autumn 2015.*

***Fig. 343:** Irrigated terraced cereal fields and fruit trees with village Tigadhiouine in the background (right). Area O4a, autumn 2015.*

***Fig. 344:** Village Tireghiste with irrigated terraced cereal fields and fruit trees. Area O4a, autumn 2015.*

6.3 Oued Moulouya catchment

All areas on the northern slope of the High Atlas Mountains in the Moulouya catchment combine the characteristics of both trough and V-shaped valleys in the same place. After crossing the foothills, the lowermost valleys pass into the huge Moulouya alluvial plain between the High Atlas Mountains and the Middle Atlas Mountains. Some of these lowermost valleys are of interest for the intended study as both, settlements and agricultural use are of a manageable size. The natural hydrological system is not disturbed by the Hassan II dam that is located further down. Intensive agriculture, however, is only possible there due to additional water from the Hassan II reservoir.

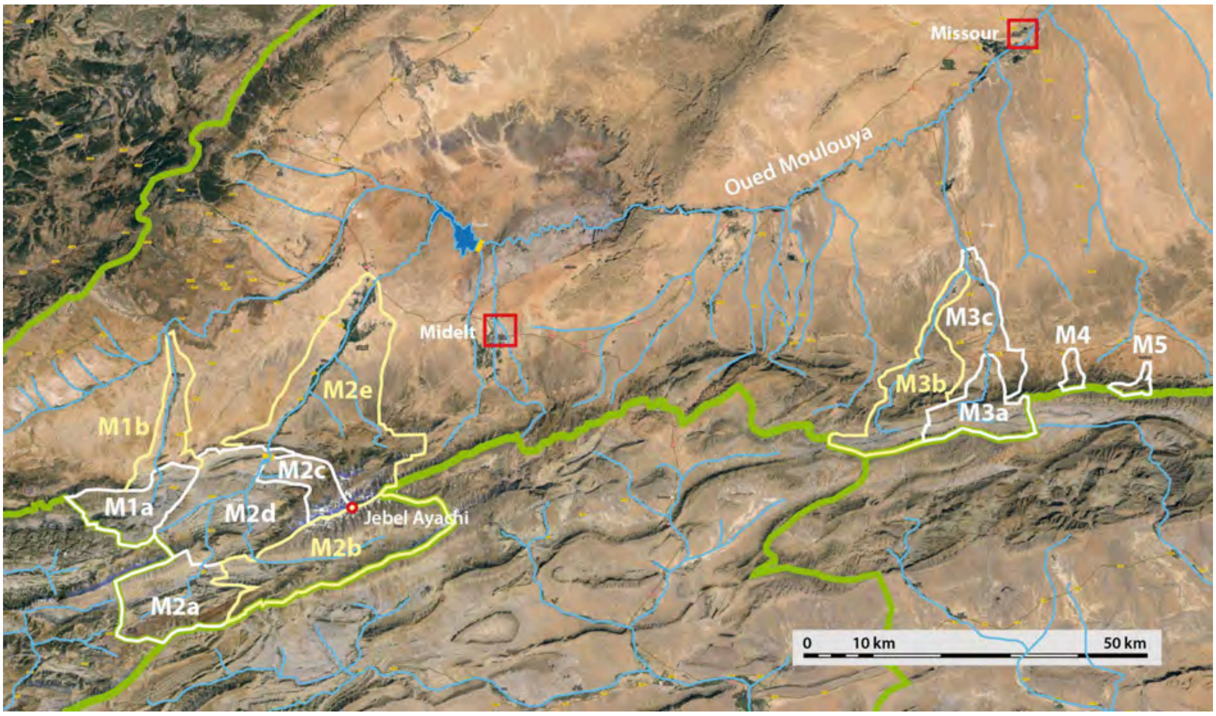


Fig. 345: *Satellite image of potential study areas in the upper Oued Moulouya catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

6.3.1 Area M1 a, b Tounfite - Tamazert

In the Tounflite – Tamazert area it may be interesting to study the hydrological relationships between the high mountain valleys and the Moulouya alluvial plain area that is dominated by intense agriculture along the stream.

Tab. 22: Key attributes of area M1 a, b.

Morphological type of the higher / inner mountain areas:	High mountain valleys with flat gradient, combining characteristics of both trough and V-shaped valleys. They are partly uninhabited or gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Meandering stream in a shallow depression of the Moulouya plain, lined with irrigated fields and fruit plantations. Additional dry farming on the hills on both sides.
Predominant rock types:	High Atlas Mts.: Predominantly carbonate rocks (limestones, marls) with subordinate igneous rocks (granites, diorites, gabbros). Foothills, Moulouya alluvial plain: Carbonate rocks, sparsely consolidated gravel, sands, clay.
Geological / tectonic units / geological periods:	See fig. 325, page 158.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials and thorn shrubs. Lower altitudes: Conifers, evergreen oaks, cedars.
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Presumably strong
Form of settlement:	Compact villages
Density of settlement:	Low - middle
Predominant form of agriculture:	Primarily irrigated, non terraced or slightly terraced fields on alluvial deposits at the side of streambeds, secondarily slightly terraced irrigated fields at the valley flanks.
Irrigation:	Irrigation channels draining main and lateral streams.
Crops:	Cultivation of grain, vegetables, cattle fodder crops, sunflowers and few apples.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible (competition with Midelt?).
Remarks:	Tourist infrastructure in Midelt and Zaïda only.
Degree of documentation:	Lower mountains and foothills: Good High Mountains: Not all areas documented.

Fig. 346: *Northern foothills of the High Atlas Mountains, natural vegetation consisting of conifers (cypresses) and evergreen oaks. Area M1b, autumn 2015.*

Fig. 347: *Village Tounfite with irrigated fields and poplar trees, sunflower fields in the foreground. Poplar wood is used for constructional purposes. Area M1a, autumn 2015.*

6.3.2 Area M2 a-e
Tagoudit - Tighermine - Imatchimen - Aït Sidi Boumoussa

Similar to area M1, it may be interesting in area M2 to study the hydrological relationships between the high mountain valleys and the Moulouya alluvial plain area that is dominated by intense agriculture along the stream. Agricultural use in the alluvial plain of area M2 is more intensive then in area M1 and irrigation is most probably supported by adducted water from the Hassan II reservoir. An additional small new dam is under construction west of Imatchimen in area M2c, the purpose of which most probably is an improvement of irrigation too.

Tab. 23: Key attributes of area M2 a-e.

Morphological type of the higher / inner mountain areas:	High mountain valleys with flat gradient, combining characteristics of both trough and V-shaped valleys. They are partly uninhabited or gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Meandering stream in a shallow depression of the Moulouya plain lined with primarily vast irrigated fruit plantations and fields in between.
Predominant rock types:	High Atlas Mts.: Predominantly carbonate rocks (limestones, marls) with subordinate igneous rocks (granites, diorites, gabbros). Foothills, Moulouya alluvial plain: Carbonate rocks, sparsely consolidated gravel, sands, clay.
Geological / tectonic units / geological periods:	See fig. 325, page 158.
Stream / river:	Permanent
Predominant natural vegetation:	Higher altitudes: Perennials and thorn shrubs. Lower altitudes: Conifers, evergreen oaks, cedars.
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Presumably strong
Form of settlement:	Compact villages
Density of settlement:	Middle
Predominant form of agriculture:	Primarily irrigated, non terraced or slightly terraced fields on alluvial deposits at the side of streambeds, secondarily slightly terraced irrigated fields at the valley flanks.
Irrigation:	Irrigation channels draining main and lateral streams.
Crops:	Cultivation of grain, vegetables, cattle fodder crops and apples.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is possible (competition with Midelt?)
Remarks:	Dam under construction west of Imatchimen (area M2c) for irrigation purposes in area M2e. Tourist infrastructure in Tagoudit and Agoudim (or Midelt and Zaïda).
Degree of documentation:	Not all areas documented.

Fig. 348: *Village Boutserfine, area M2a, autumn 2015.*

Fig. 349: *Small apple plantation and poplar trees in a lateral valley near village Boutserfine. Area M2a, autumn 2015..*

Fig. 350: *Degraded natural vegetation consisting of thinned out cedars and oaks in a lateral valley near village Agoudim. Area M2a, autumn 2015.*

Fig. 351: *Village Tagoudit, area M2a, autumn 2015.*

Fig. 352: *Irrigated cereal and vegetable fields near village Tagoudit. Area M2a, autumn 2015.*

Fig. 353: *Degraded natural vegetation consisting of thinned out cedars and oaks on the pass between Tagoudit and Aït Chrad (new road). Area M2b, d, autumn 2015.*

***Fig. 354:** Natural vegetation consisting of conifers and oaks north of the pass between Tagoudit and Aït Chrad (new road). Area M2b, d, autumn 2015.*

***Fig. 355:** Village north of Aït Chrad with fields that were flooded and covered with a thick layer (20 - 50cm) of mud and gravel in November 2014. Area M2d, autumn 2015.*

***Fig. 356:** Gorge north of Aït Chrad, with water rich in sediment after rainfall. Area M2d, autumn 2015.*

***Fig. 357:** River near Imatchimen, with water rich in sediment after rainfall. Area M2c, autumn 2015.*

***Fig. 358:** Village Aït Ouchchen, area M2c, autumn 2015.*

***Fig. 359:** Shallow depression in the Oued Moulouya plain with fruit plantations of Aït Ben Ichou. Area M2e, autumn 2015.*

6.3.3 Area M3 a-c
Eastern High Atlas Mts. north slope

Due to a decreasing precipitation rate towards east, in contrast to the areas M1 and M2, there is no intensive agricultural use of the alluvial plain in area M3 and the higher areas are sparsely populated only.

Tab. 24: Key attributes of area M3 a-c.

Morphological type of the higher / inner mountain areas:	High mountain trough valleys with flat gradient.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Meandering stream in a shallow depression of the Moulouya plain, under normal hydrological conditions infiltrating already before it reaches the plain.
Predominant rock types:	High Atlas Mts.: Predominantly carbonate rocks (limestones, marls) with subordinate igneous rocks (granites, diorites, gabbros). Foothills, Moulouya alluvial plain: Carbonate rocks, sparsely consolidated gravel, sands, clay.
Geological / tectonic units / geological periods:	See fig. 325, page 158.
Stream / river:	Permanent / periodic
Predominant natural vegetation:	Higher altitudes: Perennials and thorn shrubs. Lower altitudes: Conifers, evergreen oaks, cedars.
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Difficult to estimate, presumably locally strong.
Form of settlement:	Compact villages
Density of settlement:	Low
Predominant form of agriculture:	Primarily irrigated, non terraced or slightly terraced fields on alluvial deposits at the side of streambeds, secondarily slightly terraced irrigated fields at the valley flanks.
Irrigation:	Irrigation channels draining main and lateral streams.
Crops:	Cultivation of grain, vegetables and cattle fodder crops.
Accessibility / development of road infrastructure:	In general easy to access.
Future prospects / risks:	Peripheral area with intact agriculture.
Remarks:	No tourist infrastructure existent at all.
Degree of documentation:	Not all areas documented.

Fig. 360: *Village Tagentcha on the foot of the High Atlas Mountains with irrigated, terraced fields along the streambed. View towards east, area M3a, autumn 2015.*

Fig. 361: *Village Tagentcha with irrigated terraced fields. Area M3a, autumn 2015.*

Fig. 362: *View towards the High Atlas Mountains near village Tikoutamine. Area M3a, autumn 2015.*

Fig. 363: *Typical, local, one-storied houses in the village Tikoutamine. Area M3a, autumn 2015.*

Fig. 364: *Halfah grass steppe (Stipa tencissima) covering the southern part of the Oued Moulouya plain. View towards the High Atlas Mountains, area M3a, autumn 2015.*

7 Potential study areas with trough valleys (type 2) and canyon-like, stepped foothill valleys (type 4)

7.1 Geographic distribution and geological conditions

Potential study areas that are combinations of trough valleys in the upper high mountain parts and open, stepped foothill valleys in the lower parts are situated on the southern slope of the eastern High Atlas Mountains, facing towards the upper Drâa and Todhra valleys that form a vast high plain between the High Atlas Mountains. to the north and Jebel Saghro to the south.

The most important area D1a-e is situated along the upper Oued Drâa that is named Oued Dadès. The neighbouring area to the east is R2 (see chapter 5.2.2). This area is also a trough valley in the upper high mountain part. Its lower part, however, is the uninhabited Todhra Gorge, followed by the densely populated northern suburbs of the city of Tinerhir that are both not suitable for the intended study. Area R2 is therefore not extended down the valley.

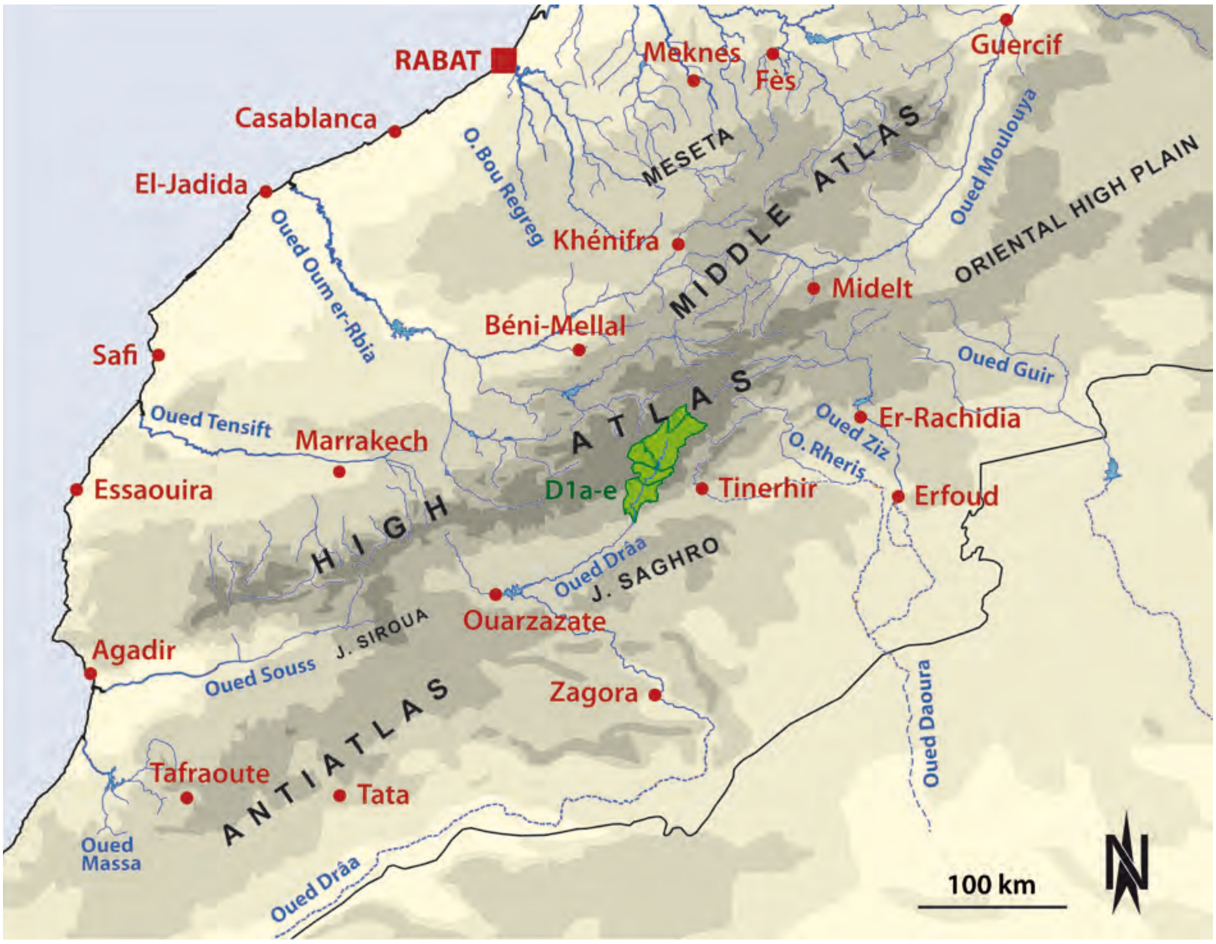


Fig. 365: Simplified map of the Atlas Mountains showing the potential study area D1 that is a combination of trough valleys (type 2) and a canyon-like, stepped foothill valley (type 4).

The morphology with trough valleys in the inner / higher mountains and rather open canyons with stepped slopes forming the outer valleys that cross the foothills and reach into the alluvial plains represents the geological conditions. Trough valleys as they are found in the High Atlas Mountains and discussed in chapter 1.2 develop within the gently folded and faulted Jurassic sedimentary rocks of the eastern High Atlas Mountains under conditions of a moderate precipitation rate. Canyon-like valleys with stepped slopes on the other hand develop in areas with rather low precipitation, but a temporarily high flow rate, as it is given on the foot of a high mountain range with a humid microclimate in a generally semi-arid or arid region. Weak, but strongly stratified sedimentary rocks accentuate their development additionally.

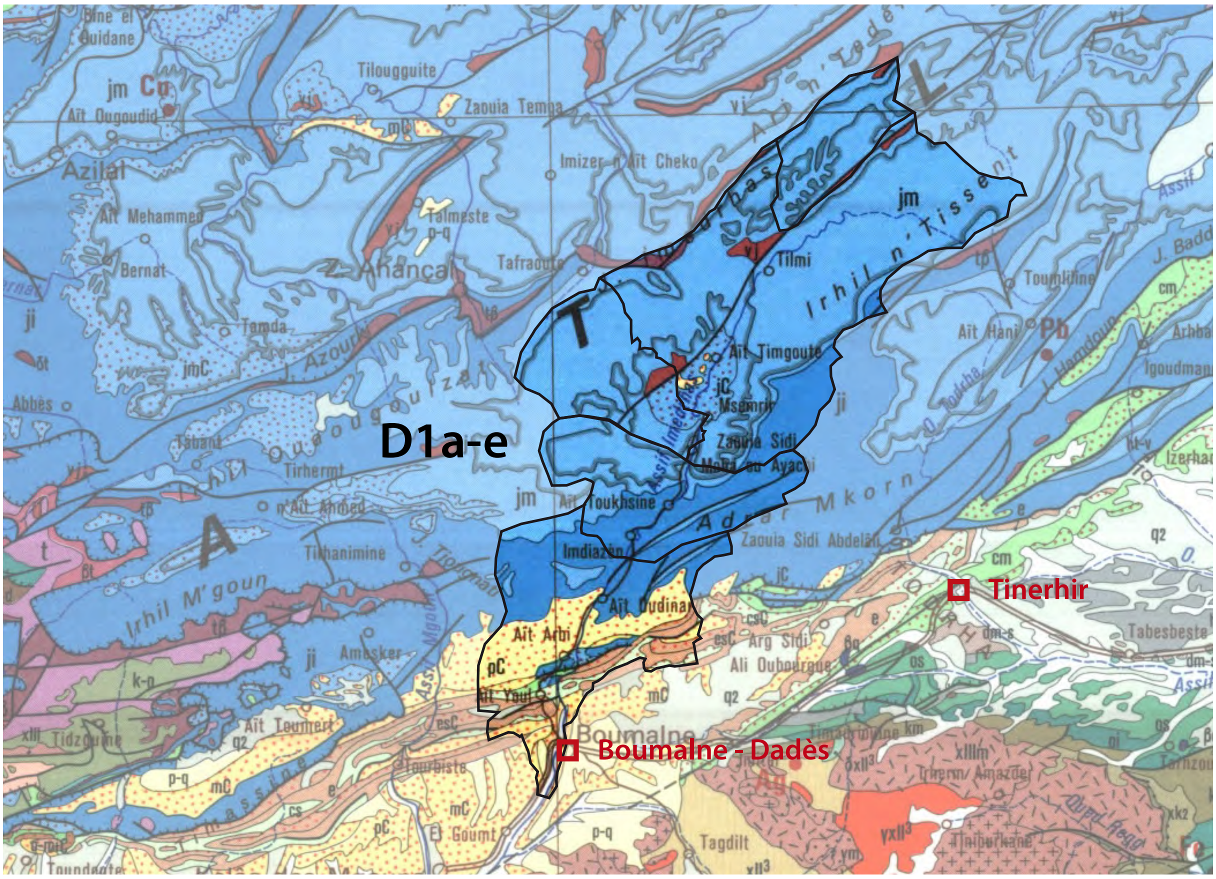


Fig. 366: Geological map of the southern slope of the eastern High Atlas Mountains near Boumalne-Dadès, showing the potential study area D1a-e that is a combination of trough valleys (type 1) and a canyon-like, stepped foothill valley (type 4); modified after Saadi, M. et al., 1985, Carte Géologique du Maroc 1:1'000'000, Editions du Service Géologique du Maroc, see also annex III.

Abbreviations for major rock types forming trough valleys (blue):

ji: Liassic (Jurassic) sedimentary rocks (grey limestones, marls, argillaceous rocks)

jm: Middle Jurassic sedimentary rocks (grey limestones, marls, argillaceous rocks)

jc: Upper Jurassic) sedimentary rocks (red marls, argillaceous rocks)

Abbreviations for rock types of minor importance (green, violet):

νj: Episyenites, diorites and gabbros of Mesozoic age

t, tβ: Tertiary sedimentary rocks (mostly red argillaceous rocks), partially with melaphyr dykes

Abbreviations for rock types forming canyon-like, stepped foothill valleys:

cs, cm: Cretaceous sedimentary rocks (limestones, marls, argillaceous rocks)

e, esC: Eocene (Tertiary) sedimentary rocks (limestones, marls, argillaceous rocks)

mC: Miocene (Tertiary) sedimentary rocks (argillaceous rocks, weakly consolidated sandstones and conglomerates)

pC: Pliocene (Tertiary) sedimentary rocks (argillaceous rocks, weakly consolidated sandstones and conglomerates)

7.2 Oued Drâa catchment

Apart from the most frequent combination of V-shaped valleys in the higher mountain regions and canyon-like, stepped valleys in the foothills as in the areas D2 to D6, in area D1 of the Oued Drâa catchment also the combination of trough valleys in the higher mountains and canyon-like, stepped valleys in the foothills occurs.

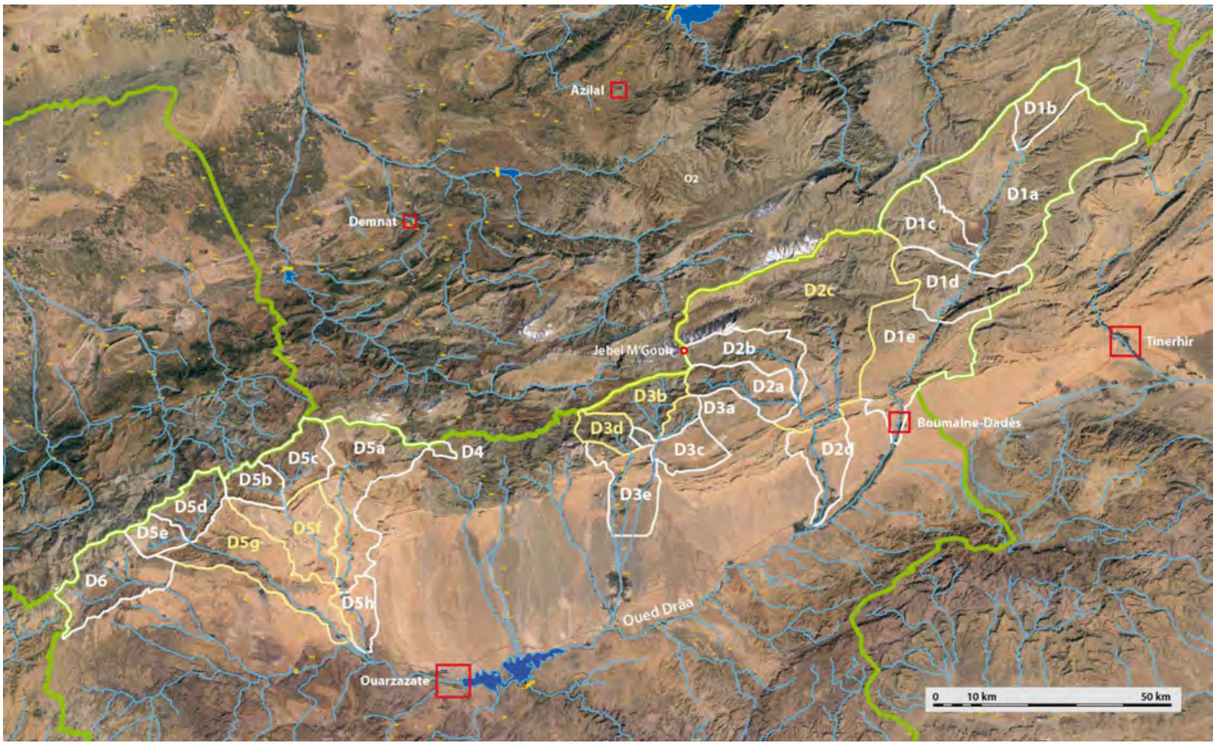


Fig. 367: *Satellite image of potential study areas on the southern slope of the High Atlas Mts. in the upper Oued Drâa catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

7.2.1 Area D1 a-e
Oued Dadès Valley

Area D1 covers the 'Gorge du Dadès', one of the scenic highlights of Morocco and therefore a touristic hot spot with a large amount of hotels in the areas D1 d and D1e. It may be of interest for the intended project to find out how the concentrated touristic infrastructure handles water and natural resources there.

Tab. 25: Key attributes of area D1 a-e.

Morphological type of the higher / inner mountain areas:	High mountain trough valleys with different opening angles and alternately flat and steeper gradient, partly uninhabited or gorges. The Msemrir area is a very open trough valley that is more like a high plain. Area D1b is rather a V-shaped valley.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Canyon-like, stepped foothill valley that opens into an alluvial plain after the final ravine (klus).
Predominant rock types:	High Atlas Mts.: Predominantly carbonate rocks (limestones, marls) with subordinate igneous rocks (granites, diorites, gabbros). Foothills: Carbonate rocks, conglomerates, sand-stones and argillaceous rocks with gypsum veins.
Geological / tectonic units / geological periods:	See fig. 366, page 173.
Stream / river:	Permanent
Predominant natural vegetation:	Perennials and thorn shrubs, trees (conifers) are very rare.
Density of natural vegetation:	Very low
Degradation of natural vegetation:	Difficult to estimate, presumably strong.
Form of settlement:	Compact villages
Density of settlement:	Middle – high
Predominant form of agriculture:	Higher mountains: Irrigated non terraced or slightly terraced fields on alluvial deposits at the side of streambeds, under normal hydrological conditions 0.5 - 2m higher than the water level, inundated at high water level. Terraced fields in area D1b as an exception. Lower mountains and foothills: Irrigated farming on alluvial land along streambeds
Irrigation:	Irrigation channels draining main and lateral streams.
Crops:	Higher altitudes: Cultivation of grain, vegetables, cattle fodder crops and apples. Lower altitudes: Additional walnuts and olives.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved road. Higher mountains: Easily passable mud roads in summertime, pass road to Agoudal not passable in wintertime.
Future prospects / risks:	Intact agriculture, further development of tourist infrastructure in the Msemrir region is possible.
Remarks:	Tourist infrastructure abundant below and in the lowest Dadés gorge, scarse in Msemrir and above.
Degree of documentation:	Sufficient to good for the whole area.

Fig. 368: *Aït Attou, highest village in the Dadès Valley with irrigated, slightly terraced fields. This lateral valley is rather V-shaped. Area D1b, autumn 2015.*

Fig. 369: *Dadès Valley above the upper gorge between Aït Attou and Aït Moussa Wichou. View down the valley, Area D1b, autumn 2015.*

Fig. 370: *Village Aït Moussa Wichou with irrigated fields on alluvial land in the Oued Dadès trough valley. Area D1a, autumn 2015.*

Fig. 371: *Tighremt in Aït Moussa Wichou, area D1a, autumn 2015*

Fig. 372: *Fields near Iznaguen that were covered with mud and gravel during flooding in 2014. Area D1a, autumn 2015.*

Fig. 373: *Village Aït Atto Moussa with irrigated fields on alluvial land along Oued Dadès. Oued Dadès trough valley, area D1a, spring 2015.*

Fig. 374: *Village Ihoudiggen with irrigated fields on alluvial land along Oued Dadès. Oued Dadès trough valley, area D1a, spring 2015.*

Fig. 375: *High plain of Msemrir with villages Aït Ou Attik (left) and Aït Toukshine (right), area D1a, autumn 2015.*

Fig. 376: *Village Aït Toukshine with irrigated fields and fruit trees on alluvial land along Oued Dadès, view up the valley. Oued Dadès trough valley, area D1a, spring 2015.*

Fig. 377: *Village Aït Toukshine with irrigated fields and fruit trees on alluvial land along Oued Dadès; irrigation channel in the foreground. View up the valley, area D1a, spring 2015.*

Fig. 378: *Village Aït Ou Attik, Oued Dadès trough valley. Area D1a, autumn 2015.*

Fig. 379: *Irrigated fields near Aït Marghad, view down the valley to Msemrir. Oued Dadès trough valley, area D1a, autumn 2015.*

Fig. 380: *Fields near Msemrir that were covered with mud and gravel during flooding in 2014. Oued Dadès trough valley, area D1a, autumn 2015.*

Fig. 381: *Tighremt in Oussikiss near village Aït Ounebgui, area D1c, autumn 2015.*

Fig. 382: *Middle Dadès gorge with distinct meanders. Area D1a, autumn 2015.*

Fig. 383: *Small fields along the meanders in the middle Dadès gorge. Area D1a, autumn 2015.*

Fig. 384: *Villages Amouguer and Tidrite at the lower end of the middle Dadès gorge, view down the valley. Area D1a, autumn 2015.*

Fig. 385: *Village Tizguine with irrigated fields on alluvial land along Oued Dadès. View up the valley, area D1d, spring 2015.*

Fig. 386: *Dadès valley near Tizguine in spring 2015. The arrow indicates the location of a heavy rockfall that occurred in summer 2015 (see fig. 387). View down the valley, area D1d.*

Fig. 387: *Heavy rockfall near Tizguine that occurred in summer 2015, view up the valley. For location see fig. 386. Area D1d, autumn 2015.*

Fig. 388: *Road through the lower Dadès gorge, that is a highlight of every touristic journey through Morocco. Area D1e, autumn 2015.*

Fig. 389: *Lower Dadès Valley, a typical canyon-like foothill valley, with the dry bed of Oued Dadès near Imouzdar. Area D1e, autumn 2015.*

Fig. 390: *Canyon-like lower Dadès foothill valley with irrigated fields along Oued Dadès near Aït Ibriren. View down the valley, area D1e, autumn 2015.*

Fig. 391: *Village Aït Ibriren in the canyon-like foothill valley of Oued Dadès. View up the valley, area D1e, autumn 2015.*

8 Potential study areas with trough valleys (type 2) and wide, lower mountain valleys / high plains (type 3)

8.1 Geographic distribution and geological conditions

Potential study areas that are combinations of trough valleys in the higher mountains and wide, open valleys or even high plains in the lower mountains are situated in the easternmost High Atlas Mountains, facing towards south. With the exception of its northwestern parts, where the mountain scenery consists of "normal" trough valleys, these areas are more like a series of high plains separated from one another by narrow but long, isolated mountain chains oriented southwest – northeast, looking out of the plains like rows of teeth or backs of crocodiles.

Two combined areas (G1a-c and G2a-c) are introduced below. Due to the large dimensions and the uniformness of the high plains, they have not been explored in detail. The through valleys in the higher mountains have not been visited at all during the reconnaissance journeys, they are, however well recognizable on satellite imagery.

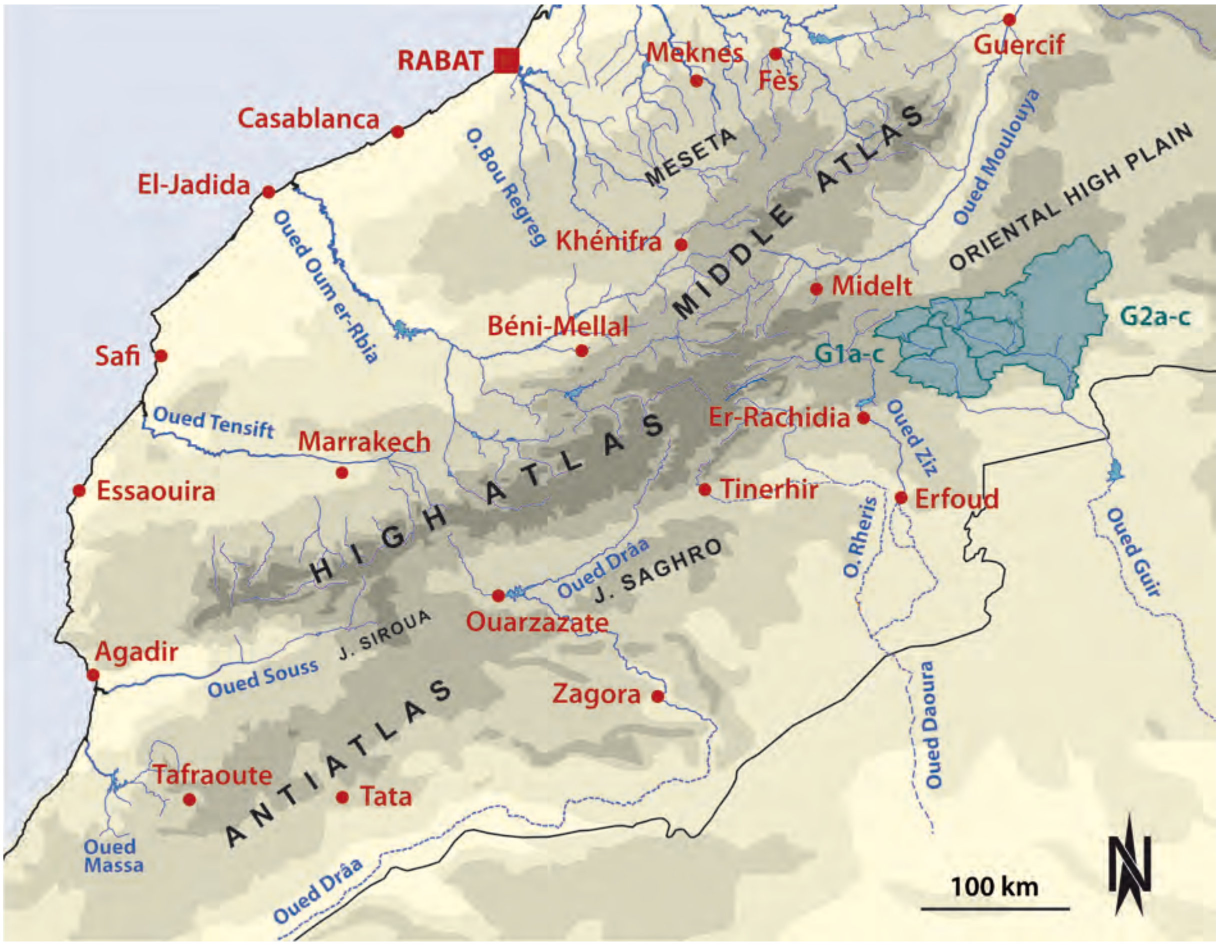


Fig. 392: Simplified map of the Atlas Mountains showing potential study areas that are combinations of trough valleys (type 2) and wide lower mountain valleys / high plains (type 3)

In eastern Morocco the High Atlas Mountains dissolve into isolated chains that submerge gently under the Oriental High Plain before they emerge again in Algeria. It is between these isolated chains that the wide, open valleys of the areas G1 and G2 developed. In spite of a hardly perceptible gradient, these valleys are flown trough by streams. In the lower parts, where the streams dry out and / or infiltrate in the ground under normal hydrological conditions, the streambeds are often vague, indicating that they can change direction or form shallow lakes with changing water levels during flooding. Despite of a moderate precipitation rate, individual rainfall events can be heavy. This results in a strong erosion of the mountain chains, filling valleys up with huge quantities of quaternary sediments such as clay, sand and gravel, displaying the nearly flat surface of typical alluvial plains.

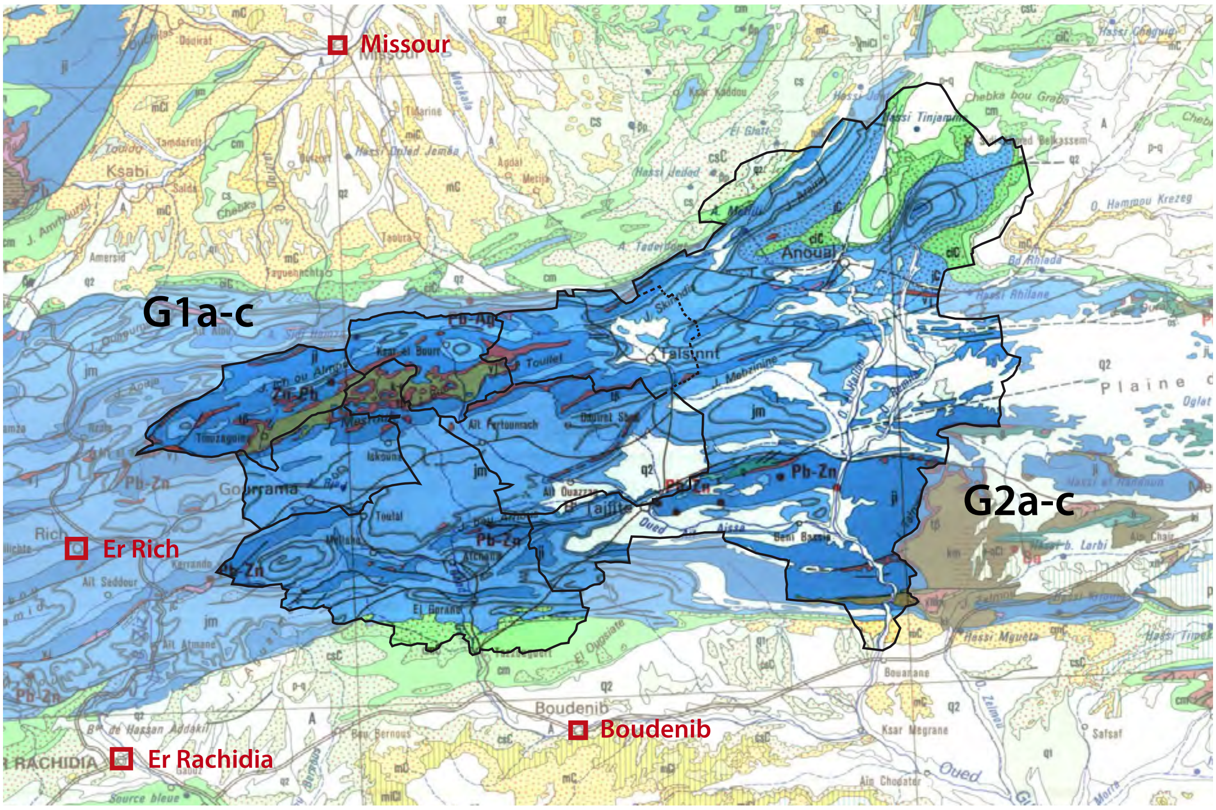


Fig. 393: *Geological map of the eastern High Atlas Mountains, showing the potential study areas that are combinations of trough valleys in the higher mountains and wide, open valleys or even high plains in the lower mountains; modified after Saadi, M. et al., 1985, Carte Géologique du Maroc 1:1'000'000, Editions du Service Géologique du Maroc, see also annex III.*

Abbreviations for rock types forming trough valleys (olivegreen, violet):

k-o: Cambrian and Ordovician sedimentary rocks, undifferenciated

νj: Episyenites, diorites and gabbros of Mesozoic age

t, tβ: Tertiary sedimentary rocks (mostly red argillaceous rocks), partially with weak melaphyr dykes

Abbreviations for rock types forming wide lower mountain valleys (blue, white):

ji: Liassic (Jurassic) sedimentary rocks (grey limestones, marls, argillaceous rocks)

jm: Middle Jurassic sedimentary rocks (grey limestones, marls, argillaceous rocks)

jc: Upper Jurassic) sedimentary rocks (red marls, argillaceous rocks)

q2, p-q: Pleistocene (Quaternary) sediments (non consolidated clays, sands and gravels)

Abbreviations for rock types of minor importance (green):

ci, cm, cmC, cs, csC: Cretaceous sedimentary rocks (limestones, marls, argillaceous rocks)

8.2 Oued Guir catchment

Oued Guir is the only catchment, where the typical wide valleys of the easternmost High Atlas Mountains occur that are rather high plains. The highest mountains, however, are dominated by trough valleys also here. After crossing the foothills through ravines (kluses), the lowermost valleys pass into the huge alluvial plain south of the High Atlas Mountains.

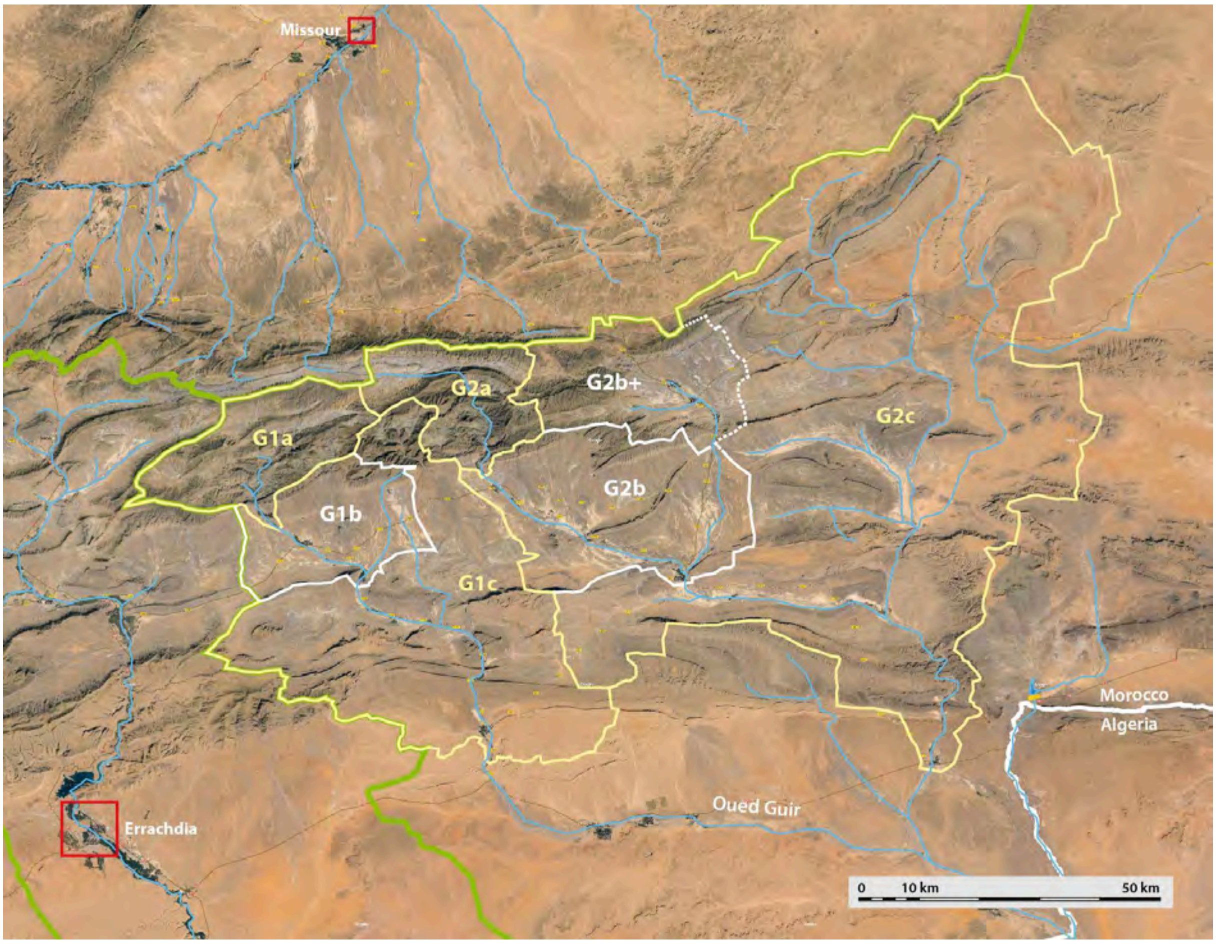


Fig. 394: *Satellite image of potential study areas in the Oued Guir catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

8.2.1 Area G1 a-c
Western branch of Guir River: Tagrirte - Gourrama – Tazougart
Area G2 a-c
Eastern branch of Guir River: Aït Aissa ou Ali - Talsint - Beni Tajite - Bouanane

Tab. 26: Key attributes of the areas G1 a-c and G2 a-c.

Morphological type of the higher / inner mountain areas:	High mountain trough valleys with alternately flat and steeper gradient, partly uninhabited or gorges.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	Wide lower mountain valleys / high plains with very flat gradient.
Predominant rock types:	Highest Mts.: Shales, argillaceous rocks, diorites and gabbros. Lower Mts.: Predominantly carbonate rocks (limestones, marls) with subordinate igneous rocks (granites, diorites, gabbros), sparsely consolidated gravel, sands, clay. Foothills: Carbonate rocks, sparsely consolidated gravel, sands, clay.
Geological / tectonic units / geological periods:	See fig. 393, page 181.
Stream / river:	Periodic / permanent
Predominant natural vegetation:	Higher altitudes: Perennials and thorn shrubs. Lower altitudes: Conifers.
Density of natural vegetation:	Very low – low
Degradation of natural vegetation:	Difficult to estimate, local relics of failed reforestations with non-indigenous pines.
Form of settlement:	Compact villages
Density of settlement:	Very low
Predominant form of agriculture:	Irrigated, non terraced or slightly terraced fields on alluvial deposits at the side of streambeds.
Irrigation:	Irrigation channels draining main or lateral streams.
Crops:	Cultivation of grain, vegetables, cattle fodder crops and olives.
Accessibility / development of road infrastructure:	Lower mountains / main valleys: Easy to access on paved roads. High mountains / lateral valleys: Partially difficult to access on mud roads.
Future prospects / risks:	Peripheral region with intact agriculture, development of tourist infrastructure is possible, but not expected due to lacking interest (too far from usual touristic itineraries).
Remarks:	Absolutely no tourism in this area, next tourist infrastructure in Er Rich (area Z1i).
Degree of documentation:	Areas G1c, G2b and G2b+: Sufficient Areas G1a, G1c, G2a, G2c: No documentation

Fig. 395: *Halfah grass steppe (Stipa tencissima), covering the northernmost range of the eastern High Atlas Mountains northeast of Talsint. Area G2b+, autumn 2015.*

Fig. 396: *Stream flowing out of the northernmost range of the eastern High Atlas Mountains. View towards west, area G2b+, autumn 2015.*

Fig. 397: *Stream northwest of village Ghazouane, remnants of a failed reforestation. View towards east, area G2b+, autumn 2015.*

Fig. 398: *River valley northwest of Beni Tajite that opens up to a high plain flanked by long, but narrow, isolated mountain ranges. Area G2b, autumn 2015.*

Fig. 399: *Irrigated fields along the stream crossing the high plain* of fig. 398 *near Ait Ouahi and Ait Ouzzoug. Area G2b, autumn 2015.*

Fig. 400: *Village Ait Ouzzoug with typical, local, one-storied houses. Northwest of Beni Tajite, area G2b, autumn 2015.*

Fig. 401: *Mountain range from fig. 398, seen from the back-side near Ait Ouzzoug. Area G2b, autumn 2015.*

Fig. 402: *Oued Ait Aissa passing through village Ait Ahmed Ohaddou. Area G2b, autumn 2015.*

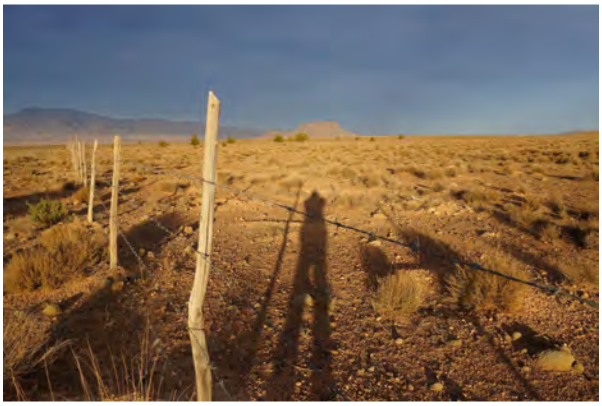


Fig. 403: *Fence and remnants of a failed reforestation in the high plain west of Gourrama, view towards east. Light of the setting sun, area G1b, autumn 2015.*

Fig. 404: *Central mountain range north of Gourrama, seen from the road through the high plain of Gourrama, view towards east. Light of the setting sun, area G1b, autumn 2015.*

9 Miscellaneous study areas that do not fit into the four most common basic valley types

9.1 Oued Oum Er-Rbia catchment

In the Oued Oum Er-Rbia catchment on the northern slope of the High Atlas Mountains numerous landscapes do not fit into the four basic valley types of the High Atlas Mountains as defined in chapter 1. This is not surprising as the Oued Oum Er-Rbia catchment shows the most variable landscapes of all High Atlas catchments. Besides trough and V-shaped valleys and combinations of both of them in the areas O1, O3 to O6 and O8b also a carbonate plateau with scattered farmsteads and dry farming occurs in area O2 (chapter 9.1.1) as well as non river-dependent individual villages in the areas O7 and O8a (chapter 9.1.2).

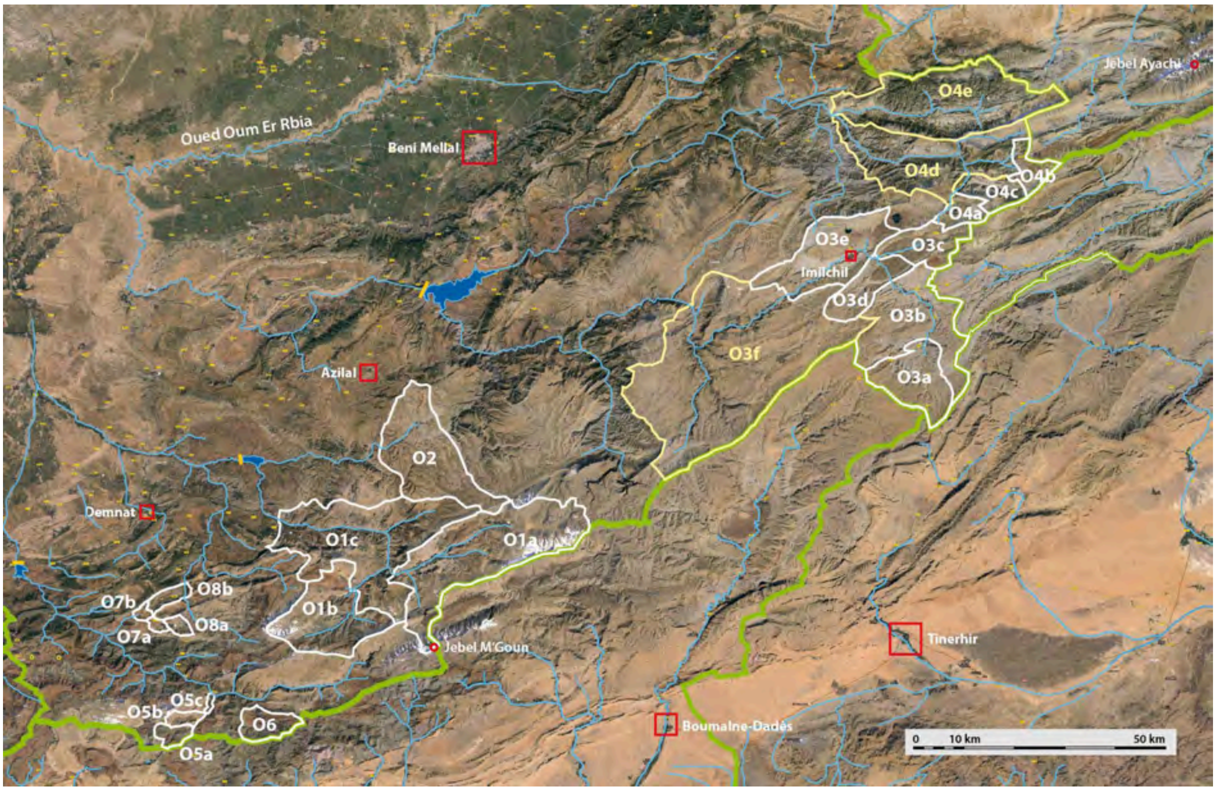


Fig. 405: *Satellite image of potential study areas in the Oued Oum Er-Rbia catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

9.1.1 Area O2
Jurassic carbonate plateau of Aït M'Hamed with upper Oued Lakhdar

Carbonate plateaus occur principally in thick Jurassic limestones and marls with subhorizontal stratification and lacking mayor folding in the central High Atlas Mountains that cover large, contiguous areas. These plateaus are hilly landscapes characterized by scattered farmsteads and dry farming. Streams are usually ephemeral and villages are rare (mostly souks). Depending on the thickness of the uppermost, hard limestone layers, the edges of the plateaus may be smooth or precipitous.

Tab. 27: Key attributes of area O2.

Morphological type of the higher / inner mountain areas	Carbonate plateau: Hilly landscape with scattered farmsteads and predominantly dry farming.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas	---
Predominant rock types	Carbonate rocks (limestones, marls)
Geological / tectonic units / geological periods	Jurassic
Stream / river	Periodic
Predominant natural vegetation	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks, undetermined trees.
Density of natural vegetation	Low – middle
Degradation of natural vegetation	Partial deforestations apparent.
Form of settlement	Scattered farmsteads, villages are rare (mostly souks).
Density of settlement	Low - middle
Predominant form of agriculture	Primarily dry farming, rare irrigated fields along streams.
Irrigation	Wells, cisterns.
Crops	Dry farming: Cultivation of grain. Irrigated farming: Cultivation of vegetables and cattle fodder crops; additional apples and walnuts where enough water.
Accessibility / development of road infrastructure:	Main valleys: Easy to access on paved road. Lateral valleys: Partially difficult mud roads.
Future prospects / risks	Intact agriculture.
Remarks	Absolutely no tourist infrastructure in this area.
Degree of documentation:	Not the whole area documented.

Fig. 406: *Western rim of the carbonate plateau that is made up of a cover of hard, yellowish-grey limestones (picture's edge on the left) and underlying weak, reddish-brown marls. Agriculture on the hard, dry calcareous soils is difficult (see figs. 408 - 410), whereas the weak marly soils are more humid and easier to plough for dry farming. View towards south, area O2, autumn 2015.*

Fig. 407: *View over the western rim of the carbonate plateau towards the High Atlas Mountains with snow-covered Jebel M'Goun in the background on the left hand side. View towards south, area O2, autumn 2015.*

Fig. 408: *Dry farming on calcareous soils with isolated evergreen oaks. View over the carbonate plateau towards northeast, area O2, autumn 2015.*

Fig. 409: *Dry farming on calcareous soils and small irrigated fields along one of the rare streams (arrow). View over the carbonate plateau towards northeast, area O2, autumn 2015.*

Fig. 410: *Scattered farmsteads and fields (dry farming on calcareous soil) on the carbonate plateau. Area O2, autumn 2015.*

Fig. 411: *Erosion gullies in a marly slope with partial deforestation (evergreen oaks). Area O2, autumn 2015.*

Fig. 412: *Reforestation with conifers between the already existing evergreen oaks on the same marly slope as shown in fig. 411. Rare irrigated fields along a stream. Area O2, autumn 2015.*

Fig. 413: *Scattered farmstead with fields on marly soil (dry farming) near one of the rare streams. Area O2, autumn 2015.*

Fig. 414: *Oued Lakhdar, the main stream on the carbonate plateau near Tighremt 'Ighram N'Caid Ahansal', southwest of Aït M'Hamed. Area O2, autumn 2015.*

Fig. 415: *Micro-dam that helps to branch irrigation channels from Oued Lakhdar. Near Tighremt 'Ighram N'Caid Ahansal', southwest of Aït M'Hamed, area O2, autumn 2015.*

Fig. 416: *Well-preserved and still inhabited Tighremt 'Ighram N'Caid Ahansal' near Oued Lakhdar southwest of Aït M'Hamed. Area O2, autumn 2015.*

9.1.2 Areas O7a, b and O8a Non river-dependent individual villages around Jebel Til

The water supply of non river-dependent, individual villages is mostly independent of superficial water courses. These villages are situated on slopes in the high mountains, mostly at the beginning of small water courses that therefore can not play any decisive role for the water supply, as they quickly dry out after rainfalls. However, it is striking that these villages frequently occur on weak, reddish argillaceous rocks of mostly Triassic age. Therefore and even without further examination of the situation it is certain that these villages dispose of water supplies other than superficial water courses. This may be sources or groundwater wells from the argillaceous rocks containing abundant pore water. The high precipitation rate on the northern slope of the High Atlas Mountains makes dry farming on large fields possible, however, it also accelerates erosion on the frequently completely deforested slopes. This type of villages is not restricted to the Oued Oum Er-Rbia catchment, but occurs in many areas on the northern flank of the High Atlas Mountains where argillaceous rocks occur.

Tab. 28: Key attributes of the areas O7 a, b and O8a.

Morphological type of the higher / inner mountain areas:	Predominantly V-shaped valleys or high plains with non river-dependent individual villages.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	Weak shales and argillaceous rocks.
Geological / tectonic units / geological periods:	Carboniferous, Triassic
Stream / river:	Periodic
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks, undetermined trees.
Density of natural vegetation:	Very low – high
Degradation of natural vegetation:	Partially very strong
Form of settlement:	Compact villages
Density of settlement:	Low - middle
Predominant form of agriculture:	Primarily irrigated farming on terraces at the flanks of V-shaped valleys.
Irrigation:	Irrigation channels draining sources, wells, cisterns (?).
Crops:	Dry farming: Cultivation of grain. Irrigated farming: Cultivation of grain, vegetables and cattle fodder crops.
Accessibility / development of road infrastructure:	Partially difficult to access on mud roads as they often are located high up in the mountains.
Future prospects / risks:	Intact agriculture.
Remarks:	Absolutely no tourist infrastructure in this area.
Degree of documentation:	Sufficient.

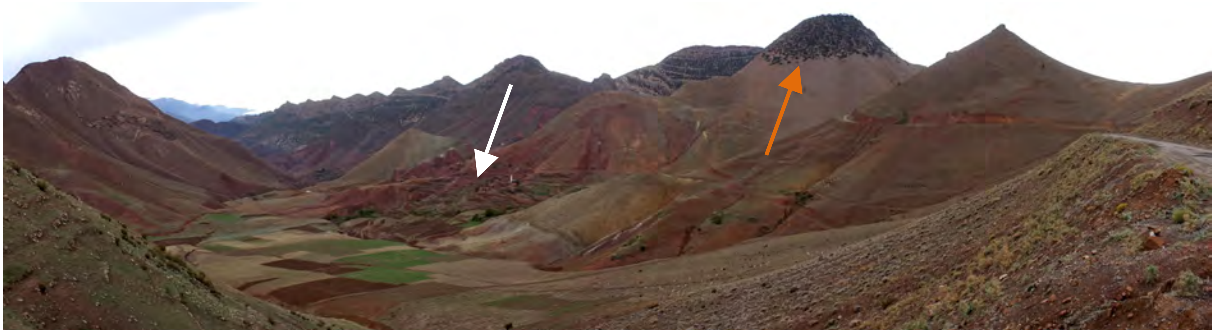


Fig. 417: *Dry farming on large fields in the foreground and terraced, irrigated fields near a village with unknown name on the opposite side (white arrow). Note the remnants of a forest on the mountain peak in the right half of the image (orange arrow). Area O7b, autumn 2015.*

Fig. 418: *Terraced, irrigated fields near the village with unknown name from fig. 417. Area O7b, autumn 2015.*

Fig. 419: *Village Aït Hammodo with dry farming in the foreground and irrigated, terraced fields in the middle ground. Area O7a, autumn 2015.*

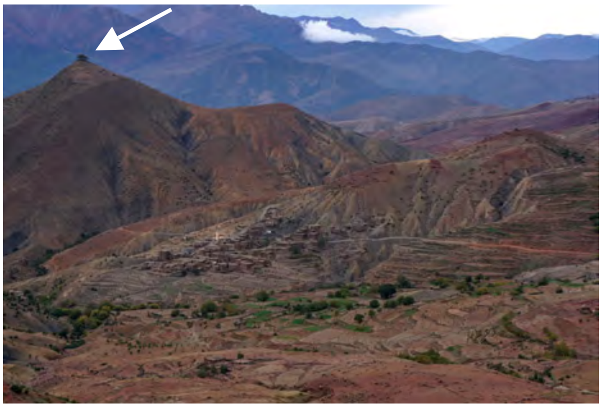


Fig. 420: *Village Aït Hammodo with irrigated, terraced fields. Note the single tree on the mountain peak at the left hand side as the last a remnant of a former forest (arrow). Area O7a, autumn 2015.*

Fig. 421: *Debris flow near Aït Hammodo due to deforestation of the steep, marly slope. Area O7a, autumn 2015.*

Fig. 422: *Dry farming on steep, deforested slopes and a village with unknown name. The intact forest on the mountain ridge in the left half of the image grows on calcareous soil that is unfavourable for agriculture. Area O8a, autumn 2015.*

Fig. 423: *Village with unknown name from fig. 422 in the midst of fields. Area O8a, autumn 2015.*

9.2 Oued Tensift catchment

The Oued Tensift catchment is quite homogenous, as all valleys occurring are V-shaped valleys in the higher mountain areas. However, the single area T2 (chapter 9.2.1) west of the combined area T1 is particular in the sense that in a V-shaped valley not only irrigated, terraced fields but also terraced dry farming is widespread.

The foothills in the Tensift catchment are dominated by marginal mountain ridges with alluvial plains in between that are cut by ravines (kluses). These areas, however, are densely populated and used for intensive farming, or their natural hydrological systems are disturbed by dams. They are therefore not appropriate for the intended studies. An exception is the small area T6 (chapter 9.2.2) with an undisturbed hydrological system.

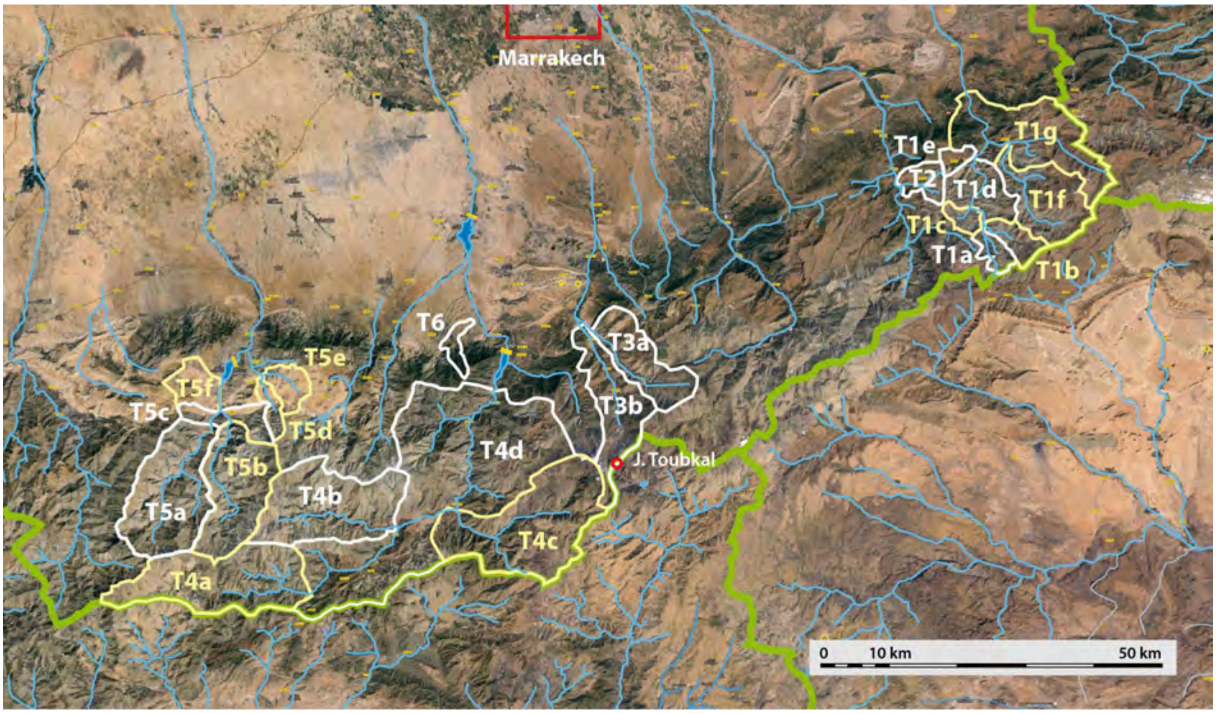


Fig. 424: Satellite image of potential study areas in the Oued Tensift catchment. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

9.2.1 Area T2 Additional dry farming along the eastern tributary of Oued Zad

Dry farming in V-shaped valleys does not occur in the western High Atlas Mountains. In the central High Atlas Mountains, however, some examples occur, including area T2.

Tab. 29: Key attributes of area T2.

Morphological type of the higher / inner mountain areas:	High mountain V-shaped valley with steep gradient.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	Red marls and argillaceous rocks.
Geological / tectonic units / geological periods:	See fig. 34, page 70.
Stream / river:	Periodic
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Partially strong
Form of settlement:	Compact villages
Density of settlement:	Middle
Predominant form of agriculture:	Irrigated farming on terraces at the flanks of V-shaped valleys and dry farming.
Irrigation:	Irrigation channels draining streams / sources in main and lateral valleys.
Crops:	Dry farming: Cultivation of grain. Irrigated farming: Cultivation of vegetables, cattle fodder crops, olives and walnuts.
Accessibility / development of road infrastructure:	In general easy to access on paved road.
Future prospects / risks:	Intact agriculture. Too close to Marrakech to develop tourist infrastructure.
Remarks:	Absolutely no tourist infrastructure in this area.
Degree of documentation:	In general good.

Fig. 425: *Terraced fields for dry farming near Aït Slimane. View towards the Oued Zad valley (southwest), area T2, autumn 2015.*

Fig. 426: *Irrigated terraces (irrigation channel see arrow) with walnut trees near Aït Ouiksane. View towards south, area T2, autumn 2015.*

Fig. 427: *Irrigated terraces with olive and walnut trees naar Aït Ouiksane. View towards south, area T2, autumn 2015.*

Fig. 428: *Terraced fields in the foreground and in the middle ground (arrow) for dry farming near Aït Ouiksane. View towards the Oued Zad valley (southwest), area T2, autumn 2015.*

Fig. 429: *Erosion gullies that developed in the deforested part of a steep slope are stabilized with micro-dams. East of Aït Ouiksane, area T2, autumn 2015. For details see fig. 430.*

Fig. 430: *Detail of fig. 429: Erosion gullies that developed in the deforested part of a steep slope are stabilized with micro-dams. East of Aït Ouiksane, area T2, autumn 2015.*

9.2.2 Area T6
Foothill valley of Aghbalou

In contrast to most of the foothill areas in the Tensift catchment north of the High Atlas, in the small area T6 neither the natural hydrological system is disturbed through a dam, nor is it too densely populated or used for intensive, mechanical farming.

Tab. 30: Key attributes of area T6.

Morphological type of the higher / inner mountain areas:	Meandering stream in a shallow depression on the foot of High Atlas Mts., under normal hydrological conditions infiltrating already before it reaches the Oued Tensif alluvial plain.
Morphological type of the lower / outer mountain / foothill / alluvial plain areas:	---
Predominant rock types:	Slates, conglomerates, sandstones, partly with poor consolidation.
Geological / tectonic units / geological periods:	Precambrian, Miocene
Stream / river:	Periodic
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Conifers, evergreen oaks.
Density of natural vegetation:	Low – high
Degradation of natural vegetation:	Difficult to estimate.
Form of settlement:	Loose village
Density of settlement:	Low
Predominant form of agriculture:	Primarily dry farming, possible irrigated farming in case the stream carries water.
Irrigation:	In case the stream carries water (?).
Crops:	Cultivation of grain and olives; few vegetables and cattle fodder crops.
Accessibility / development of road infrastructure:	Easy to access on paved road.
Future prospects / risks:	Intact agriculture.
Remarks:	Absolutely no tourist infrastructure in this area.
Degree of documentation:	In general good.

Fig. 431: *View towards east over the northern foothills of the High Atlas Mountains. East of Aghbalou, area T6, autumn 2015.*

Fig. 432: *View towards east over the northern foothills of the High Atlas Mountains with the village Aghbalou and dry farming on the slopes above the village. Area T6, autumn 2015. for details see fig. 433.*

Fig. 433: *Detail of fig. 432 with the village Aghbalou. Area T6, autumn 2015.*

Fig. 434: *Village Aghbalou with fields for dry farming. View towards the High Atlas Mountains and the snow-covered Jebel Toubkal range in the background. Area T6, autumn 2015.*

9.3 Westernmost High Atlas Mountains (‘Atlantic Atlas’), transition to the Atlantic Ocean coast

9.3.1 Areas WA1, WA2 a-d, WA3 a-c and WA4 a, b Carbonate plateaus and valleys of the ‘Atlas Atlantique’ north of Agadir

The westernmost foothills of the High Atlas Mountains are called ‘Atlantic Atlas’ in this report, although they don’t have an own official name. They reach 1400 m altitude and are separated from the rest of the High Atlas Mountains by the broad Aït Messaoud valley with its Abdelmoumen Dam.

The difference in colour between the rather beige Atlantic Atlas Mountains and the reddish Aït Messaoud valley, as seen in fig. 435, is a result of the geological conditions (fig. 436): Whereas the Aït Messaoud valley consists of rather weak, dark read marls and argillaceous rocks of Triassic age (fig. 87), the Atlantic Atlas consists of mainly hard, beige Jurassic limestones that form plateaus and canyon-like valleys. In two depressions within the carbonate plateaus the underlying reddish Triassic marls and argillaceous rocks reach the surface (areas WA3a and WA3b).

The Jurassic limestones are covered with thin Terra Rossa soils that allow the growth of mostly loose conifer forests on the plateaus, whereas agriculture is restricted to the valleys. In areas dominated by limestones with carstic drainage, only dry framing is possible in spite of a precipitation rate of 400 - 800 mm. In these areas most rainwater seeps directly into the ground, and streams and rivers only contain water after extraordinary rainfalls. Some rainwater is stored in matfias (closed cisterns) or in small dams. In the two depressions with marly and argillaceous Triassic rocks, however (WA3a and WA3b), more water is available, allowing irrigated farming, too.

Settlements are mostly loose, often with scattered farmsteads. Compact, larger villages are restricted to the lower river valleys.

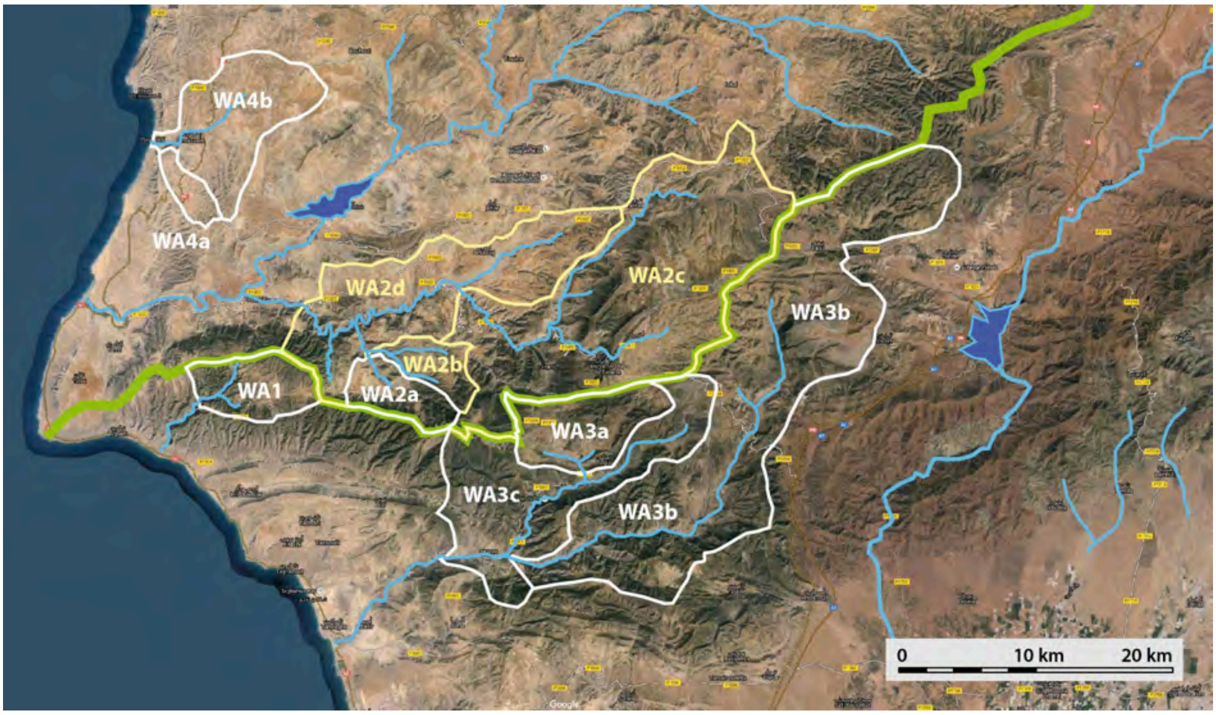


Fig. 435: *Satellite image of potential study areas in the westernmost High Atlas Mountains (‘Atlantic Atlas’). Note the reddish Aït Messaoud valley that consists of rather weak, dark read marls and argillaceous rocks of Triassic age east of the Atlantic Atlas. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

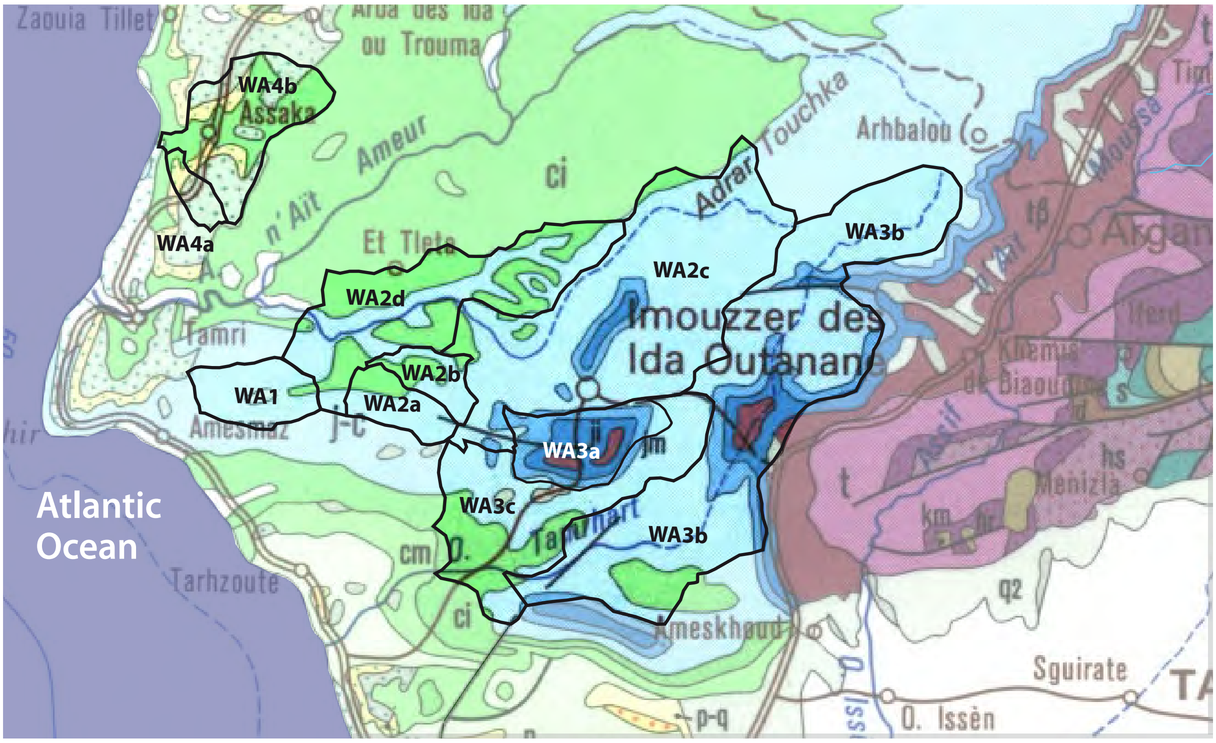


Fig. 436: *Geological map of the westernmost High Atlas Mountains showing potential study areas; modified after Saadi, M. et al., 1985, Carte Géologique du Maroc 1:1'000'000, Editions du Service Géologique du Maroc, see also annex III.*

Abbreviations for rock types forming mainly scarce carbonate plateaus and canyons (blue, green):

ji: Liassic (Jurassic) sedimentary rocks (grey limestones, few marls)

jm: Middle Jurassic sedimentary rocks (grey limestones, few marls)

j-C: Upper Jurassic sedimentary rocks with some Cretaceous rocks that are difficult to distinguish (grey limestones, few marls)

ci: Lower Cretaceous sedimentary rocks (grey limestones, marls)

Abbreviations for rock types forming fertile depressions and valleys (violet):

tβ: Triassic sedimentary rocks (mostly red marls and argillaceous rocks)

Tab. 31: Key attributes of the areas WA1 - WA4

Morphology:	Carbonate plateaus with canyon-type valleys and depressions.
Predominant rock types:	Carbonate plateaus and canyon-type valleys: Predominantly limestones and few marls. Depressions: Red marls and argillaceous rocks.
Geological / tectonic units / geological periods:	See fig. 436, page 199
Stream / river:	Predominantly periodic, in the 'Paradise Valley' permanent.
Predominant natural vegetation:	Loose or dense conifer forest (3-4 m high), shrubs.
Density of natural vegetation:	Middle – high
Degradation of natural vegetation:	Low
Form of settlement:	Loose villages, scattered settlements
Density of settlement:	Low-middle

Tab. 31: Key attributes of the areas WA1 - WA4, continuation from page 199.

Predominant form of agriculture:	Carbonate plateaus: Dry farming Depressions and canyons: Irrigated farming
Irrigation:	Irrigation channels draining streams / sources in main valleys.
Crops:	Carbonate plateaus: Cereals Depressions and canyons: Cereals, vegetables, cattle fodder crops and olives.
Accessibility / development of road infrastructure:	Few paved roads, many tough mud roads on the carbonate plateaus.
Future prospects / risks:	Intact agriculture. Development of tourist infrastructure is questionable as too close to Agadir.
Remarks:	Tourist infrastructure in the 'Paradise Valley' and in Imouzzer Ida ou Tanane.
Degree of documentation:	WA1, WA4a: Good WA2a, WA3a-c: Sufficient WA2b-d, WA4b: No documentation

***Fig. 437:** Conifer forest on the Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA1, autumn 2015.*

***Fig. 438:** Scattered settlement on the Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA1, autumn 2015.*

***Fig. 439:** Ploughed cereal fields and argan trees on the Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA1, autumn 2015.*

***Fig. 440:** Giant argan tree on the Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA1, autumn 2015.*

Fig. 441: *Traditional matfia (cistern) on the Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA1, autumn 2015.*

Fig. 442: *Traditional matfia (cistern) from fig. 441, seen from the opposite side. The water flows in the direction of the blue arrow through the hole (red arrow) into the matfia. Jurassic carbonate plateau in the Atlantic Atlas Mountains, area WA1, autumn 2015.*

Fig. 443: *Scattered farmsteads and terraced fields on the Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA1, autumn 2015.*

Fig. 444: *Modern matfia (cistern) and small dam (background) on the Jurassic carbonate plateau in the Atlantic Atlas Mountains. Areas WA2a+b, autumn 2015.*

Fig. 445: *Modern matfia (cistern) from fig. 444, seen from the opposite side. Jurassic carbonate plateau in the Atlantic Atlas Mountains, areas WA2a+b, autumn 2015.*

Fig. 446: *Village on the Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA2c, autumn 2015.*

Fig. 447: *Road cut showing Triassic marls and argillaceous rocks with a dark red colour that is characteristic for these rocks in the whole High Atlas Mountains. Carbonate plateau in the Atlantic Atlas Mountains. Area WA2c, autumn 2015.*

Fig. 448: *Road cut showing the boundary between weak Triassic marls and overlaying, harder Lower Jurassic limestones. Carbonate plateau in the Atlantic Atlas Mountains. Area WA2c, autumn 2015.*

Fig. 449: *Irrigated fields on Triassic red marls and argillaceous rocks near Aquestri. Carbonate plateau in the Atlantic Atlas Mountains. Area WA3a, autumn 2015.*

Fig. 450: *View into one of the valleys cutting through the Lower Jurassic carbonate plateaus in the Atlantic Atlas Mountains. View towards northwest, area WA2c, autumn 2015.*

Fig. 451: *Giant formation of calcareous sinter at the outflow of a karstic cavern system in the Jurassic limestones in the valley below Imouzzer des Ida ou Tanane. Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA2c, autumn 2015.*

Fig. 452: *Olive trees with irrigation channels in the valley below Imouzzer des Ida ou Tanane. Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA2c, autumn 2015.*

Fig. 453: *Deep valley named 'Vallée du Paradis' for touristic reasons, cutting through the Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA3c, autumn 2015.*

Fig. 454: *Deep valley ('Vallée du Paradis') cutting through the Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA3c, autumn 2015.*

Fig. 455: *Road cut showing a coarse breccia representing a solidified debris flow. Cracks and pockets are filled with red brown 'Terra Rossa' soil. 'Vallée du Paradis', Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA3c, autumn 2015.*

Fig. 456: *Argan- olive- and palm trees on a terrace above the 'Vallée du Paradis'. Jurassic carbonate plateau in the Atlantic Atlas Mountains. Area WA3c, autumn 2015.*

Fig. 457: *View from the eastern edge of the Jurassic carbonate plateau eastwards into the Asif Tamrakhte Valley with its weak, dark read, Triassic marls and argillaceous rocks. Atlantic Atlas Mountains, area WA3b, autumn 2015.*

Fig. 458: *View from below the eastern edge of the Jurassic carbonate plateau into the Asif Tamrakhte Valley (view up the valley). Atlantic Atlas Mountains, area WA3b, autumn 2015.*

Fig. 459: *View from the western edge of the Jurassic carbonate plateau westwards to the Atlantic Ocean. Atlantic Atlas Mountains, southwest of area WA4a, spring 2015.*

Figs. 460 and 461: *Village Afra (scattered settlement) on the western edge of the Jurassic carbonate plateau in the Atlantic Atlas Mountains. View towards east, area WA4a, spring 2015.*

Part V Potential study areas in the Antiatlas Mountains

1 Morphological types

In this report the Antiatlas Mountains are subdivided into two regions of different size. The western slope of the westernmost Antiatlas belongs to the small Oued Massa catchment that is provided with enough humidity from the close Atlantic Ocean to dispose of little, but mostly permanent streams flowing together to form Oued Massa. All areas east of the Oued Massa catchment belong to the Oued Sousse and to the very large Oued Drâa catchments. Since in these semi-arid and arid regions with precipitation rates between 100 and 400 mm/y the water of local streams never reaches a main river under normal hydrologic conditions, a subdivision into watersheds is not appropriate for this report. The potential study areas are thus subdivided into northern slope areas (AN) and southern slope areas (AS) only. Even large areas that belong to the same hydrologic system are poor in water, streams and rivers mostly disappearing in the underground already before they reach the foot of the mountains.

In the Antiatlas Mountains, morphology is strongly dependent on the geological conditions, even more than in the High Atlas Mountains. To simplify matters one could say that morphology is the direct expression of the various rocks types. Due to a low precipitation rate even sub-catchments are large and often cover several geological units, resulting in a variable morphology within one and the same sub-catchment.

The spatial arrangement of the rocks in the Antiatlas Mountains is principally the result of a rare type of deformation that led to the formation of domes and depressions, comparable to a egg crate, but less regular. The domes of this egg crate are called “boutonnières” (button holes) in French, and in English the name “inlier” is common for this phenomenon.

The Antiatlas Mountains can roughly be subdivided into four lithological domains (fig. 4), sorted in accordance with their geological age from oldest to youngest:

1.1 Domain A: Inliers with predominantly Precambrian granites, schists and gneiss

The resistance to mechanical weathering under desert conditions such as insolation bursting of most of these rocks is low, so that type A domains mostly form flat, deeply eroded pans, surrounded by cliffs of domain B and/or C

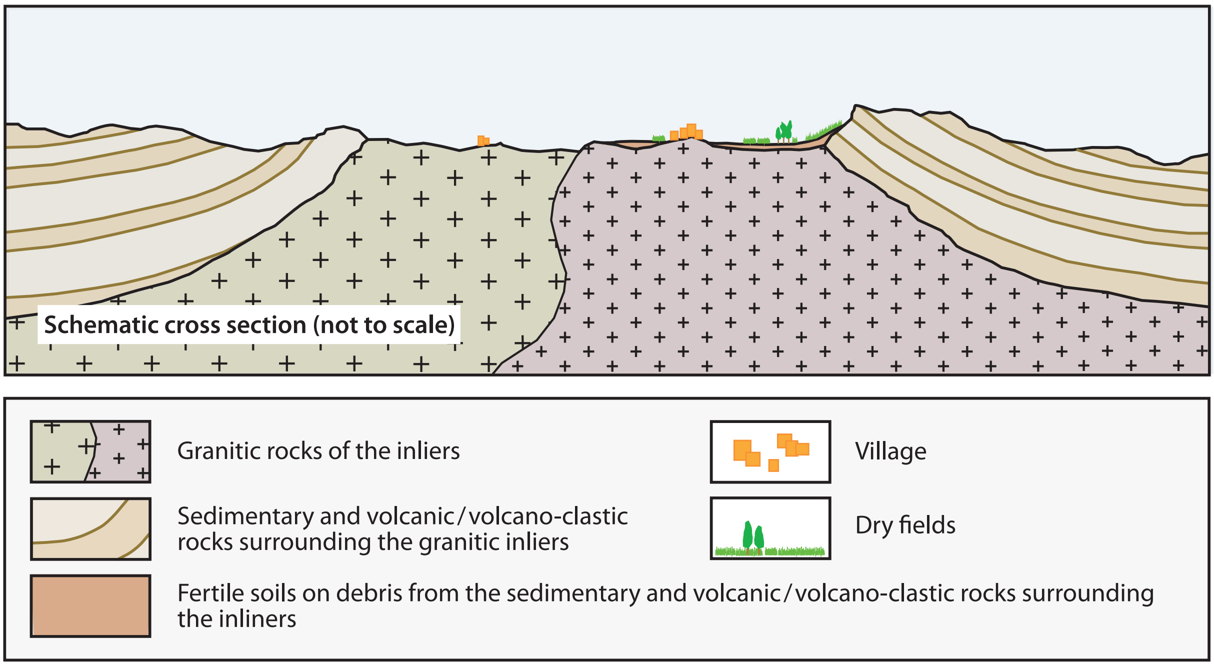


Fig. 1: *Schematic cross section of an inlier with Precambrian granites. On these generally infertile soils agriculture is restricted to those areas, where debris from the surrounding domain C rocks contribute to an amelioration of the soil.*

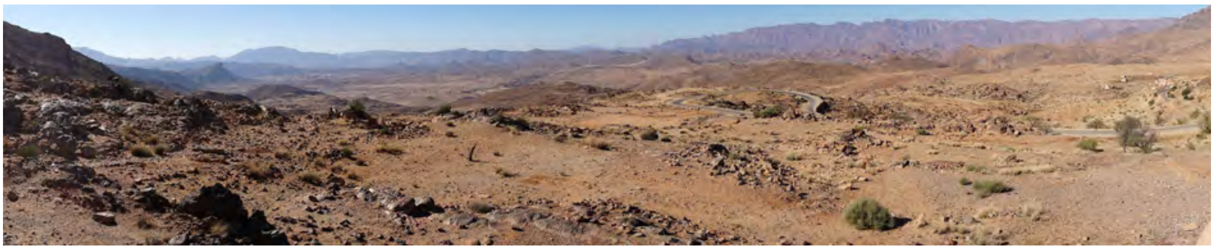


***Fig. 2:** View towards northwest over the deeply eroded lowest Precambrian granite pan west of Tafraoute from its southern rim. Area Ma3d, autumn 2015.*

***Fig. 3:** View into the northern part of the deeply eroded granite pan of Tazenackht from its western rim near Kourkouda. North of area AN4b, autumn 2015.*

rocks (figs. 1-3). Soil formation processes apparently do hardly take place, the fertility of the soils is therefore very low. Accordingly the settlement density is minimal, with the exception of the areas south of Tazenackht and the surroundings of Aït Soulyman in the southwestern Antiatlas, where farming is possible on more fertile soils that presumably developed on debris and alluvial material from the surrounding domain B and C volcanic rocks and conglomerates. Domain A areas do not play an important role in the selection of study areas for the project.

1.2 Domain B: Inliers with predominantly Precambrian quartzites, conglomerates and volcanic rocks

These areas build the highest elevations in the Antiatlas Mountains, reaching over 2300 m altitude, including pronounced peaks but also plateaus (figs. 5-7). Whereas quartzitic areas are not, or only scarsely inhabited as they build jagged, steep rocks, conglomerates and volcanic rocks host numerous small villages in valleys resembling gutters that are distributed criss-cross along fault zones. The quartzites, however, seam to play an important role for the water supply as numerous sources emerge at the foot of mountains made of quartzite. Most valleys in the type B domains are V-shaped valleys with periodic, or locally even permanent streams. Numerous villages in this domain were also built high up on the mountain slopes without any relation to mayor surface watercourses, the yield of sources being obviously sufficient for them.

***Fig. 4, fold-out plate:** Comparison between a satellite image and a geological map showing an outstanding correlation between morphology and geology. The four main geo-morphologic domains of the Antiatlas Mountains are.*

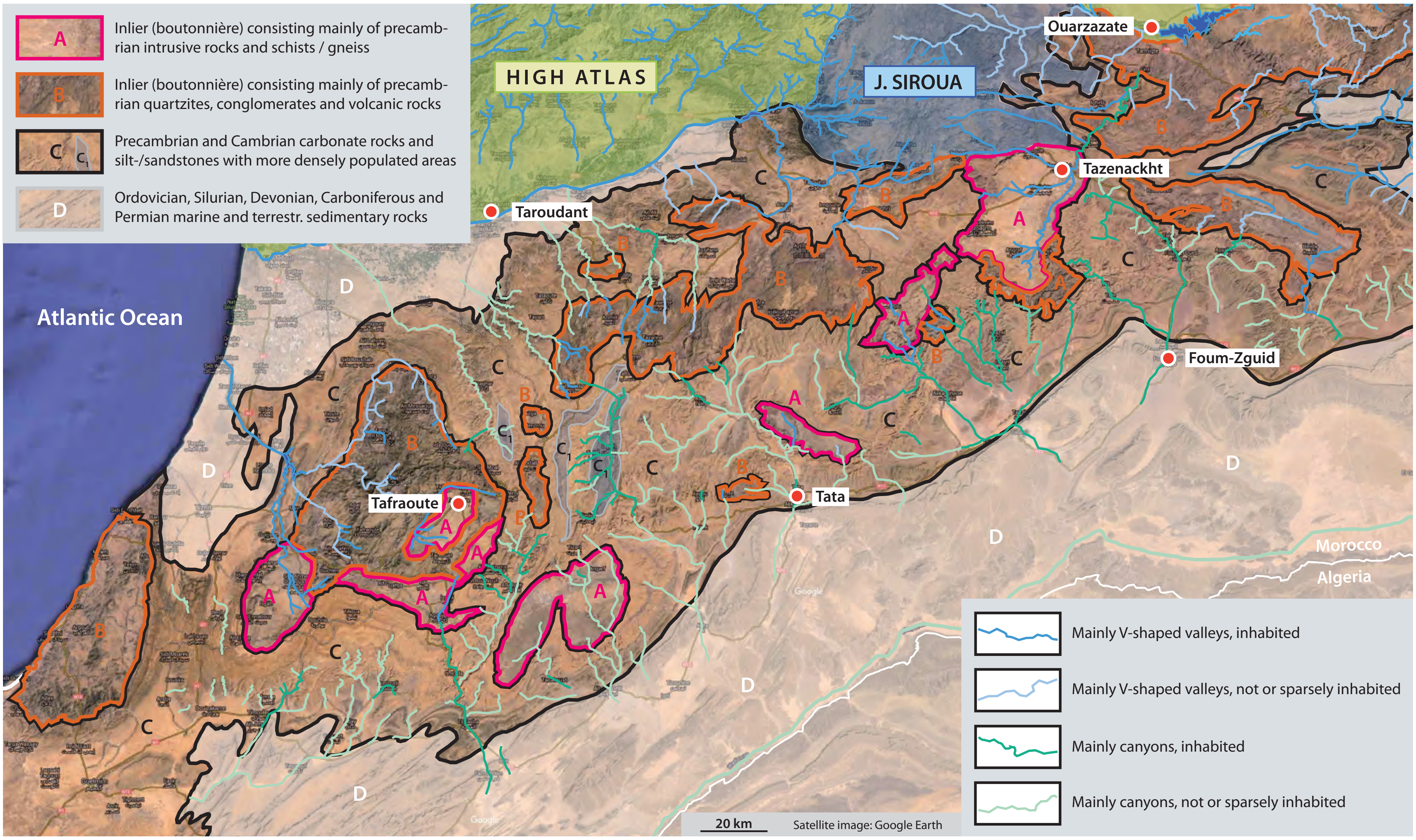
***Domain A:** Inliers with predominantly Precambrian granites, schists and gneiss, consisting of the following rock types: MxI: Migmatites; xI: Micashists, gneiss; yxI, $yxII^1$, $yxII^2$, $yxII^3$: Granites and diorites; δxI: Gabbros and dolerites.*

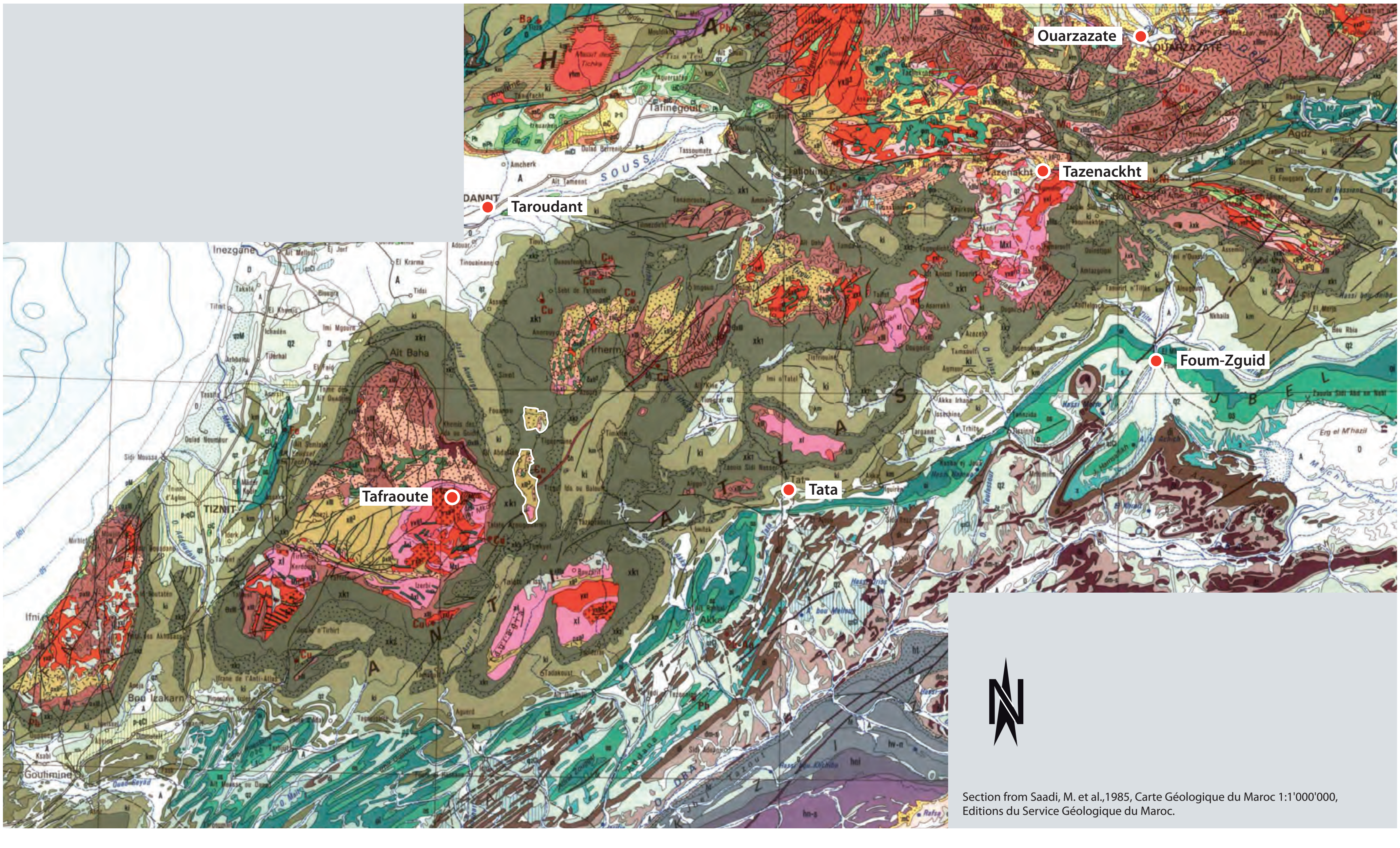
***Domain B:** Inliers with predominantly Precambrian quartzites, conglomerates and volcanic rocks, consisting of the following rock types: xII^2Q: Quartzites and locally dolomites; δxII^2: Gabbros and dolerites; xII^3: Schistose sandstones and conglomerates; xIII: Acidic volcanic rocks and volcano-clastic rocks (mostly conglomerates), and subordinate yxI: Granites and diorites.*

***Domain C:** Hilly highlands furrowed with deep canyons towards their edges, mainly consisting of the following rock types: xk1: Thin bedded (5 cm to 1 m) limestones, dolomites and silt-/sandstones of uppermost Precambrian age; xk2: Thin bedded silt- and sandstones of mostly dark reddish colour ("lie de vin" or Taliouinien Beds); ki: Limestones, dolomites and silt-/sandstones of Lower Cambrian age; km: Shales, silt- and sandstones of Middle Cambrian age.*

***Domain C_1:** Areas with higher density of settlements (xk2 and parts of km).*

***Domain D:** The lowlands with mostly isolated, parallel mountain ridges in the Jebel Bani consist of marine carbonate and detritic rocks of Ordovician (o, oi, os), Silurian (s) and Devonian (di, dm, dm-s) ages, partly intruded by Triassic dolerites (δt).*


A Inlier (boutonnière) consisting mainly of precambrian intrusive rocks and schists / gneiss
B Inlier (boutonnière) consisting mainly of precambrian quartzites, conglomerates and volcanic rocks
C C1 Precambrian and Cambrian carbonate rocks and silt-/sandstones with more densely populated areas
D Ordovician, Silurian, Devonian, Carboniferous and Permian marine and terrestr. sedimentary rocks
HIGH ATLAS
J. SIROUA
Ouarzazate
Tazenackht
Taroudant
Atlantic Ocean
Foum-Zguid
Tafraoute
Tata
Morocco
Algeria
Mainly V-shaped valleys, inhabited
Mainly V-shaped valleys, not or sparsely inhabited
Mainly canyons, inhabited
Mainly canyons, not or sparsely inhabited
20 km
Satellite image: Google Earth


Ouarzazate
Tazenackht
Taroudant
Foum-Zguid
Tafraoute
Tata
N
Section from Saadi, M. et al.,1985, Carte Géologique du Maroc 1:1'000'000, Editions du Service Géologique du Maroc.

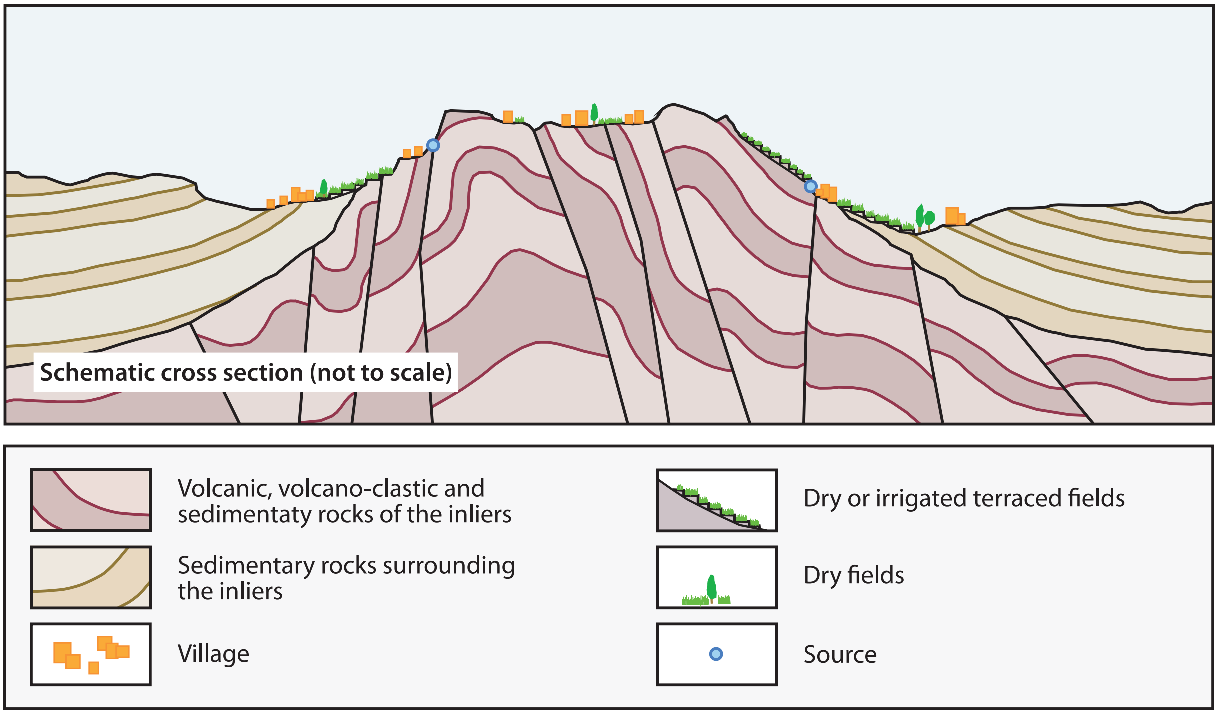


Fig. 5: *Schematic cross section of an inlier with Precambrian volcanic, volcano-clastic and sedimentary rocks. Most inliers underwent strong deformation during compression, that led to the formation of numerous steep faults.*

Fig. 6: *High valley between Tagadirt and Azgéér in the mountains north of Tafraoute, representing the biggest inlier that also forms the highest elevations. Dark brown rocks are conglomerates, and light brown rocks are quartzites. Area Ma1b, autumn 2015.*

Fig. 7: *Small, rather flat inlier with lower elevations east of Tafraoute, with the villages Amzawr (left) and Zghnghen (right), view towards south. In the background the high elevations of the inlier north of Tafraoute (see fig. 6) are visible. Rocks are predominantly conglomerates. Area AN3a, spring 2015.*

1.3 Domain C: Hilly highlands consisting of Precambrian and Cambrian carbonate and clastic rocks, furrowed with deep canyons towards the edges

Due to a low precipitation rate periodic or episodic streams only manage to carve gentle hills out of these mostly thinly bedded sedimentary rocks (figs. 9, 10). Irrigated agriculture along the streams is not possible and the thin, poor soils that are typical for arid, carbonate-dominated regions only allow dry farming in sinks where additional soil has been accumulated over the centuries. Accordingly most villages have been built independently from streams and are without any access to mayor surface watercourses. In most areas dominated by Precambrian rocks, villages are rare. In the silty and partially also argillaceous Precambrian "Lie de vin" or 'Taliouinien Beds' and in some Lower Cambrian beds (C_1 in fig. 4), however, the density of villages is higher. This may be the result of more advantageous weathering processes resulting in more fertile soils or / and a higher content of pore water that can be used as groundwater.

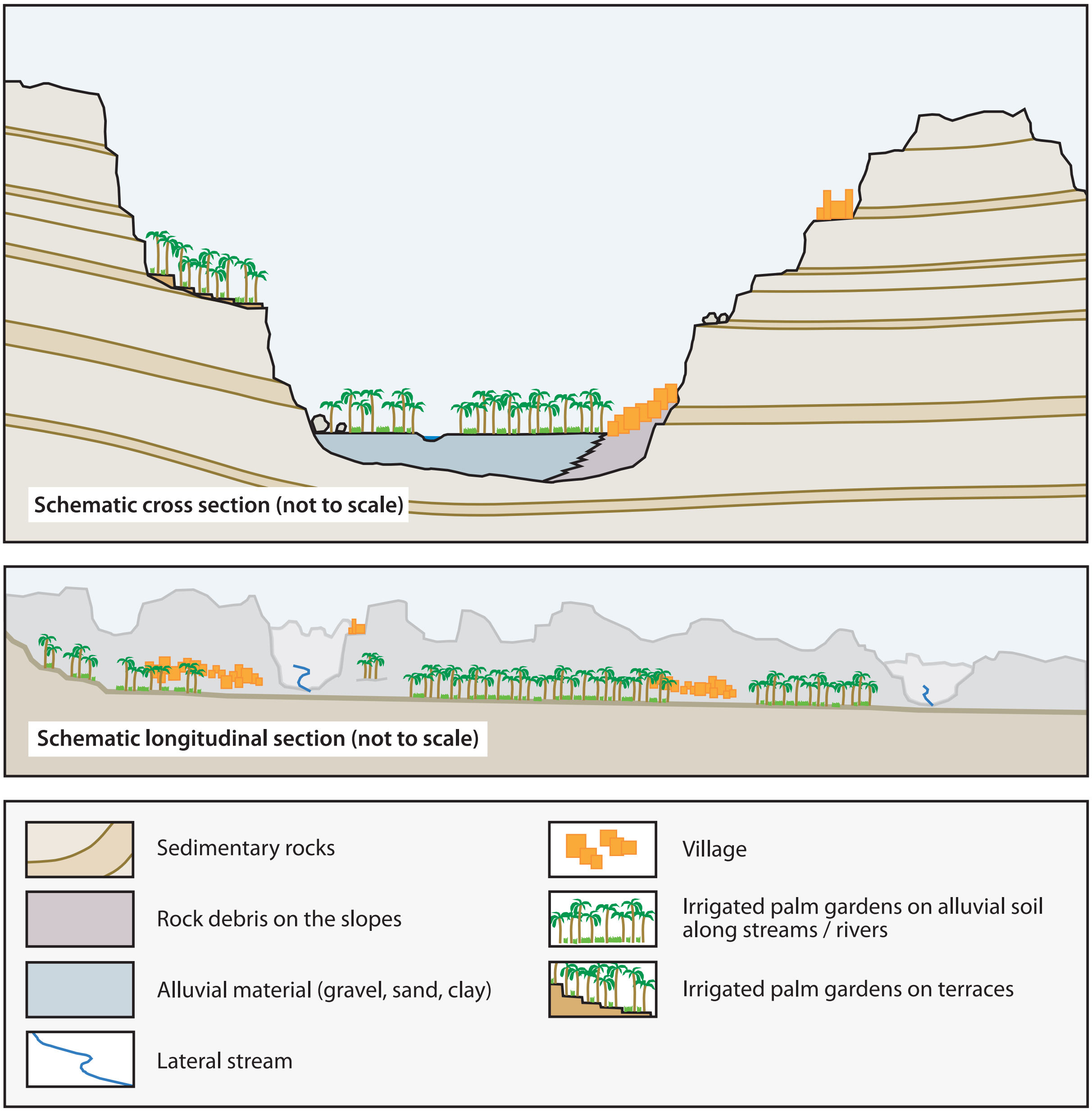


Fig. 8: *Schematic cross and longitudinal sections of a canyon, cutting through the edge of the Precambrian / Cambrian hilly highlands with characteristic steep walls and palm oases. Terraced palm gardens high up in the rock walls are typical for these areas, but in general they are rather rare. The fields are irrigated by means of irrigation channels leading water from lateral valleys and from the main valley on higher levels and parallel to the contour lines to the fields.*

Towards the edges, dozens of streambeds that are hardly visible in the dry season join together and transform into deep, long canyons that are cut into the highlands. They can be over 50 km long and several hundred meters deep (figs. 8, 11, 12). Due to different erosion resistances, canyons in Precambrian rocks (xk1, xk2 in fig. 4) are mostly steep and rough, whereas in Cambrian rocks (ki, km in fig. 4) more open, gentle valleys were formed. The most impressive canyons are to be found on the southern edge of the highlands between Taghijit and Tata and between Akka Irhen and Foum Zguid.

Fig. 9: *View over the highlands towards northwest from Agadir Tasguent. Areas AN3d and AN3f, autumn 2015.*

Fig. 10: *Highlands with the villages Titeki (left) and Aferni (right), view towards east. Area AN3c, spring 2015.*

Fig. 11: *Outflow of the Amtoudi canyon through uppermost Precambrian sedimentary rocks (xk1/xk2) with a high resistance towards erosion. View down the valley, area AS2, autumn 2015.*

Fig. 12: *Lower canyon of Assif N'Innt cutting through Lower Cambrian rocks with a lower resistance towards erosion compared with fig. 11. Village Imouzlag on the right hand side, area AS1i, autumn 2015.*

1.4 Domain D: Foothills and lowlands with mostly isolated, parallel mountain ridges of Paleozoic age in the Jebel Bani and the Drâa Valley

The southernmost mountain range of the Antiatlas Mountains is called Jebel Bani. It extends from southwest to northeast and consists of mostly isolated, long ridges of Paleozoic sedimentary rocks that are joined together like garlands, an impression that is underlined on the geological map by numerous large-scale folds affecting these garlands (fig. 4, bottom left). The mountain ridges rise up out of broad and flat, bent valleys filled with alluvial detritus (figs. 13, 14) through which dry riverbeds search their way towards the south, equal to a labyrinth. These areas are sparsely populated with some towns that are mostly situated in passage-ways, where rivers cut through mountain ridges (kluses). Domain D areas do not play an important role in the selection of study areas for the project.

Fig. 13: *Parallel mountain ridges oriented SW-NE with an alluvial plain in between, consisting of lower Paleozoic rocks. Between Timoulay and Taghijit, Jebel Bani, southern Morocco, autumn 2015.*

Fig. 14: *Parallel low ridges consisting of Ordovician rocks oriented SW-NE southwest of Aït Ouabelli. Jebel Bani, southern Morocco, autumn 2015.*

The potential study areas in the Antiatlas Mountains are subdivided into three groups:

- Ma: All areas belonging to the Oued Massa catchment in the westernmost Antitalas.
- AN: All areas on the northern slope of the Antiatlas, draining into the Oueds Sousse and Drâa.
- AS: All areas on the southern slope of the Antiatlas, draining into Oued Drâa.

The geographical and geologic situations are depicted in figures 15 and 19, respectively.

2 How are local incomes generated?

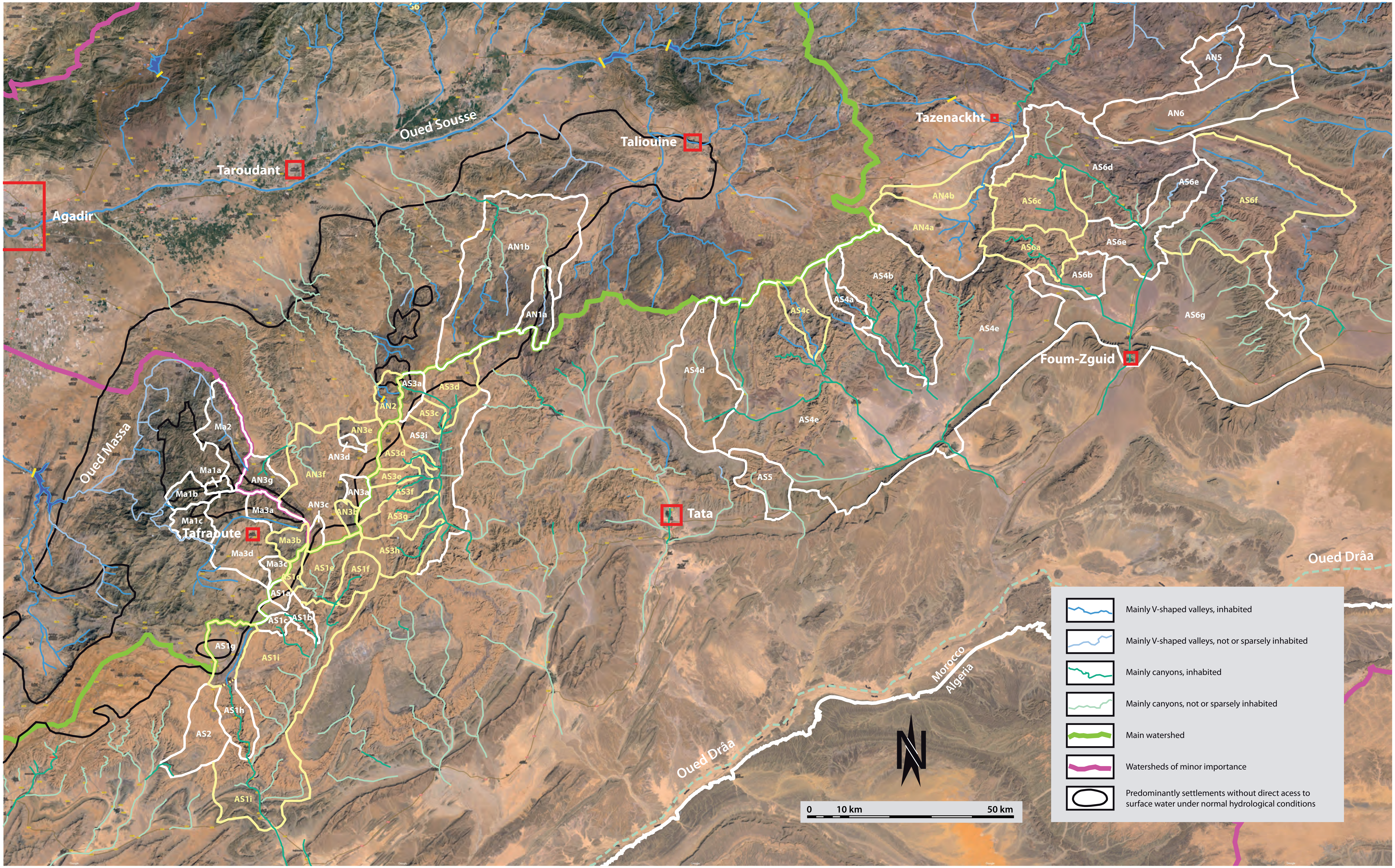
In contrast to the High Atlas Mountains, where agriculture is the main income generating activity in most of the areas, this seems not to be the case in numerous regions particularly of the western Antiatlas. Three observations contribute to this finding:

1. In large parts of the western Antiatlas Mountains, wherever the steepness, the geological conditions and the fertility of the soil allow agriculture, the slopes are terraced with narrow terraces for dry cultivation of grain. In many areas, however, these terraces are about to disintegrate and to vanish in the natural vegetation (fig. 16). Also many almond plantations are drying up with numerous almond trees being already dead.
2. In many western Antiatlas villages numerous large, modern, newly painted yellow or salmon pink, but often vacant houses made of bricks and concrete attract the attention, because they are not in relation to the moderate income provided by agriculture (figs. 17, 18), whereby many traditional houses made of mud and stones are not inhabited any more and are about to disintegrate or are already ruins.
3. The industrial sector is rudimentary or non-existent in the mountainous areas. The services sector, too, is not at all developed in such a way that it could generate incomes allowing to built so many and so big new houses.

This indicates that an important part of the local income is not generated in the villages any more, but in cities like Agadir, Casablanca, Rabat or Tangier. As the eighty ears old owner of a local museum in Oumesnat explained, migration has a long tradition in the western Antiatlas and already his parents worked in Tangier, travelling only twice a year back home for some weeks. Today, most families have successful relatives in one of the big cities outside the Antiatlas, their economic success being expressed with new houses that are inhabited during summer holidays only. The decline of agriculture may be the result of the very limited prospects of success compared

Fig. 15, fold-out plate: *Satellite image of potential study areas in the Antiatlas Mountains. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.



Oued Sousse
Taroudant
Agadir
Taliouine
Tazenackht
Oued Massa
Tafraoute
Tata
Foum-Zguid
Oued Drâa
Oued Drâa
Morocco
Algeria
AN5
AN6
AN4b
AN4a
AS6d
AS6e
AS6c
AS6f
AS6a
AS6e
AS6b
AS6g
AN1b
AN1a
AS4b
AS4a
AS4c
AS4e
AS4d
AS4e
AS5
AS3a
AS3d
AN2
AS3c
AN3e
AS3i
AN3d
AS3d
AN3f
AS3e
AN3g
AN3a
AS3f
AN3c
AN3b
AS3g
AS3h
Ma2
Ma1a
Ma1b
Ma1c
Ma3a
Ma3b
Ma3d
Ma3c
AS1e
AS1f
AS1a
AS1c
AS1b
AS1g
AS1i
AS1h
AS2
AS1i
0
10 km
50 km
Mainly V-shaped valleys, inhabited
Mainly V-shaped valleys, not or sparsely inhabited
Mainly canyons, inhabited
Mainly canyons, not or sparsely inhabited
Main watershed
Watersheds of minor importance
Predominantly settlements without direct acess to surface water under normal hydrological conditions

with the necessary workload on steep mountain slopes and it may have been accelerated by the implementation of wild boars by the government in order to sell hunting licences to wealthy city dwellers as explained by the museum owner. The summery wave of temporary homecomers, however, brings the local water supplies to the brink of collapse every year.

Fig. 16: *Most of these artfully arranged terraces near Azouran and Tilian west of Tafraoute are about to disintegrate. Domain B, area Ma1c, autumn 2015*

Fig. 17: *An overdimensioned modern building, perceived as a foreingn body in the landscape, seen between Tafraoute and Ida Oussemlal, autumn 2015.*

Fig. 18*: A traditional village (left on the hill) and its modern offshoot with salmon pink, new houses (right) between Tafraoute and Ida Oussemlal, autumn 2015.*

Fig. 19, fold-out plate: *Geological map of the Antiatlas Mountains showing potential study areas (modified after Saadi, M. et al., 1985, Carte Géologique du Maroc 1:1'000'000, Editions du Service Géologique du Maroc, see also annex III).*

Abbreviations (from oldest to youngest):

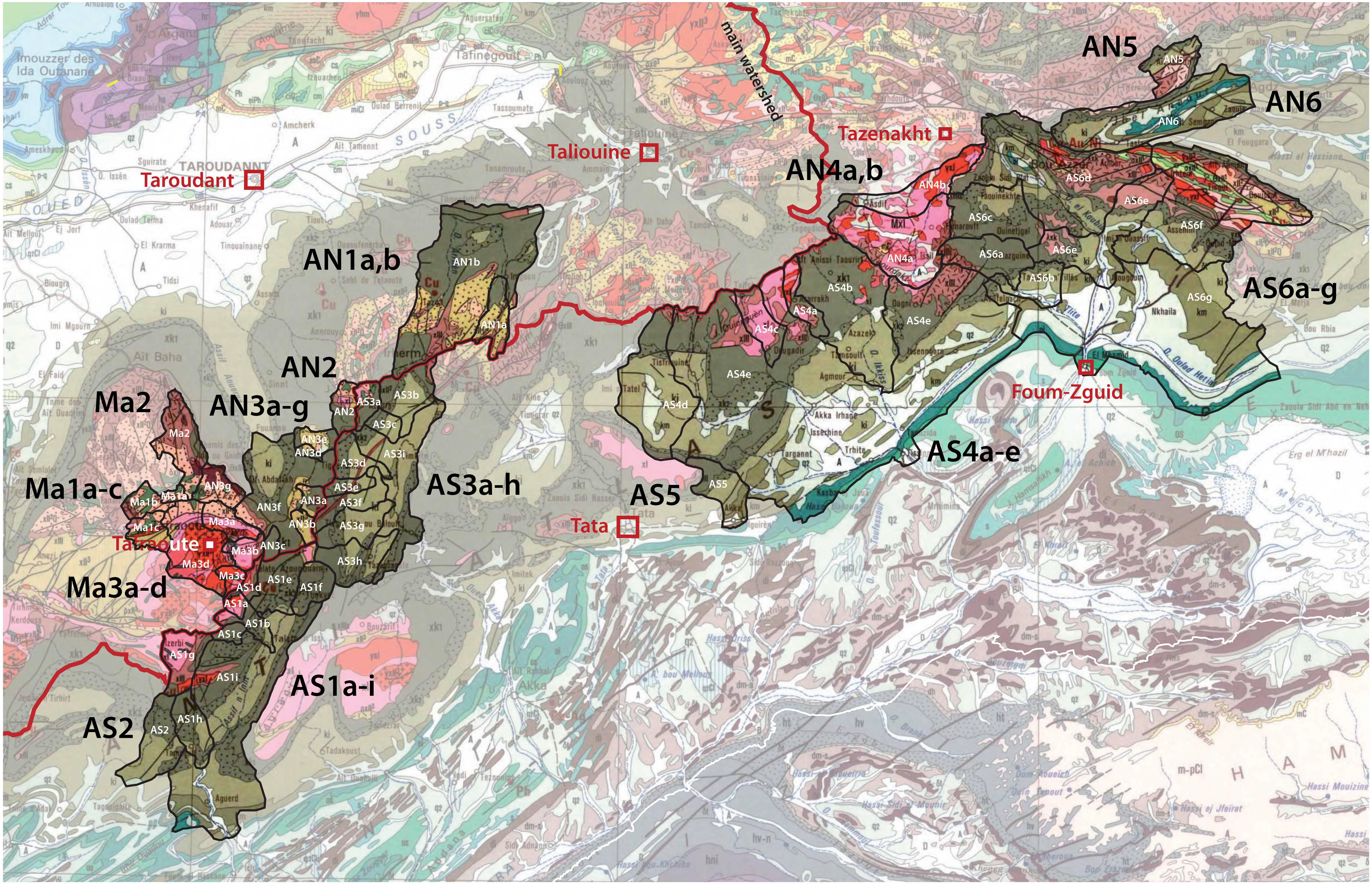
Precambrian I: *MxI: migmatites; xI: Micashists, gneiss; yxI: Granites and diorites, δxI: Gabbros and dolerites.*

Precambrian II: *$yxII^1$, $yxII^2$, $yxII^3$: Granites and diorites; xII^2Q: Quartzites and locally dolomites; δxII^2: Gabbros and dolerites; xII^3: Schistose sandstones and conglomerates;*

Precambrian III: *xIII: Acidic volcanic rocks and volcanoclastic rocks (mostly conglomerates).*

Uppermost Precambrian: *xk1: Thin bedded (5 cm to 1 m) limestones, dolomites and silt-/sandstones; xk2: Thin bedded silt- and sandstones of mostly dark reddish colour ("lie de vin" or Taliouinien Beds).*

Paleozoic: *ki: Limestones, dolomites and silt-/sandstones of Lower Cambrian age; km: Shales, silt- and sandstones of Middle Cambrian age; marine carbonates and detritic rocks of Ordovician (o, oi, os), Silurian (s) and Devonian (di, dm, dm-s) ages, partly intruded by Triassic dolerites (δt).*


main watershed
Taroudant
Taliouine
Tazenakht
Tata
Foum-Zguid
Tafraoute
AN1a,b
AN2
AN3a-g
AN4a,b
AN5
AN6
AS1a-i
AS2
AS3a-h
AS4a-e
AS5
AS6a-g
Ma1a-c
Ma2
Ma3a-d

3 Potential study areas in the Oued Massa catchment

3.1 Areas Ma1 a-c and Ma3 a-d
Tafraoute and the surrounding areas in the westernmost Antiatlas Mountains

The areas Ma1 and Ma3 are introduced together because they belong to the same central sub-catchment of Oued Massa and they could well also be processed as one area. However, they are very different from one another, area Ma1 mostly being dominated by domain B rocks and area Ma3 mostly being dominated by domain A rocks. Area Ma1 is therefore more fertile and its slopes are terraced with narrow terraces for dry cultivation of grain wherever possible. Most of them, however, are out of use today (see chapter 2). Those parts of area Ma3 that contain domain A rocks in contrast are largely infertile. Particularly pure granitic soils are completely barren.

The areas M3a and M3d are part of the Ammeln valley, in the villages of which rnumerous comfortable and mostly oversized houses have been built in the last decade that mainly serve as holiday residences for emigrated locals. The town of Tafraoute is developing fast and new tourist infrastructure is built every year. All this results in an increasing demand for water that is difficult to cover particularly in summer time. The Tafraoute administration tries to force the villages in the Ammeln valley to provide the town with water, which of course does not meet with their approval. Thus, conflicts about water are inevitable in the Ammeln valley – Tafraoute region.

Tab. 1: Key attributes of the areas Ma1 a-c and Ma3 a-d.

	Areas		
	Ma1a, Ma1b, Ma1c	Ma3a	Ma3b, Ma3c, Ma3d
Geol. / morphological domain:	B	A, B	A
Rock types, units / periods:	See fig. 19, page 212.		
Stream / river:	Permanent / periodic	Periodic	Periodic / episodic
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Replaced by argan trees.		Perennials; in Ma3d also argan trees in lower altitudes.
Density of natural vegetation:	Low - middle		Very low - low
Degradation of natural vegetation:	Higher altitudes: Low Lower altitudes: Replaced by argan trees.		Low
Form of settlement:	Loose villages, partly scattered; along watercourses and high up on slopes.	Compact villages	Compact villages
Density of settlement:	Low	High	Low
Predominant form of agriculture:	Dry cultivation on terraces.	Dry cultivation on terraces, irrigated in valley bottom.	Rare, except in area Ma3d (similar to Ma3a).
Irrigation:	Sources, rare	Sources, wells	--
Crops:	Grain, almonds, argan		
Accessibility / development of road infrastructure:	Easy to access on paved roads.		
Future prospects / risks:	Agriculture is not intact, many incomes depend on migrants.		
Remarks:	Tourist infrastructure is concentrated in Tafraoute and the Ammeln valley.		
Degree of documentation:	Ma1a, Ma1c: Good Ma1b: Poor	Good	Ma3b: No documentation Ma3c, Ma3d: Good

Fig. 20: *Mountains made of Quartzite (yellowish-brown) and conglomerate (reddish brown) southwest of Tazka. Representative for domain B, area Ma1a, autumn 2015.*

Fig. 21: *Scattered settlement near Tazka. Representative for domain B, area Ma1a, autumn 2015.*

Fig. 22: *Scattered settlement near Tazka. Representative for domain B, area Ma1a, autumn 2015.*

Fig. 23: *Terraced fields with almond trees between Tagadirt and Azgéér. Domain B, area Ma1a, autumn 2015.*

Fig. 24: *Village between Tagadirt and Azgéér with almond trees. Domain B, area Ma1b, autumn 2015.*

Fig. 25: *Traditional, isolated farmhouse in a valley between Tagadirt and Azgéér. Domain B, area Ma1b, autumn 2015.*

Fig. 26: *Terraced mountain slopes with Argan trees near Azouran and Tilian, view towards southwest. Domain B, area Ma1c, autumn 2015.*

Fig. 27: *Terraced mountain slopes with Argan trees near Azouran and Tilian, view towards southwest. Domain B, area Ma1c, autumn 2015.*

Fig. 28: *Section from fig. 27. Domain B, area Ma1b, autumn 2015.*

Fig. 29: *Terraced mountain slopes with Argan trees near Azouran and Tilian, view towards southwest. Domain B, area Ma1c, autumn 2015.*

Fig. 30: *Tilian, view towards southwest. Domain B, area Ma1c, autumn 2015.*

Fig. 31: *Traditional houses in extraordinarily good condition in Azouran. Domain B, area Ma1c, autumn 2015.*

Fig. 32: *View towards southwest over Thmani and Tisi. Domain B, area Ma1c, autumn 2015.*

Fig. 33: *Modern matfia (cistern) for the storage of rain water running off quickly. Near Tagezin, view towards southwest over Thmani and Tisi. Domain B, area Ma1c, autumn 2015.*

Fig. 34: *View towards west into the uppermost Ammeln Valley with a terraced mountain slope and Argan trees. Domain B, area Ma3a, autumn 2015.*

Fig. 35: *Village Tifghalt with numerous modern houses in the uppermost Ammeln Valley. Area Ma3a, autumn 2015.*

Fig. 36: *Village Imi N'Tizght with Argan trees in the upper Ammeln Valley. Domain B, area Ma3a, autumn 2015.*

Fig. 37: *Village Oumesnat in the upper Ammeln Valley. Domain B, area Ma3a, autumn 2015.*

***Fig. 38:** Inhabited traditional houses in the foreground and disintegrated traditional houses in the middle ground. Village Oumesnat in the upper Ammeln Valley, domain B, area Ma3a, autumn 2015.*

***Fig. 39:** Argan trees in Oumesnat, upper Ammeln Valley. Area Ma3a, autumn 2015.*

***Fig. 40:** Local rural development association in Oumesnat, upper Ammeln Valley. Area Ma3a, autumn 2015.*

***Fig. 41**: Irrigation channel (arrow) and olive trees, Oumesnat, upper Ammeln Valley. Area Ma3a, autumn 2015.*

***Fig. 42**: Plastic taps for irrigation in Oumesnat, upper Ammeln Valley. Each tap belongs to one family and is connected to a specific source in a lateral valley. A common distributing system does not exist. Area Ma3a, autumn 2015.*

***Fig. 43:** Lower Ammeln Valley with terraced slopes and Argan trees, view towards northeast. Mountains up to 2300 m altitude made of quartzite and conglomerate are in the background and on the left hand side. The right hand side consists of slightly metamorphic clastic sediments. Domain B, area Ma3d, autumn 2015.*

***Fig. 44:** Lower Ammeln Valley with quartzite and conglomerate mountains on the left hand side and in the background, and slightly metamorphic clastic sediments on the right hand side. View towards northeast, domain B, area Ma3d, autumn 2015.*

***Fig. 45:** View towards southwest over Village Asguine and the lower Ammeln Valley. Domain B, area Ma3d, autumn 2015.*

***Fig. 46:** Road into the lateral valley of Tagdicht in the quartzite and conglomerate mountains east of Asguine. Domain B, area Ma3d, autumn 2015.*

***Fig. 47**: Dry stream bed in the lateral valley of Tagdicht. Domain B, area Ma3d, autumn 2015.*

***Fig. 48:** Lateral valley of Tagdicht, view down the valley towards southwest. Domain B, area Ma3d, autumn 2015.*

***Fig. 49:** View towards northwest over the deeply eroded lowest Precambrian granite pan west of Tafraoute from its southern rim. Domain A, area Ma3d, autumn 2015.*

Fig. 50: *Remnants of erosion-resistant granite bodies in the deeply eroded lowest Precambrian granite pan west of Tafraoute. Domain A, area Ma3d, autumn 2015.*

Fig. 51: *Remnants of erosion-resistant granite bodies in the deeply eroded lowest Precambrian granite pan west of Tafraoute. Domain A, area Ma3d, autumn 2015. The background consists of domain B quartzites and conglomerates.*

Fig. 52: *Village Ayighd on a high plain between Tafraoute and Tasserirt. Domain B, area Ma3c, autumn 2015.*

Fig. 53: *View towards northwest over the deeply eroded lowest Precambrian granite pan west of Tafraoute from the pass road to Tasserirt on its southern rim. Domain A, area Ma3d, autumn 2015.*

3.2 Area Ma2
Valley of Biougra - Tahougat

Area Ma2 consists of one central valley only that mainly is situated within domain B rocks. It is therefore quite homogenous regarding the geological conditions. In this area, few villages only have an easy access to a mayor surface watercourse and to the related groundwater. Numerous villages were built high up on the slopes, where they apparently depend from sources that emerge from quartzite and conglomerate rocks.

Tab. 2: Key attributes of area Ma2.

	Area
	Ma2
Geol. / morphological domain:	B
Rock types, units / periods:	See fig. 19, page 212.
Stream / river:	Permanent / periodic
Predominant natural vegetation:	Higher altitudes: Perennials. Lower altitudes: Replaced by argan trees.
Density of natural vegetation:	Middle – high
Degradation of natural vegetation:	Higher altitudes: low Lower altitudes: Replaced by argan trees.
Form of settlement:	Loose villages, partly scattered, along watercourses and high up on slopes.
Density of settlement:	Low - middle
Predominant form of agriculture:	Dry cultivation on terraces.
Irrigation:	Wells, rare
Crops:	Grain, almonds, argan
Accessibility / development of road infrastructure:	Easy to access on paved roads.
Future prospects / risks:	Agriculture is not intact; many incomes depend on migrants.
Remarks:	Modest tourist infrastructure in Madao.
Degree of documentation:	Good

***Fig. 54:** Beginning of the valley near Amzkhssane, view towards east. Domain B, area Ma2, autumn 2015.*

***Fig. 55:** Kasbah Tizourgane in the high plain of Ida Ou Gnidif, view towards southwest. Domain B, area Ma2, spring 2015.*

Fig. 56: *Kasbah Tizourgane in the high plain of Ida Ou Gnidif, dry cultivation of grain and Argan trees. View towards northwest, domain B, area Ma2, spring 2015.*

Fig. 57: *Lateral valley with a village. Domain B, area Ma2, spring 2015.*

Fig. 58: *View over the upper valley towards northwest, dry cultivation of grain and Argan trees. Domain B, area Ma2, spring 2015.*

Fig. 59: *Terraced slope with dry cultivation of grain and Argan trees in the upper valley. Domain B, area Ma2, spring 2015.*

Fig. 60: *Villages high up in the mountains without any spatial relation to mayor surface watercourses (arrows). Domain B, area Ma2, spring 2015.*

Fig. 61: *Disintegrated Agadir at the rim of a terraced slope near Imhiln. Domain B, area Ma2, spring 2015.*

Fig. 62: *Village high up in the mountains without any spatial relation to a mayor surface watercourse near Tahgat (arrow). Domain B, area Ma2, spring 2015.*

Fig. 63: *Village Tahgat (Tahougate), a typical scattered settlement of the upper valley. Domain B, area Ma2, spring 2015.*

Fig. 64: *View over the upper valley towards southeast with terraced slopes and Argan trees. Domain B, area Ma2, spring 2015.*

Fig. 65: *Terraced slope and village on a ridge in the lower valley. Domain B, area Ma2, spring 2015.*

Fig. 66: *River in the lower valley. Domain B, area Ma2, spring 2015.*

Fig. 67: *Lower valley near Biougra. Domain B, area Ma2, spring 2015.*

4 Potential study areas on the northern slope of the Antiatlas Mountains

4.1 Area AN1 a, b
Imgoune – Tingarf valley

Compared with the rugged domain B inlier with narrow valleys between jagged mountains north of Tafraoute (areas Ma1, Ma2, Ma3), the domain B rocks northeast of Igherm rather form extended high plains between bumpy mountains. This allows extended fields for dry cultivation of grain even at higher altitudes. In many places, agricultural structures are largely intact with many ploughed fields and maintained terraces, indicating that agriculture is an important source of income for the local population. In most villages, old, traditional houses are predominant. This also contrasts with the areas Ma1, Ma2 and Ma3. Towards north, the valleys become rather flat with broad, dry riverbeds and rare villages and traces of agriculture respectively.

Tab. 3: Key attributes of area AN1 a, b.

	Areas
	AN1a, AN1b
Geol. / morphological domain:	B, C
Rock types, units / periods:	See fig. 19, page 212.
Stream / river:	Periodic, episodic
Predominant natural vegetation:	Shrubs, perennials
Density of natural vegetation:	Very low – low
Degradation of natural vegetation:	Low
Form of settlement:	Compact villages along watercourses and on slopes / in high planes.
Density of settlement:	Low - middle
Predominant form of agriculture:	Dry cultivation on large fields and on terraces. Very rare irrigated terraced fields in valleys. Agriculture is very rare in the lower, very open valleys towards north.
Irrigation:	Wells, rare
Crops:	Grain, almonds
Accessibility / development of road infrastructure:	Easy to access on paved or mud roads.
Future prospects / risks:	Agriculture is still intact in the mountains. General accessibility for labour market is poor due to remote location.
Remarks:	Tourist infrastructure outside the area in Taliouine.
Degree of documentation:	AN1a: Good; AN1b: Poor

Fig. 68: *Dry farming north of area AN1b. Domain C, autumn 2015.*

Fig. 69: *Alluvial plain north of area AN1b. Domain C, autumn 2015.*

Fig. 70: *Village Tagnit north of area AN1b. Domain C, autumn 2015.*

Fig. 71: *Storage basin with a concrete dam retaining the water of a small episodic river north of area AN1b. Domain C, autumn 2015.*

Fig. 72: *Modern matfia (cistern) for the storage of rain water running off quickly. North of area AN1b, domain C, autumn 2015.*

Fig. 73: *Nomad cavern that is still used in Precambrian carbonate sediments. Domain C, area AN1b, autumn 2015.*

Fig. 74: *Canyon of Imgoune. Domain C, area AN1a, autumn 2015.*

Fig. 75: *Village Imgoune with draw well in the riverbed (arrow). Domain C, area AN1a, autumn 2015.*

Fig. 76: *Village Tifarki, domain B, area AN1a, autumn 2015.*

Fig. 77: *Draw well and water pump in the riverbed near Tifarki. Domain B, area AN1a, autumn 2015.*

Fig. 78: *Village Ouzoune with numerous new houses (yellow, salmon pink). Domain B, area AN1a, autumn 2015.*

Fig. 79: *Terraced slopes for dry cultivation with ploughed fields, and dry riverbed near Touadil. Domain B, area AN1a, autumn 2015.*

Fig. 80: *Terraced slopes with ploughed fields for dry cultivation, and threshing floor near Touadil. Domain B, area AN1a, autumn 2015.*

Fig. 81: *Dry riverbed near Touadil, view down the valley. Domain B, area AN1a, autumn 2015.*

Fig. 82: *Village Touadil with unusually many traditional houses in good condition. Ploughed, terraced fields for dry cultivation in the middle ground, view down the valley. Domain B, area AN1a, autumn 2015.*

Fig. 83: *View down the valley over an olive plantation towards village Touadil. Domain B, area AN1a, autumn 2015.*

Fig. 84: *Village Tingarf with a rare irrigation channel (left) and small, irrigated fields. Domain B, area AN1a, autumn 2015.*

Fig. 85: *Village Tingarf with unusually many traditional houses in good condition. Domain B, area AN1a, autumn 2015.*

Fig. 86: *View down the valley towards north from the rim of the central Talate N'Ouamane – Adrar high plain. Domain B, area AN1a, autumn 2015.*

Fig. 87: *Ploughed fields for dry farming and almond trees on the central Talate N'Ouamane – Adrar high plain. Domain B, area AN1b, autumn 2015.*

Fig. 88: *Ploughed fields for dry farming and Talate N'Ouamane with modern pink buildings on the central Talate N'Ouamane – Adrar high plain. Domain B, area AN1b, autumn 2015.*

Fig. 89: *Village Tekhfert (left) with dry farming on terraced slopes and almond trees. The striking colour boundary between dark red brown on the left and bright yellow brown on the right is the boundary between two acidic volcanic rock types of different colour. Domain B, AN1b, autumn 2015.*

4.2 Area AN2
Ossemgane mountains

This area is not documented more precisely. It is, however, comparable with the neighbouring area AS3a that also includes domain B and C rocks.

Fig. 90: *Ossemgane Mountains with left area AN2 (villages Ifgh, Doubhar) and right area AS3a (village Azoura). Domains B (reddish-brown mountains in the background) and C (yellow-ish-brown hills in the foreground), autumn 2015.*

Fig. 91: *Sheepfold and almond trees. Domain C, area AN2, spring 2015.*

4.3 Area AN3 a-g
Highlands triangle Agadir Tasguent - Aït Abdallah - Madao / Asif Oussaka

Area AN3 is a typical Antiatlas highland with gentle hills, mainly consisting of carbonate and clastic rocks that are characteristic for domain C, and few small domain B inliers. Similar gentle domain C hills also occur in the highlands of the areas AS1, AS2 and AS3, whereas in the more eastern areas AS4, AS5 and AS6 the domain C hills are rougher.

With a few exceptions most villages in domain C are located on slopes or on the top of hills without any access to mayor surface watercourses, thus they largely depend on groundwater. In domain B inliers in contrast, most villages are situated along surface watercourses with groundwater in the underlying gravel. In general, villages are rare, their density depending on the fertility of the soil and on the availability of abundant ground water (for specifications see chapter 1.3). The canyons cutting through the northwestern rim of the highlands and heading towards the Oued Sousse plain are barely inhabited, area AN3 thus being limited to the highlands only.

Tab. 4: Key attributes of area AN3 a-g.

	Areas		
	AN3a, AN3d, AN3e, AN3f	AN3b, AN3g	AN3c
Geol./morphological domain:	B, C	B	C
Rock types, units/periods:	See fig. 19, page 212.		
Stream/river:	Periodic, episodic		
Predominant natural vegetation:	Perennials		
Density of natural vegetation:	Very low - low		
Degradation of natural vegetation:	Low		
Form of settlement:	Compact or loose villages partly along surface watercourses and partly independent from them.		
Density of settlement:	In general very low and concentrated in the domain B inliers.		
Predominant form of agriculture:	Dry cultivation on large fields and on terraces.		
Irrigation:	Rare, draw wells and groundwater pumps (?)		
Crops:	Grain, almonds		
Accessibility/development of road infrastructure:	Easy to access on paved or mud roads.		
Future prospects / risks:	Agriculture is not intact; many incomes depend on migrants.		
Remarks:	Tourist infrastructure in Madao or outside the area in Tafraoute.		
Degree of documentation:	AN3a, AN3d, AN3f: Good; AN3e: No documentation	AN3b: No documentation AN3g: Good	Good

Fig. 92: *Village Tasguent with threshing floors in the fore-ground. Domain B, area AN3d, autumn 2015.*

Fig. 93: *Agadir Tasguent, one of the best kept berber storage castles. Domain B, area AN3d, autumn 2015.*

Fig. 94: *Inside Agadir Tasguent with single family-safes for grain, oil and valuables behind each door. Area AN3d, autumn 2015.*

Fig. 95: *View over the highlands towards northwest from Agadir Tasguent. Domains B and C, areas AN3d and f, autumn 2015.*

Fig. 96: *Dry farming near the village Aït Ounrar. Domain B, area AN3d, autumn 2015.*

Fig. 97: *Highlands near village Alma. Domain B, area AN3d, autumn 2015.*

***Fig. 98:** View towards west over the hilly highlands of domain C towards the high elevations of domain B in the areas Ma1 - Ma3. Southwest of Issouka, areas AN3f, AN3g and Ma3a, autumn 2015.*

***Fig. 99:** Village Amzawr with predominantly new houses in yellow and pink. Evening light, domain B, area AN3a, autumn 2015.*

***Fig. 100:** Villages Amzawr (left) and Zghnghen (right) with numerous new buildings in pink, and with terraced slopes. View towards south, domain B, area AN3a, spring 2015.*

***Fig. 101:** Villages Titeki (left) and Aferni (right), view towards east. Domain C, area AN3c, spring 2015.*

***Fig. 102:** Aferni with numerous new buildings in pink. Terraced slopes and almond trees. Domain C, area AN3c, spring 2015.*

Fig. 103: Valley southwest of Madao. Domains C (foreground) and B (background left), area AN3f, autumn 2015.

Fig. 104: Dry riverbed and almond trees near village Madao. Domain B, area AN3g, autumn 2015.

4.4 Area AN4 a, b
Granite pan south of Tazenackht

Deeply eroded granite pans as found in domain A regions are generally sparsely populated ore even uninhabited because of their infertile granitic soils. Regarding this, area AN4 is an exception since it exhibits numerous villages and extended agricultural land. This is due to a system of episodic streams flowing down from the rims of the pan, forming groundwater. These streams, however, also transport debris and soil particles from the surrounding, more fertile domains B and C into the granite pan, where they have been helping to amelioratie the soil for centuries.

The areas AN4a and AN4b have not been visited, they are, however, similar to the well-known areas north of it.

Tab. 5: Key attributes of area AN4 a, b.

	Areas
	AN4a, AN1b
Geol./morphological domain:	A (at the edges also small parts of domains B and C).
Rock types, units/periods:	See fig. 19, page 212.
Stream/river:	Periodic, episodic
Predominant natural vegetation:	Perennials
Density of natural vegetation:	Very low - low
Degradation of natural vegetation:	Low
Form of settlement:	Compact villages mostly situated close to surface watercourses.
Density of settlement:	Low
Predominant form of agriculture:	Dry mechanized grain cultivation on large fields, and olive plantations.
Irrigation:	Groundwater for olive plantations.
Crops:	Grain, olives
Accessibility/development of road infrastructure:	Easy to access on paved or mud roads.
Future prospects / risks:	Mechanized agriculture is on the advance and many new olive plantations have been established recently (agricultural development programme of the government to transform wasteland into agricultural land), bringing up questions about the water consumption.
Remarks:	Modest Tourist infrastructure outside the area in Tazenackht.
Degree of documentation:	No documentation

Fig. 105: *View into the northern part of the deeply eroded granite pan of Tazenackht from its western rim near Kourkouda with national road N10. Domain A, north of area AN4b, autumn 2015.*

Fig. 106: *Inside the northern part of the deeply eroded granite pan of Tazenackht with national road N10. View towards its eastern rim consisting of domain B and C rocks. Domain A, north of area AN4b, autumn 2015.*

Fig. 107: *View over village Kourkouda into the northern part of the deeply eroded granite pan of Tazenackht with numerous recent olive tree plantations. Domain A, north of area AN4b, spring 2015.*

Fig. 108: *Natural, steppe-like vegetation in the northern part of the deeply eroded granite pan of Tazenackht near Aïn Igourramene. Domain A, north of area AN4b, spring 2015.*

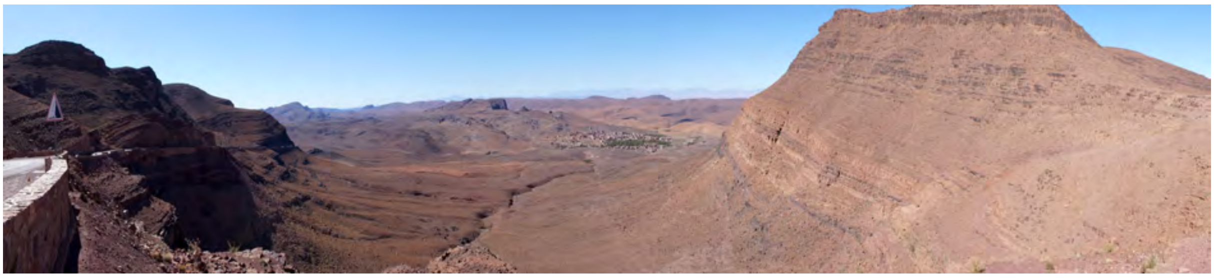
Fig. 109: *Vilage Aïn Igourramene in the northern part of the deeply eroded granite pan of Tazenackht with natural steppe-like vegetation. Domain A, north of area AN4b, spring 2015.*

4.5 Area AN5
High plain of Aït Saoun

Area AN5 is a clearly delimited, flat valley crossed by a system of branched streams with periodic flow conditions and populated with only one village.

Tab. 6: Key attributes of area AN5.

	Area
	AN5
Geol. / morphological domain:	C
Rock types, units / periods:	See fig. 19, page 212.
Stream / river:	Periodic, episodic
Predominant natural vegetation:	Perennials
Density of natural vegetation:	Very low – low
Degradation of natural vegetation:	Low
Form of settlement:	One compact village at the stream.
Density of settlement:	Low
Predominant form of agriculture:	Few irrigated fields in and close to the village, new (quite dry) olive plantations along the river.
Irrigation:	Mainly groundwater
Crops:	Grain, olives
Accessibility / development of road infrastructure:	Easy to access on paved road.
Future prospects / risks:	Hardly any development possible.
Remarks:	Tourist infrastructure outside the area in Ouarzazate or Agdz.
Degree of documentation:	Sufficient



***Figs. 111 and 112:** The Aït Saoun High plain with the village Aït Saoun (centre) from Tizi N'Tinifift. Tizi N'Tinifift is in domain C rocks whereas Aït Saoun is in domain B rocks. View towards north, area AN5, autumn 2015.*

4.6 Area AN6
Tasla - Aït Semghane - Ourika Tanslifte valley

Area AN6 is a long, open valley oriented roughly west – east and parallel to the mountain ridges of Upper Precambrian to Lower Ordovician age. This is one of the few areas where Paleozoic rocks are folded in between Precambrian inliers.

Tab. 7: Key attributes of area AN6.

	Area
	AN6
Geol. / morphological domain:	D
Rock types, units / periods:	See fig. 19, page 212.
Stream / river:	Periodic, episodic
Predominant natural vegetation:	Perennials
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Low
Form of settlement:	Compact villages at the stream.
Density of settlement:	Low
Predominant form of agriculture:	Irrigated fields and new olive plantations along the river.
Irrigation:	Mainly groundwater
Crops:	Grain, olives
Accessibility / development of road infrastructure:	Easy to access on paved road.
Future prospects / risks:	New plantations bring up questions about the water consumption.
Remarks:	Tourist infrastructure outside the area in Agdz.
Degree of documentation:	Sufficient.

Fig. 112: *Long valley with dry riverbed (left), parallel to Paleozoic mountain ridges. View to the east, domain D, area AN6, autumn 2015.*

Fig. 113: *Long valley with dry riverbed (left), parallel to Paleozoic mountain ridges. View to the east, domain D, area AN6, autumn 2015.*

Fig. 114: *Village Tasla. Domain D, area AN6, autumn 2015.*

Fig. 115: *Village Ait Semghane, view to the east. Domain D, area AN6, autumn 2015.*

Fig. 116: *Dry riverbed with palm trees in the lower valley. Domain D, area AN6, autumn 2015.*

5 Potential study areas on the southern slope of the Antiatlas Mountains

5.1 Area AS1 a-i
Canyonlands of Assif N'Innt (south of Tafraoute)

The canyons of this area belong to the longest and most impressive of southern Morocco. The rivers that cut them start in domain A granite pans, where apparently large quantities of water are collected during periods of heavy rainfall that are able to erode the adjacent Precambrian and Cambrian sedimentary rocks. Effective erosion, however, only takes place episodically, most of the time the rivers are completely dried out. As it is typical for domain C canyons, their morphology depends on the erosion resistivity of the rocks. The harder the rocks are, the steeper and rougher are the canyons.

The canyons are partly inhabited, with large palm oases. Numerous nomad caverns that are still in use indicate that nomadic animal husbandry is wide spread in this desert terrain with sparse natural vegetation. Similar to the domain A areas AN4a and AN4b, in the granite pans of the areas AS1a, AS1b, AS1d and AS1g debris and alluvial material from the surrounding domain B and C mountains enable the formation of a more fertile soil, additionally enriched by weathering products of basic dykes. Thus, moderate agriculture is possible there.

Tab. 8: Key attributes of area AS1 a-i.

	Areas		
	AS1a, AS1b, AS1d	AS1c, AS1e, AS1f, AS1h, AS1i	AS1g
Geol. / morphological domain:	A, C	C	A
Rock types, units / periods:	See fig. 19, page 212.		
Stream / river:	Periodic, episodic		
Predominant natural vegetation:	Perennials		
Density of natural vegetation:	Low – middle		
Degradation of natural vegetation:	Low		
Form of settlement:	Compact villages at the streams / rivers.		
Density of settlement:	Low - middle	Very low	Low - middle
Predominant form of agriculture:	Dry cultivation mostly on terraces; irrigated palm gardens in some canyons.	Irrigated palm gardens in some canyons.	Dry cultivation on large fields and on terraces.
Irrigation:	Dry cultivation: Rare Palm gardens: Wells in lateral valleys, groundwater.	Wells in lateral valleys, groundwater.	Rare
Crops:	Grain	Grain, vegetables, cattle fodder crops.	Grain
Accessibility / development of road infrastructure:	Easy to access where paved roads, some long and difficult mud roads.		Easy to access on paved roads.
Future prospects / risks:	Intact agriculture in the canyons, development of tourist infrastructure is possible, especially in the most spectacular canyons.		Agriculture ?
Remarks:	Tourist infrastructure in Imiter only (area AS1h).		
Degree of documentation:	AS1a, AS1b: Good AS1d: No documentation	AS1c, AS1e, AS1f: No doc. AS1h: Good; AS1i: Sufficient	AS1g: Poor

***Fig. 117:** Village Tasserirt (Souk N'Tasrirt) on the granite high plain (granite pan) southeast of Tafraoute. View towards southeast, domain A, area AS1a, autumn 2015.*

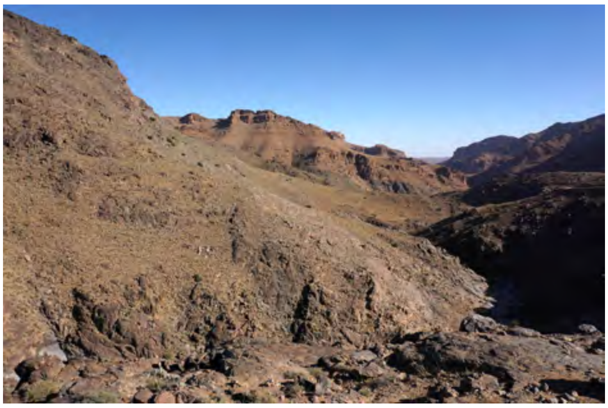


***Fig. 118:** Beginning of the Aït Mansour gorge southwest of Tasserirt. Domain A, view towards southeast into domain C. Areas AS1a, AS1b, autumn 2015.*

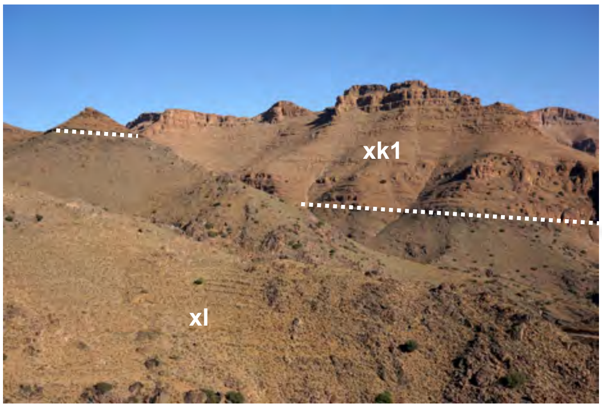


***Fig. 119:** Boundary between the lowermost Precambrian xl gneisses and migmatites and the overlying uppermost Pre-cambrian xk1 sedimentary rocks. Domain A, area AS1a, autumn 2015.*

***Fig. 120:** Road through the lowermost Precambrian xl gneisses and migmatites at the beginning of the Aït Mansour gorge southwest of Tasserirt, view up the valley. The rocks in the dry riverbed are well polished, indicating periodical heavy floods. Domain A, area AS1a, autumn 2015.*

***Fig. 121:** Aït Mansour gorge with xk1 uppermost Precambrian sedimentary rocks. Domain C, area AS1b, autumn 2015.*

***Fig. 122:** Narrow middle part of Aït Mansour gorge with palm oases along the riverbed. Domain C, area AS1b, autumn 2015.*

Fig. 123: *Palm oasis in the narrow middle part of Aït Mansour gorge. Domain C, area AS1b, autumn 2015.*

Fig. 124: *Small agadir (berber storage castle) within the rock face of Aït Mansour gorge. Domain C, area AS1b, autumn 2015.*

Fig. 125: *Lower Aït Mansour gorge. Domain C, area AS1b, autumn 2015.*

Fig. 126: *Village Flayighir below Aït Mansour gorge, view down the valley. Domain C, area AS1b, autumn 2015.*

Fig. 127: *Village Flayighir below Aït Mansour gorge. Domain C, area AS1b, autumn 2015.*

Fig. 128: *Exceptionally large Berber living cavern near Village Flayighir (below Aït Mansour gorge). Domain C, area AS1b, autumn 2015.*

Fig. 129: *Village near Flayighir (below Aït Mansour gorge) with many new buildings. Domain C, area AS1b, autumn 2015.*

Fig. 130: *Village northwest of Gdourt (below Aït Mansour gorge). View up the valley, domain C, area AS1b, autumn 2015.*

Fig. 131: *Village Gdourt (below Aït Mansour gorge). View down the valley, domain C, area AS1b, autumn 2015.*

Fig. 132: *Village southeast of Gdourt (below Aït Mansour gorge). Domain C, area AS1b, autumn 2015.*

Fig. 133: *Village Bou Nour. Domain C, area AS1c, autumn 2015.*

Fig. 134: *View towards east over the Bou Nour canyon from a small pass between the areas AS1c and AS1g. Domain C, area AS1c, autumn 2015.*

Fig. 135: *View towards west over the deeply eroded granite pan of Aït Soulyman with village Ighil Ouaman from a small pass between the areas AS1c and AS1g. Domain A, area AS1g, autumn 2015.*

Fig. 136: *Uppermost village Ighmir with modern "high-rise" buildings due to a shortage of space in the narrow canyon. Domain C, area AS1h, autumn 2015.*

Fig. 137*: Irrigation channel in the village Ighmir, fed by streams and sources in lateral valleys. Domain C, area AS1h, autumn 2015.*

Fig. 138: *Irrigated palm oasis with the dry riverbed near village Ighmir. View up the valley, domain C, area AS1h, autumn 2015.*

Fig. 139: *Irrigation channel in the palm oasis near village Ighmir, fed by streams and sources in lateral valleys. Domain C, area AS1h, autumn 2015.*

Fig. 140: *Gorge between the villages Ighmir and Ighir Smouguen. Domain C, area AS1h, autumn 2015.*

Fig. 141: *Gorge between the villages Ighmir and Ighir Smouguen. Domain C, area AS1h, autumn 2015.*

Fig. 142: *Road cut showing an interbedded sequence of calcareous (grey) and clastic (yellowish brown) uppermost Precambrian sedimentary rocks. Domain C, area AS1h, autumn 2015.*

Fig. 143: *Villages Anamir (left) and Ighir Smouguen (right) with huge palm oasis. View up the valley, domain C, area AS1h, autumn 2015.*

Fig. 144: *Palm oasis with irrigated fields near village Anamir. The dry riverbed is also used as road. Domain C, area AS1h, autumn 2015.*

Fig. 145: *Village Anamir with modern "high-rise" buildings due to a shortage of space between the palm gardens and the steep rock faces. Domain C, area AS1h, autumn 2015.*

Fig. 146: *Village Timoula with huge palm oasis. View down the valley, domain C, area AS1h, autumn 2015.*

***Fig. 147:** Old village of Timoula with some exceptionally well-preserved traditional houses. Domain C, area AS1h, autumn 2015.*

***Fig. 148:** Palm gardens near village Aguejgal. Domain C, area AS1h, autumn 2015.*

***Fig. 149:** Canyon south of village Aguejgal, view up the valley. Domain C, area AS1i, autumn 2015.*

***Fig. 150:** Lower canyon of Assif N'Innt with a impressively broad, dry riverbed. View up the valley, domain C, area AS1i, autumn 2015.*

***Fig. 151:** Groundwater level in the lower canyon of Assif N'Innt coming to the surface in a depression in the loose sediment. View up the valley. Domain C, area AS1i, autumn 2015.*

***Fig. 152:** Lower canyon of Assif N'Innt with village Imouzlag. Domain C, area AS1i, autumn 2015.*

***Fig. 153:** Lower canyon of Assif N'Innt with village Tanghroute. Domain C, area AS1i, autumn 2015.*

***Fig. 154:** Villages Tislgite (foreground) and Ighir Oughenayne (background) in the lower canyon of Assif N'Innt. View down the valley, domain C, area AS1i, autumn 2015.*

Fig. 155: Old village Aguerd on the lowermost Assif N'Innt. *Domain C, area AS1i, autumn 2015..*

Fig. 156: New village Aguerd with its mosque on the lowermost Assif N'Innt. *Domain C, area AS1i, autumn 2015.*

***Fig. 157:** Open cistern for irrigation of palm gardens near Aguerd on the* lowermost Assif N'Innt. *Domain C, area AS1i, autumn 2015.*

5.2 Area AS2
Canyonlands of Amtoudi

The water cutting the Amtoudi canyon into the sedimentary rocks is collected within the almost uninhabited sedimentary domain C highlands northeast of Amtoudi. Amtoudi is situated at the outflow of the canyon into an alluvial plain, and is the only village in the area.

Tab. 9: Key attributes of area AS2.

	Area
	AS2
Geol./morphological domain:	C
Rock types, units/periods:	See fig. 19, page 212.
Stream/river:	Periodic, episodic
Predominant natural vegetation:	Perennials
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Low
Form of settlement:	Compact village at the outflow of the canyon into the alluvial plain.
Density of settlement:	Very low
Predominant form of agriculture:	Irrigated palm gardens in the canyons.
Irrigation:	Mainly groundwater
Crops:	Grain, vegetables, cattle fodder crops
Accessibility/development of road infrastructure:	Amtoudi is easy to access on a paved road; the backcountry is hardly accessible by car.
Future prospects / risks:	Development of tourist infrastructure is possible, especially with respect to the two well-preserved agadirs Aguelloui and Id Aissa.
Remarks:	Modest tourist infrastructure in Amtoudi.
Degree of documentation:	Amtoudi: good; back country: no documentation.

***Fig. 158:** Agadir Aguelloui (Berber storage castle) above Amtoudi at the outflow of the Amtoudi canyon. Domain C, area AS2, autumn 2015.*

***Fig. 159:** Agadir Id Aissa (Berber storage castle) above Amtoudi at the outflow of the Amtoudi canyon. Domain C, area AS2, autumn 2015.*

Fig. 160: *Agadir Aguelloui (Berber storage castle) above Amtoudi. Domain C, area AS2, autumn 2015.*

Fig. 161: *View from Agadir Aguelloui (Berber storage castle) into the Amtoudi canyon. Domain C, area AS2, autumn 2015.*

Fig. 162: *Village Amtoudi at the outflow of the Amtoudi canyon with cemetery (yellowish brown grassy grounds with walls around) and several threshing floors (grey ovals). View down the valley, domain C, area AS2, autumn 2015.*

Fig. 163: *Irrigation channel in the palm gardens of Amtoudi. Domain B, area Ma2, spring 2015.*

5.3 Area AS3 a-i
Upper course of Oued Akka

The upper course of Oued Akka mainly crosses sedimentary rocks of lower Cambrian age (ki) that are less resistant to erosion than the uppermost Precambrian sedimentary rocks (xk1 / xk2). The slopes of the main Oued Akka valley, draining the typical hilly highlands of domain C, are thus for the most part more gentle than the steep walls of the canyons in mainly Precambrian rocks as for example in area AS1. The lateral canyons, however, can be steep and rough, where they cross the uppermost Precambrian sedimentary rocks (xk1 / xk2). These canyons are partly inhabited. Due to their poor accessibility they are not documented.

The highest area AS3a with the village Azoura and its surroundings is particularly fertile and disposes of sources supplying enough water for irrigation. Agricultural structures are largely intact there and the cultivation of grain is apparently an important source of income for the locals. The hilly highlands of domain C are in every aspect similar to those in area AN3.

Tab. 10: Key attributes of area AS3 a-i.

	Areas	
	AS3a	AS3b – AS3i
Geol. / morphological domain:	B, C	C
Rock types, units / periods:	See fig. 19, page 212.	
Stream / river:	Permanent, periodic, episodic	Periodic, episodic
Predominant natural vegetation:	Perennials	
Density of natural vegetation:	Very low – low	
Degradation of natural vegetation:	Low	
Form of settlement:	Compact villages	
Density of settlement:	Low – middle	Canyons: Low – middle Highlands: Uninhabited – very low
Predominant form of agriculture:	Irrigated terraced fields.	Canyons: Irrigated fields along streams Highlands: Dry framing
Irrigation:	Wells	Mainly groundwater
Crops:	Grain, vegetables, cattle fodder crops	Canyons: Grain, vegetables, cattle fodder crops Highlands: Grain
Accessibility / development of road infrastructure:	Easy to access on a paved road + short mud roads.	Main valley: Easy to access on a paved road; lateral valleys: Long mud roads not always leading to their end.
Future prospects / risks:	Development of tourist infrastructure?	Lateral valleys are very remote.
Remarks:	Modest tourist infrastructure in Azoura.	Modest tourist infrastructure in Igherm, Hotels in Tata outside the area.
Degree of documentation:	Good	AS3b, AS3d: Poor AS3c, AS3e, AS3f, AS3g, AS3h: No doc. AS3i: Sufficient

Fig. 164: *Village Taghdir N'Aït Ali northeast of Azoura with terraced fields for dry cultivation and almond trees. Domain B, view towards east into domain C. Area AS3a, spring 2015.*

Fig. 165: *Village Taghdir N'Aït Ali with terraced fields (left). The rocks are quartzites, typical for Domain B. Area AS3a, autumn 2015.*

Fig. 166: *Villages Azoura (left) and Agard Walous (right) with irrigated, terraced fields and almond trees. Domain B, area AS3a, spring 2015.*

Fig. 167: *Section from fig. 166 showing the irrigation channel supplying the terraced fields on the left hand side (arrow) with water from a source emerging at the foot of the quartzite mountains. Domain B, area AS3a, spring 2015.*

Figs. 168 and 169: *Azoura in spring (left) and in autumn (right). Domain B, area AS3a, 2015.*

***Fig. 170:** Terraced fields for dry cultivation of grain and almond trees near Azoura. Domain C, area AS3a, spring 2015.*

***Fig. 171:** Villages at the foot of the domain B "Ossemgane" mountains. Azoura is on the right hand side (arrow). View from domain C towards north, area AS3a, autumn 2015.*

***Fig. 172:** Ploughed fields and almond trees near Douar Toussergа. Domain C, close to the areas AS3a and AS3b, autumn 2015.*

***Fig. 173:** Village Issouka with ploughed fields. Domain C, area AS3d, autumn 2015.*

***Fig. 174:** Sheep near Tiguermine. Domain C, area AS3d, spring 2015.*

***Fig. 175:** Village Issil with ploughed fields and water pipe for irrigation. Domain C, area AS3i, autumn 2015.*

Fig. 176: *Village Issil with water tower (arrow), ploughed fields and water pipe for irrigation. Domain C, area AS3i, autumn 2015.*

Fig. 177: *Draw well built in 1972 (left) and water pipe for irrigation near Village Issil. Domain C, area AS3i, autumn 2015.*

Fig. 178: *Villages south of Issafén with oasis (Issafén is outside the right image margin) along the upper course of Oued Akka. View up the valley (towards north), domain C, area AS3i, autumn 2015.*

Fig. 179: *Dry upper course of Oued Akka. View up the valley (towards north), domain C, area AS3i, autumn 2015.*

5.4 Area AS4 a-e
Alluvial plain of Akka Ighane – Tissint and adjacent canyons

The enormous alluvial plain of Akka Ighane – Tissint collects the water flowing down from extended highlands through several canyons, forming a perfectly closed hydrological system with the only “drain valve” or outflow at the ravine (klus) of Akka N'Ait Sidi northwest of Tissint. The alluvial plain is filled with fluvial and lacustrine sediments of unknown thickness that are supposed to host groundwater resources. It is inhabited on its northern and southern edges, where also extended palm oases occur. Most of the plain, however, is not used for agriculture and some parts are transformed to infertile badlands, cut criss-cross by erosion channels. This is the consequence of deep erosion of the lacustrine chalk due to the lowering of the erosion basis at the outflow north of Tissint after the deposition of the sediments. That’s also why deep canyons have been cut into these sediments towards the outflow.

The tributaries that flow into the alluvial plain cut long valleys into the flat southern slope of the Antiatlas Mountains. Their morphology strongly depends on the rocks occurring. In domain B rocks mostly steep, V-shaped valleys occur, whereas in domain C, either canyons in Precambrian rocks (xk1, xk2) or open, gentle valleys in Cambrian (ki, km) rocks were formed. Most tributaries are inhabited, exhibiting partly impressive palm oases.

Tab. 11: Key attributes of area AS4 a-e.

	Areas		
	AS4a, AS4c	AS4b, AS4e	AS4d
Geol. / morphological domain:	A, B	C, subordinately also A, B, D	C
Rock types, units / periods:	See fig. 19, page 212.		
Stream / river:	Periodic, episodic		
Predominant natural vegetation:	Perennials		
Density of natural vegetation:	Very low – low		
Degradation of natural vegetation:	Low		
Form of settlement:	Compact villages at the streams / rivers.		
Density of settlement:	AS4a: Low - middle AS4c: Very low	Very low	Low - middle
Predominant form of agriculture:	Canyons: Irrigated palm gardens. Mountains outside canyons: Dry farming on large fields and terraces; irrigated farming along periodic / episodic streams / rivers (not every year possible?) Alluvial plain: Irrigated palm gardens on the northern and southern edge; new plantations with little success so far.		
Irrigation:	Palm gardens: Sources in lateral valleys, groundwater, surface water when available. Irrigated farming along periodic / episodic streams / rivers: Surface water when available. Dry farming: No irrigation. Alluvial plain: Groundwater, surface water when available.		
Crops:	Palm gardens: Grain, vegetables, cattle fodder crops. Irrigated farming along periodic / episodic streams / rivers and dry farming: Grain. Alluvial plain: Grain, vegetables, cattle fodder crops, olives.		

Tab. 11: Key attributes of area AS4 a-e, continuation from page 252.

Accessibility / development of road infrastructure:	Easy to access where paved roads, some long and difficult mud roads.		
Future prospects / risks:	Intact agriculture in the canyons, development of tourist infrastructure is possible, especially in the most spectacular canyons.		
Remarks:	Tourist infrastructure in Aguinane (area AS4a) and Foum Zguid / Tata outside the area.		
Degree of documentation:	AS4a: Good AS4c: No documentation	AS4b: Suffcient AS4e: Alluvial plain: Good; Mountains: No document.	AS4d: Sufficient

Fig. 180: *Oasis of Aguinane including several villages at the beginning of the Aguinane canyon. View up the valley (towards northwest), domain B, area AS4a, autumn 2015.*

Fig. 181: *Oasis of Aguinane with irrigated fields at the beginning of the Aguinane canyon. View up the valley (towards northwest), domain B, area AS4a, autumn 2015.*

Fig. 182*: Irrigation channel in the Oasis of Aguinane. Domain B, area AS4a, autumn 2015.*

Fig. 183: *In the oasis of Aguinane palm trees are not only cultivated along the riverbed, but also on irrigated terraces on the steep slopes. Compared to other oasis in southern Morocco this is outstanding. Domain B, area AS4a, autumn 2015.*

Fig. 184: *Terraces with palm trees in the oasis of Aguinane. Domain B, area AS4a, autumn 2015.*

Fig. 185: *Palm trees cultivated on the steep slopes of the Aguinane canyon. Domain B, area AS4a, autumn 2015.*

Fig. 186: *Dry riverbed in the Aguinane canyon that is used to keep cows. The cows are fed with fodder crops, and with palm leafs. Domain B, area AS4a, autumn 2015.*

Fig. 187: *Open cistern for irrigation in the Aguinane oasis. Domain B, area AS4a, autumn 2015.*

Fig. 188: *New draw well in the Aguinane oasis. Domain B, area AS4a, autumn 2015.*

Fig. 189: *Village Azegza with irrigated, terraced fields. View up the valley, domain B, area AS4a, autumn 2015.*

Fig. 190: *Village Azegza with irrigated, terraced fields. Domain B, area AS4a, autumn 2015.*

Fig. 191: *Zawiyas from different epochs near Kiriwt. Domain B, area AS4a, autumn 2015.*

Fig. 192: *Village Timzoughine, view up the valley. Domain B, area AS4a, autumn 2015.*

Fig. 193: *Draw well in the riverbed near Timzoughine, view down the valley towards domain C rocks. Area AS4a, autumn 2015.*

Fig. 194: *Broad, dry riverbed below the Agiunane canyon. View towards east, domain C, area AS4b, autumn 2015.*

Fig. 195: *Village Adghers N'Warfaln with a huge Agadir (Berber storage castle) that is about to disintegrate. View up the valley, domain C, area AS4b, autumn 2015.*

Fig. 196: *Agadir (Berber storage castle) of Adghers N'Warfaln that is about to disintegrate. Domain C, area AS4b, autumn 2015.*

Fig. 197: *Irrigated fields north of Adghers N'Warfaln. Domain C, area AS4b, autumn 2015.*

Fig. 198: *Village Tamsoulte in the lowest part of the valley. View down the valley, domain C, area AS4b, autumn 2015.*

Fig. 199: *Irrigated fields of village Tamsoulte in the lowest part of the valley. Domain C, area AS4b, autumn 2015.*

Fig. 200: *Trickle in the broad riverbed below Tamsoulte. Domain C, area AS4b, autumn 2015.*

Fig. 201: *Village Imi N'Tatelate (Ibn Yacoub). Domain C, area AS4d, autumn 2015.*

Fig. 202: *Village Imi N'Tatelate (Ibn Yacoub). Domain C, area AS4d, autumn 2015.*

Fig. 203: *Village Tisnassemine. Domain C, area AS4e, autumn 2015.*

Fig. 204: *Dry riverbed between Tisnassemine and Akka Ighane. View up the valley, domain C, area AS4e, autumn 2015.*

Fig. 205: *Dry riverbed with eye-catchingly folded sedimentary rocks between Tisnassemine and Akka Ighane. View down the valley, domain C, area AS4e, autumn 2015.*

Fig. 206: *Dry riverbed near Akka Ighane on the northern edge of the Akka Ighane – Tissint alluvial plain. View towards the Antiatlas Mountains. Domain C, area AS4e, autumn 2015.*

Fig. 207: *Palm oasis of Tizkmoudine on the northern edge of the Akka Ighane – Tissint alluvial plain. View towards the Antiatlas Mountains. Domain C, area AS4e, autumn 2015.*

Fig. 208: *Akka Ighane – Tissint alluvial plain with acacias. View from the northern edge towards south. The mountain ridge on the horizon belongs to domain D. Area AS4e, autumn 2015.*

Fig. 209: *Weathering of a carbonate debris by carbonic acid in the rainwater. Akka Ighane – Tissint alluvial plain, Domain C, area AS4e, autumn 2015.*

Fig. 210: *Open cistern with a petrol driven groundwater pump for the irrigation of an isolated garden in the Akka Ighane – Tissint alluvial plain. Domain C, area AS4e, autumn 2015.*

Fig. 211: *Akka Ighane – Tissint alluvial plain with acacias, view from the southern edge northwards towards the Antiatlas Mountains. Domain C, area AS4e, spring 2015.*

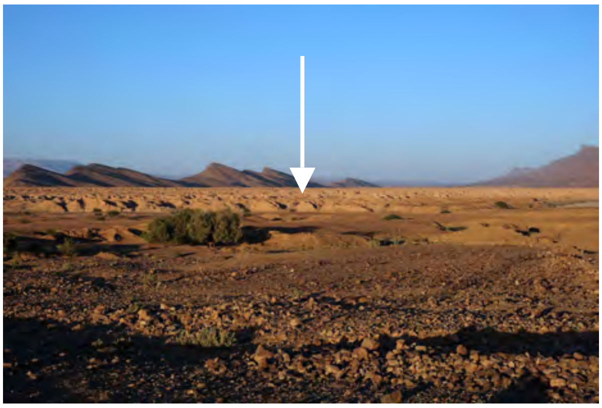


Fig. 212: *Akka Ighane – Tissint alluvial plain, with extended badlands consisting of eroded lacustrine chalk on its southern edge (arrow). Domain C, area AS4e, autumn 2015.*

Fig. 213: *Dry riverbed crossing the badlands of the Akka Ighane – Tissint alluvial plain along its southern edge. Domain C, area AS4e, spring 2015.*

Fig. 214: *Poor palm gardens on the badlands on the southern edge of Akka Ighane – Tissint alluvial plain. View towards the Antiatlas Mountains, domain C, area AS4e, autumn 2015.*

Fig. 215: *Village Tghit (Trit) on the southern edge of Akka Ighane – Tissint alluvial plain. Domain C, area AS4e, autumn 2015.*

Fig. 216

Fig. 217

Figs. 216 and 217: *Fig. 216 is the continuation of fig. 217 to the right. Both photos show the confluence of the two rivers draining the alluvial plain of Akka Ighane – Tissint below village Akka N'Aït Sidi (northwest of Tissint). In fig. 216 the view is towards west, in fig. 217 it is towards north. Both rivers cut into the lacustrine chalk that was deposited when parts of the alluvial plain were covered by a shallow lake. Domain C and D, area AS4e, autumn 2015.*

5.5 Area AS5
Akka Iguirene

Akka Iguirene is a village situated in an alluvial plain at the end of a long, uninhabited canyon with a well defined hydrologic system, the lower limit of which is given by a mountain chain cut by a ravine (klus). The area belongs to domain C, the inherent catchment has not been investigated closer.

Fig. 218: *Alluvial plain of Akka Iguirene, view northwards to the Antiatlas Mountains. Domain C, area AS5, autumn 2015.*

Fig. 219: *Satellite image of Akka Iguirene above the ravine (klus). Domain C, area AS5.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

5.6 Area AS6 a-g
Oued El Koubia / Oued Zguid

The Oued El Khoubia / Oued Zguid area is to a certain extent similar to the Akka Ighane – Tissint area (AS4) with several long valleys showing different morphologies as a function of the geological conditions that all end in an alluvial plain with one outflow at the ravine (klus) north of Foum Zguid. The geology of the areas AS6d and AS6f, however, is more complex since also ophiolitic rocks occur, representing the unique occurrence of these rocks in the Moroccan Atlas Mountains outside the Rif Mountains at the Mediterranean coast. This makes the morphology of the area more complex and less predictable, a significant disadvantage since most of the area is not documented. With Bou Azzer in area AS6d and Bleida in area AS6f two of the largest and most famous multi-mineral mines of the country are established there.

Tab. 12: Key attributes of area AS6 a-g.

	Areas	
	AS6a, AS6d, AS6e, AS6f	AS6b, AS6c, AS6g
Geol. / morphological domain:	B, C	C, subordinately also D in area AS6g
Rock types, units / periods:	See fig. 19, page 212.	
Stream / river:	Periodic, episodic	
Predominant natural vegetation:	Perennials	
Density of natural vegetation:	Very low – low	
Degradation of natural vegetation:	Low	
Form of settlement:	Compact villages	
Density of settlement:	Low – middle	
Predominant form of agriculture:	Canyons: Irrigated palm gardens along the streams / rivers. Alluvial plains: Partly irrigated fields, olive plantations. Area AS6d: New olive plantations in the northeastern part.	
Irrigation:	Groundwater, surface water when available, in the canyons possibly wells.	
Crops:	Palm gardens: Grain, vegetables, cattle fodder crops. Alluvial plains: Grain, vegetables, cattle fodder crops, olives.	
Accessibility / development of road infrastructure:	Alluvial plain and main valleys: Easy to access on a paved road + short mud roads. Lateral valleys: Mud roads.	
Future prospects / risks:	Intact and partly developing agriculture, development of tourist infrastructure in some lateral valleys is possible.	
Remarks:	Tourist infrastructure in Foum Zguid and in Tazenackht outside the area. Mines of Bou Azzer and Bleida in the areas AS6d and AS6f.	
Degree of documentation:	AS6a, AS6f: No documentation AS6d: Sufficient; AS6e: Poor	AS6b, AS6g: Sufficient AS6c: No documentation

Fig. 220: *Co / Ni-mine Bou Azzer (deep mining). Domain B, area AS6d, autumn 2015.*

Fig. 221: *Silt- and sandstones with ripple marks and olive green colour typical for the Middle Cambrian (km) in Morocco. Large-scale anticline between Tazenackht and Bou Azzer. Domain C, area AS6d, autumn 2015.*

Fig. 222: *Village Armazzer in the upper Oued El Koubia valley. Domain C, area AS6d, spring 2015.*

Fig. 223: *Village Aït Aissa in the upper Oued El Koubia valley. Domain C, area AS6d, spring 2015.*

Fig. 224: *Concrete ford destroyed by flooding of the Oued El Koubia. Domain C, area AS6d, spring 2015.*

Fig. 225: *Village Mrabte in the Oued El Koubia valley. Domain C, area AS6d, spring 2015.*

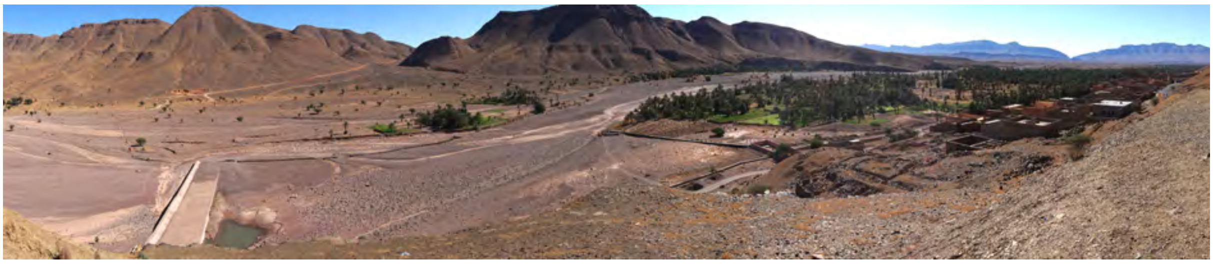


Fig. 226: *Oasis Al Ougoum in autumn. On the left is a dam to collect irrigation water. View towards south, Domain C, area AS6e, autumn 2015.*

Fig. 227: *Oasis Al Ougoum in spring. Fields with grain are light yellow. View towards south, Domain C, area AS6e, spring 2015.*

Fig. 228: *Groundwater pump of Al Ougoum (arrow). Domain C, area AS6e, spring 2015.*

Fig. 229: *Cistern for household supply on the slope above Al Ougoum. Domain C, area AS6e, spring 2015.*

Fig. 230: *Dry bed of Oued Zguid with acacias, near Foum El Oued. Domain C, area AS6e, spring 2015.*

Fig. 231: *Alluvial plain west of village N'Soula with acacias. View towards west, domain C, area AS6b, autumn 2015.*

Part VI Potential study areas in the Jebel Saghro

Together with the almost completely uninhabited Jebel Ougnat, Jebel Saghro is the easternmost part of the Anti-atlas Mountains, separated from the western and central parts by the Oued Drâa. In this report, it is not specifically subdivided. The areas JS1a-d and JS2 are situated on the southern slope and JS3 is on the northern slope (fig. 1).

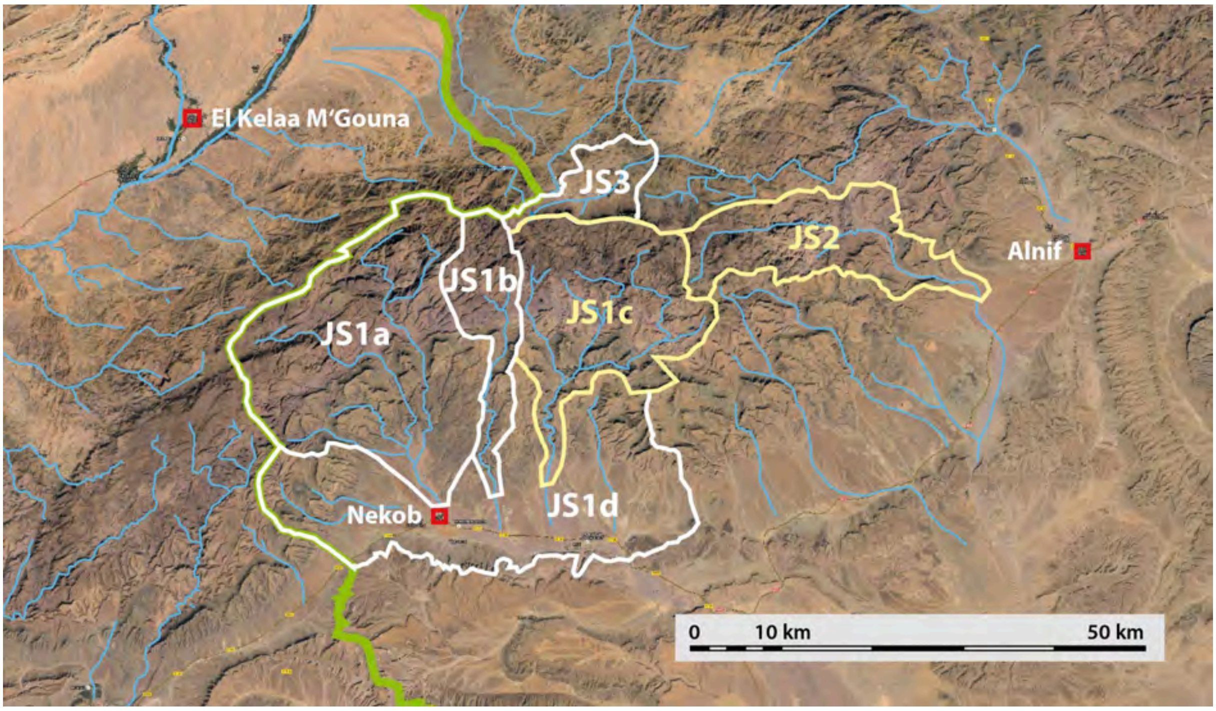


Fig. 1: *Satellite image of potential study areas in the Jebel Saghro. Streams and rivers are light blue, watersheds are light green. Boundaries of well documented study areas are white. Boundaries of areas with insufficient documentation are yellow. These areas, however, are similar to well known neighbouring areas.*

Satellite image: Google Earth 2016, Astrium, Cnes/Spot Image, DigitalGlobe, Landsat.

Regarding tectonics, Jebel Saghro is similar to the western and central Antitalas Mountains, with a domain B inlyer in the centre and Domain C / D rocks around (fig. 2). For characterization of domains C and D see part V, chapters 1.3 and 1.4. In contrast to the western and central Antiatlas, domain B inliers do not primarily consist of volcanic rocks and conglomerates (see part V, chapter 1.2), but also of granites that are very resistant to weathering. Thus, granites do not form deeply eroded pans as in the western and central Antiatlas (named 'domain A' there, see part V, chapter 1.1), but some of the highest peaks of Jebel Saghro (2700 m).

The gently ascending southern slope of Jebel Saghro is built of slightly inclined beds of lower and middle Cambrian and lower Ordovician marine and clastic sedimentary rocks (domains C and D), leaning against the volcanic, volcanoclastic and granitic rocks of the domain B inlier like a pile of books fallen over, cut by several basic dykes of Mesozoic age. The northern slope consists of domain B rocks and is steeper.

Accordingly, also the morphology resembles the western and central Antiatlas. The volcanic, volcanoclastic and granitic rocks in the centre and on the northern slope of the mountains mostly form V-Shaped valleys, whereas the sedimentary rocks on the southern slope are cut by deep, impressive canyons. The roughness of these canyons depends on the resistance to weathering of the rocks, the southernmost and uppermost Cambrian rocks being the most resistant ones. Thus, the more gentle, inner / higher parts of the canyons are generally more inhabited and used for agriculture than the rough outer / lower parts that lead towards the alluvial plain south of the mountains. On the foot of the mountains, at the outflow of the rivers into the alluvial plain, large areas are used for irrigated agriculture and numerous villages and scattered settlements are situated there. The streams / rivers are dried out most of the time. Even after heavy rainstorms, which form the most common way of rainfall in these regions (fig. 3), water quickliy infiltrates into the alluvial plain, filling the main river at its southern rim only rarely with water. The groundwater resources in the alluvial plain are used for agriculture and to supply the town of Nekob.

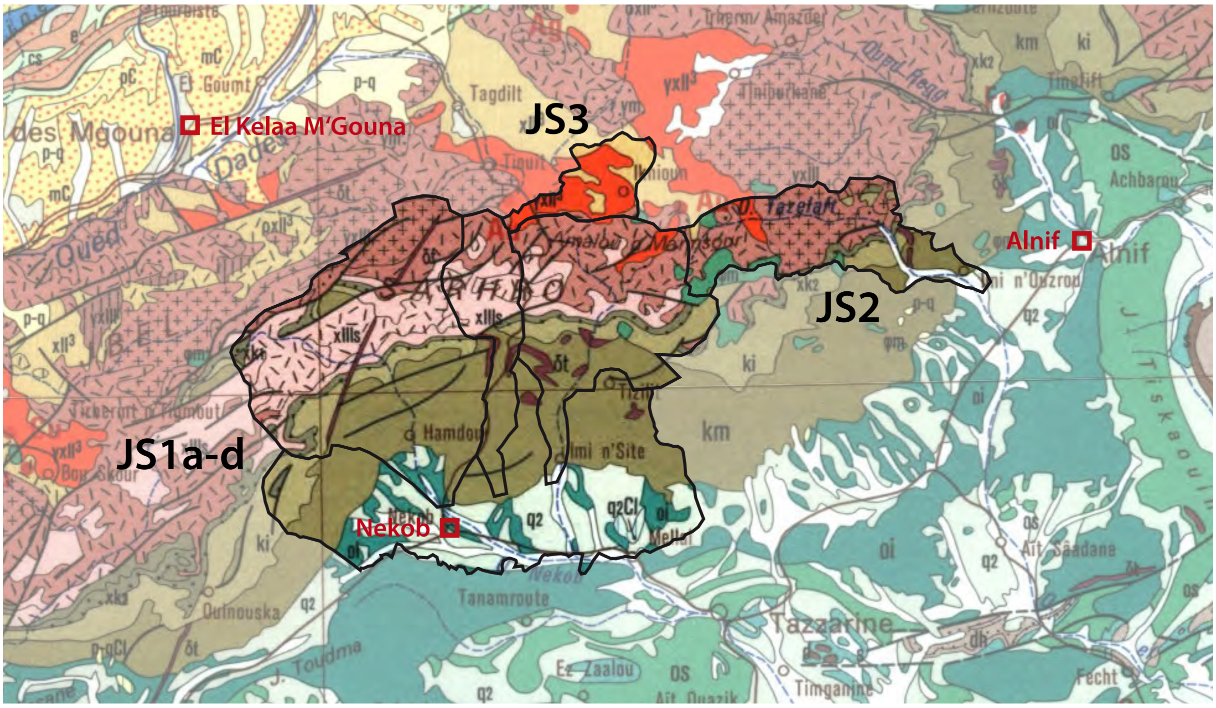


Fig. 2: *Geological map of Jebel Saghro showing potential study areas that are combinations of V-shaped valleys in the centre of the mountains and canyons on their southern slopes; modified after Saadi, M. et al., 1985, Carte Géologique du Maroc 1:1'000'000, Editions du Service Géologique du Maroc, see also annex III.*

Abbreviations for rock types forming V-shaped valleys:

yxII^3: Precambrian intrusive rocks (granites and granitoids)

xII^3: Precambrian schistose sandstones and conglomerates

yxIII: Precambrian granitic and subvolcanic rocks

xIII, xIIIm, xIIIs: Precambrian volcanic and volcanoclastic rocks

Abbreviations for rock types forming canyons:

ki: Lower Cambrian sedimentary rocks (predominantly shales)

km: Middle Cambrian sedimentary rocks (predominantly carbonates and clastic rocks)

δt: Triassic and Liassic dolerite dykes and sills

Abbreviations for rock types in the alluvial plain:

o: Ordovician sedimentary rocks (predominantly shales)

q2: Quaternary gravel and sand.

Fig. 3: *Rainstorms over Jebel Saghro under low cloud density conditions. Seen from Skoura in the Ouarzazate – Boumalne du Dadès high plain (view towards south), autumn 2015.*

1 Potential study areas on the southern slope

1.1 Area JS1 a-d
Alluvial plain of Nekob and adjacent canyons

The enormous alluvial plain of Neklob collects the water flowing down southwards from the Jebel Saghro through several canyons, forming a perfectly closed hydrological system with the only “drain valve” or outflow at the ravine (klus) near Izakheniouen / Tamesahlet or – with slightly enlarged, but less clearly delimited catchment – north of Tazzarine. The alluvial plain is filled with fluvial sediments of unknown thickness that host groundwater resources. It is mainly used for agriculture that concentrates at the outflows of the mayor tributaries (palm gardens, grain, olive plantations). The town of Nekob is a local centre and the largest settlement in the alluvial plain.

The tributaries flowing into the alluvial plain cut long valleys into the flat southern slope of Jebel Saghro. In the central parts of the mountains, with predominant igneous rocks, the V-shaped valleys often follow the weakness of fault zones. Their ways are therefore often crooked and do not follow the expected line of greatest slope. The subsequent canyons cutting through the sedimentary rocks are wide open and used for agriculture in their upper parts. Towards the foot of the mountains, in the hardest sedimentary rocks, however, they transform to narrow and sparsely inhabited, meandering canyons.

Tab. 1: Key attributes of area JS1 a-d.

	Areas
	JS1 a-d
Rock types, units / periods:	See fig. 2, page 266.
Stream / river:	Periodic, episodic
Predominant natural vegetation:	Perennials
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Low
Form of settlement:	Compact villages and scattered settlements along the streams and at the outflow of the canyons into the alluvial plain.
Density of settlement:	Very low - low
Predominant form of agriculture:	Irrigated fields along the streams; palm gardens in the canyons and in the alluvial plain; plantations in the alluvial plain.
Irrigation:	Mainly groundwater, surface water when available.
Crops:	Grain, vegetables, cattle fodder crops, almonds, olives.
Accessibility / development of road infrastructure:	Nekob is easy to access on a paved road; the canyons are only accessible on long and partly difficult mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure in the centre of the mountains is possible, especially with respect to the partly impressive sceneries.
Remarks:	Good tourist infrastructure in Nekob, modest “auberges” on the Nekob – Boumalne du Dadès mud road over Tizi N’Tazazert.
Degree of documentation:	JS1a, JS1b, JS1d: Good; JS1c: No documentation.

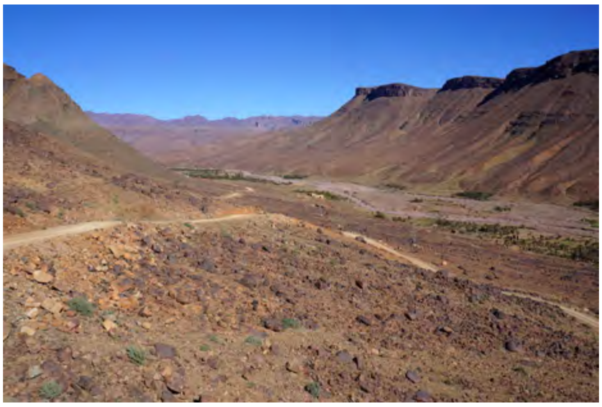


Fig. 4: *Open, upper part of the Handour canyon with irrigated fields. Domain C, area JS1a, autumn 2015.*

Fig. 5: *Village in the upper part of the Handour canyon with dry riverbed and cliffs made of Precambrian volcanoclastic rocks overlaid by sediments. Domains B and C, area JS1a, autumn 2015..*

Fig. 6: *Irrigated fields and almond trees in the open, upper part of the Handour canyon. Domain C, area JS1a, autumn 2015.*

Fig. 7: *Open cistern and groundwater pump with irrigated fields in the open, upper part of the Handour canyon. Domain C, area JS1a, autumn 2015.*

Fig. 8: *Corn harvest in the open, upper part of the Handour canyon. Domain C, area JS1a, autumn 2015.*

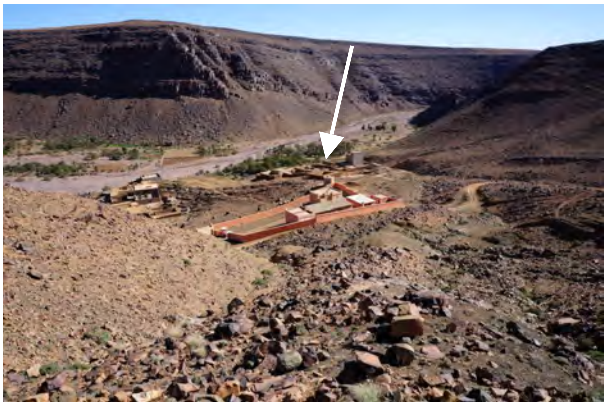


Fig. 9: *Village with school buildings (behind the salmon pink walls) and cistern (arrow). Open, upper part of the Handour canyon just before the river enters the lower, narrow part. Domain C, area JS1a, autumn 2015.*

__Fig. 10:__ Village with palm gardens in the lower, narrow part of the Handour canyon. Domain C, area JS1a, autumn 2015.

__Fig. 11:__ Village with palm gardens in the lower, narrow part of the Handour canyon. Domain C, area JS1a, autumn 2015.

__Fig. 12:__ View towards west over the sedimentary rocks on the southern slope of Jebel Saghro that are slightly inclined towards south. Domains C and D, areas JS1a and JS1d, autumn 2015.

__Fig. 13:__ View from the foot of the mountains towards south over the alluvial plain with villages and agricultural land at the outflow of the Handour canyon. Domains C and D, areas JS1a and JS1d, autumn 2015.

__Fig. 14:__ View from the foot of the mountains towards south over the outflow of the Handour canyon with its dry riverbed, a village and agricultural land. Domains C and D, areas JS1a and JS1d, autumn 2015.

__Fig. 15:__ A new (left) and an older (right) cistern for the water supply of villages on the foot of the mountains. Domain C, area JS1a, autumn 2015.

Fig. 16: *Shafts belonging to a water pipe leading from the cisterns (fig. 15) down to the villages on the foot of the mountains. Domain D, area JS1d, autumn 2015.*

Fig. 17: *Open cistern for irrigation and petrol-driven groundwater pump in the alluvial plain near Nekob. Domain D, area JS1d, autumn 2015.*

Fig. 18: *Rhyolites (reddish) and overlaying granites (grey) forming a peak in the principal range of Jebel Saghro near Tizi N'Tazazert. Domain B, area JS1b, spring 2015.*

Fig. 19: *High plain in the peak area of Jebel Saghro, forming Tizi N'Tazazert. View towards north, domain B, area JS1b, spring 2015.*

Fig. 20: *Fault zone in volcanic and volcanoclastic rocks forming one of the scenic highlights of the long and difficult Tizi N'Tazazert mud road. Domains B and C, areas JS1b and JS1c, spring 2015.*

Fig. 21: *View from the Tizi N'Tazazert mud road southwards into the open upper part of the Ousdiden canyon with its irrigated fields (arrow). Domain C, area JS1b, spring 2015.*

Fig. 22: *Open, upper part of the Ousdiden canyon with irrigated fields. The rock towers in the background are named Bab N'Ali. Domain C, area JS1b, spring 2015.*

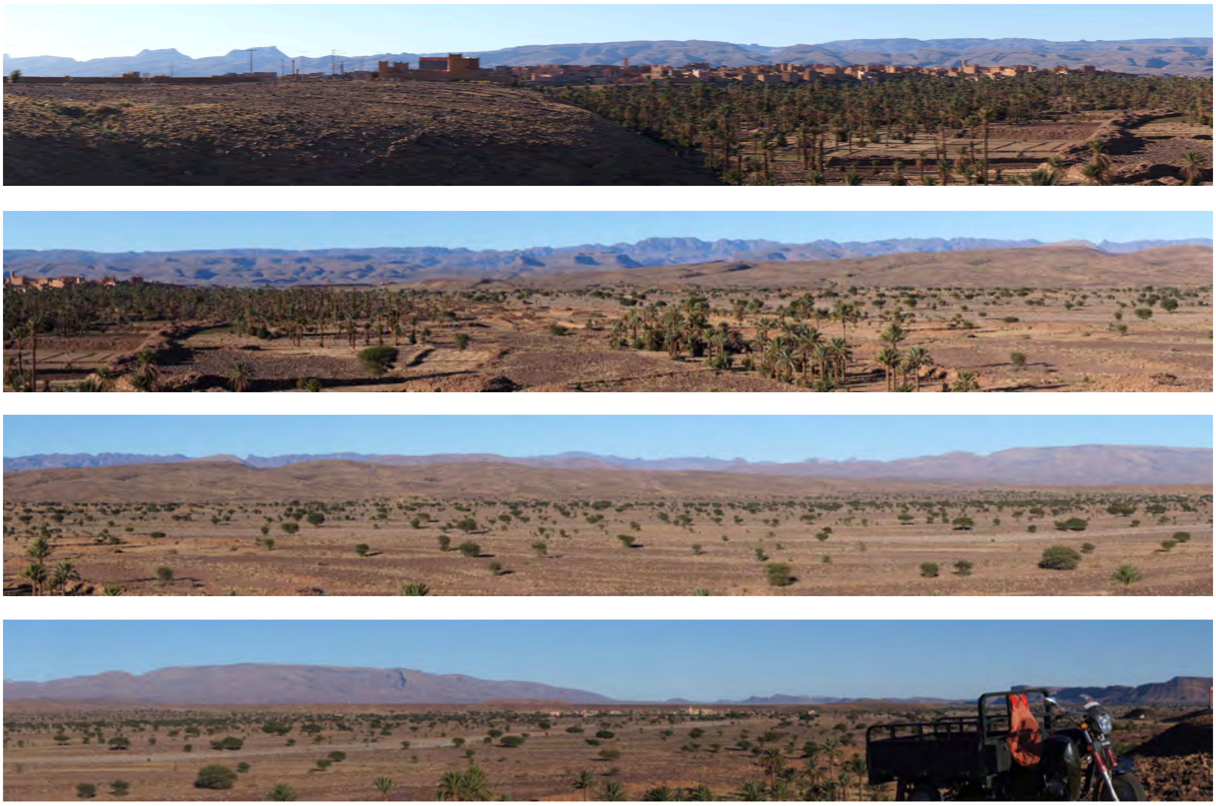
Fig. 23: *Open, upper part of the Ousdiden canyon with irrigated fields, view towards south. Domain C, area JS1b, spring 2015.*

Fig. 24*: Irrigated grain field in the lower, narrow part of the Ousdiden canyon. Domain C, area JS1b, spring 2015.*

Fig. 25: *Village Adar N'Tassoute with irrigated palm gardens in the lower, narrow part of the Ousdiden canyon. Domain C, area JS1b, spring 2015.*

Figs. 26 and 27: *Two of the numerous small Barite mines on the southern slope of Jebel Saghro. Domain C, areas JS1a and JS1b, spring 2015.*

Figs. 28 - 31: *Coherent panoramas (west – north – east) of the alluvial plain and Jebel Saghro west of Nekob. Nekob is on the lowest panorama in the centre. Areas J1 a-d, autumn 2015.*



Figs. 32 - 35: *Coherent panoramas (west – north – east) of the alluvial plain and Jebel Saghro east of Nekob. Nekob is on the uppermost panorama in the centre. Areas J1 a-d, autumn 2015.*

Fig. 36: *Palm gardens with irrigation channel (arrow) east of Nekob. Nekob is in the background. Area JS1d, autumn 2015.*

Fig. 37: *Palm gardens with irrigated fields east of Nekob. Nekob is in the background. Area JS1d, autumn 2015.*

Fig. 38: *In the town of Nekob numerous traditional mud houses are in a good condition. Area JS1d, autumn 2015.*

Fig. 39: *View from Nekob eastwards over the palm gardens. Area JS1d, autumn 2015.*

Fig. 40: *Caddle fodder crops (lucerne) drying in the streets of Nekob. This underlines the rural character of the town. Area JS1d, autumn 2015.*

Fig. 41: *Dry riverbed with Tamarisk trees at the outflow of the alluvial plain near Izakhenioue n / Tamesahlet. View valley upwards towards west, domain D, area JS1d, autumn 2015.*

1.2 Area JS2
Canyon of Imi N'Ouzrou – Tazelaft

This canyon near Alnif has not been further investigated, it is, however, similar to the canyons adjacent to the alluvial plain of Nekob.

2 Potential study areas on the northern slope

2.1 Area JS3
Aït Ouallal - Outaaoui

The Aït Ouallal – Ouataaoui area is interesting because it is one of the few areas that has a modern micro dam, being capable to store rainwater that falls within a few hours per year during episodic rainstorms. Although the local population of Jebel Saghro is in favour of the construction of a whole network of such dams, apparently no further dams are in prospect at the moment.

Tab. 2: Key attributes of area JS3.

	Area
	JS3
Rock types, units/periods:	See fig. 2, page 266.
Stream/river:	Periodic, episodic
Predominant natural vegetation:	Perennials
Density of natural vegetation:	Low – middle
Degradation of natural vegetation:	Low
Form of settlement:	Compact villages and scattered settlements along the streams.
Density of settlement:	Very low - low
Predominant form of agriculture:	Irrigated fields along the streams.
Irrigation:	Mainly groundwater, surface water when available.
Crops:	Grain, vegetables, cattle fodder crops, almonds, olives.
Accessibility/development of road infrastructure:	Easy to access on paved and mud roads.
Future prospects / risks:	Intact agriculture, development of tourist infrastructure is not relevant.
Remarks:	Good tourist infrastructure outside the area in the Dadès and Drâa valleys.
Degree of documentation:	Good

***Fig. 42:** Uppermost settlements north of Tizi N'Tazazert (left) with a new micro dam (right). Domain B, area JS3, spring 2015.*

***Fig. 43:** Micro dam for irrigation and household water supply (see also fig. 42). Domain B, area JS3, spring 2015.*

***Fig. 44:** Uppermost settlements with irrigated fields north of Tizi N'Tazazert (see also fig. 42). Domain B, area JS3, spring 2015.*

***Fig. 45:** Village Amjdadar with dry riverbed and improvised irrigation channel crossing the mud road. View southwards to the main range of Jebel Saghro. Domain B, area Ma2, spring 2015.*

***Fig. 46:** Groundwater pumps in the dry riverbed near village Amjdadar. Domain B, area JS3, spring 2015.*

Annex I Glossary

Agadir (pl.: Igoudar)	Collective, fortified granary owned by a tribal subgroup of Berber in southern Morocco (Taschelhit term).
Aït	Berber name affix with the meaning 'people of', referring to the descent from a certain common male ancestor. As „Aït …." term for tribal subgroups of Berber, often also eponymous for villages or ksour inhabited by the members of this specific tribal subgroup; e.g. Aït Ben Haddou.
Asif, Assif	River, mostly perennial (Tamazight term).
Douar	Originally a group of fixed or mobile, temporary or permanent homesteads, inhabited by people with a common paternal affiliation. Today the term means a 'small village', a 'hamlet', or a 'group of rural dwellings', which comprises 50 to 400 households and constitutes the administrative basic unit of rural communities.
Jebel, Jabal	Mountain (single peak) or mountain range (Arabic term).
Kasbah	A type of medina or walled citadel found in North African cities and towns. Formerly often guarded by armed forces and/or residence of governors and leading families. In Morocco the term is also used for fortresses outside the towns in the Atlas Mountains, where they were built to protect the hinterland against rebellious Berber tribes. Since the end of the 19^{th} century the term is also used for Berber Tighremt and Ksour.
Ksar (pl.: Ksour)	General meaning of 'fortified village' or 'fort' in the Maghreb, typically consisting of attached houses, often having collective granaries and other structures like a mosque, bath, and oven, usually entirely within a continuous wall. Ksars form one of the main manifestations of Berber architecture. The original word for 'ksar' used by the Berber-speaking populations in Morocco is *aghrem* (sg.) or *igherman* (pl.).
Matfia	Collective, closed cisterns that are usually built outside the villages, either in the underground or above ground, where storm streams are collected.
Oued	A valley, gully, or streambed that remains dry except during the rainy season, and a stream that flows through such a channel (Arabic term, malapropism: 'wadi').
Séguia	Open irrigation channel.
Tamazight	On the one hand one of the several berber languages and on the other hand a generic term for all berber languages (also: Amazight).
Taschelhit	Berber language spoken specifically in southern Morocco (also called '*Chleuh'* or '*Souss-tamazight')*.
Tighremt	Berber living castle with mostly three floors and four prominent corner towers made of tamp clay in southern Morocco (Tamazight term).
Tizi	Pass, hill
Zawiya	Tomb of a venerated marabout. Today 'marabout' means 'saint' in the Berber language, and refers to Sufi Muslim teachers who head a lodge or school called a zaouïa, The roots of this tradition can be traced back to ancient times when the Berbers believed in polytheistic religions.

The Annexes II and III need a lot of storage capacity and are therefore offered as separate ducuments.