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P11

Vegetation Dynamics and its Impacts on the Hydrological Cycle

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PROBLEM: Vegetation is the principal biotic agent of the water cycle in semiarid regions. Plants act as consumer of water and, at the same time, the vegetation cover reduces surface run off and enhances water infiltration in the soil. Thus, the vegetation controls the sensible balance between groundwater regeneration, stream flow and evapotranspiration. The vegetation itself underlies complex dynamics, driven principally by land use patterns and climatic processes. The dynamic subprocesses of this regulation and the quantitative consequences for regional water balances of semiarid regions are still far from being entirely understood.

OBJECTIVES

- Analyze and model spatiotemporal vegetation dynamics.
- Quantify plant water consumption of important plant species.
- Approximate the role of the rangeland vegetation for the water cycle.
- Help stakeholders to manage vegetation resources in a way that anticipates future changes according to change scenarios.

RESPONSE INDICATORS

- Structural and floristic parameters of the native steppe vegetation can serve as response indicators to evaluate biotic shifts and hydrological impacts.

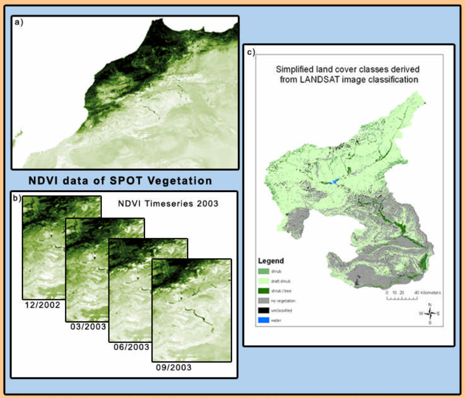

Fig.1: NDVI timeseries derived from SPOT Vegatation data and reclassified LANDSAT mosaic with simplified classes of land cover

1.Time Series Analysis and Change Detection of Vegetation Pattern using multi-temporal Remote Sensing Data

Time series of the **SPOT Vegetation Sensor** from 1998 to present are used to analyse in detail the relationship of vegetation dynamics and climatic parameters in the Drâa Catchment. Therefore, **10 day composites** (Fig.1b) of synthetic, cloudless and radiometrically corrected **NDVI** (Normalised Difference Vegetation Index) data with a spatial resolution of 1 km are analysed and statistically correlated to climatic data derived from a climatic model on a daily basis.

In a first step intra-annual changes of the NDVI for a model year 2002/2003 are correlated to precipitation and temperature data derived from the climatic model. Simplified vegetation pattern (Fig.1c) are currently being used for a first coarse analysis of time delays between climatic trigger events and vegetation responses.

In a second step, detailed **multi-temporal vegetation classification** of a LANDSAT mosaic, refined by using a high resolution Digital Elevation Model (DEM) and ground data on vegetation communities, will be used as an input for modelling intra- and inter-annual changes in vegetation cover for the different subunits of the Drâa Catchment.

The results of that first model year will finally be integrated in a model of **intra-annual vegetation dynamics** for the region. This model will be related to different climatic scenarios until 2020.

2.Vegetation Shifts under Global Change

Vegetation plays a major role in water cycle dynamics. Transpiration of plants consumes water resources which are deviated to the atmospheric compartment of the hydrologic cycle. As vegetation is not randomly distributed in a landscape, it is important to describe the **spatial pattern of species and communities** to analyse its function for the hydrological cycle. The niche size of species and communities and therefore its spatial distribution pattern is determined by **environmental and biotic factors**.

Global change effects like rising mean temperatures are assumed to act as driving forces for shifting vegetation units. A **habitat model approach** was chosen to predict the actual distribution of plant species and vegetation communities in the High Atlas region. These models calculate the **probable habitat** occupied by species or communities.

In the next step, habitat models were fed with **climatic scenario data** to predict the habitat shifts till 2020. Temperature rising by 1.3°C would cause an altitudinal migration of *Alyssum spinosum* by 200 meters upwards. Habitat area for this species is shrinking by 18 % (Fig.2).

Habitat models will be constructed further for all important species and the principal plant communities of the Drâa area. Results will play a fundamental role for the SAVANNA model.

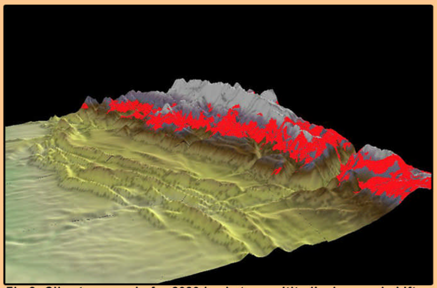

Fig.2: Climate scenario for 2020 leads to an altitudinal upward shift for *Alyssum spinosum*. Red zone indicates predicted habitat loss.

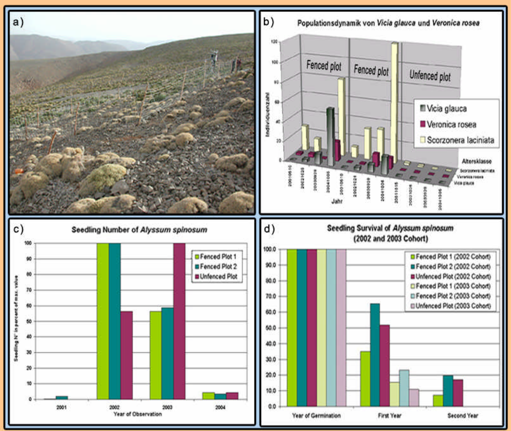

Fig.3: a) Testsite Tichki at 3200m b) Distribution of palatable species in- and outside the fence c) Climate effects on *Alyssum spinosum* regeneration d) Self thinning of *Alyssum spinosum* cohorts

3.Vegetation Dynamics as Response on Grazing Effects

Over the last 4 years, vegetation composition and structure was observed in 35 individual based monitoring plots along the test site transect. Comparison of **permanent plots** with and without exclosure allows us to analyse vegetation dynamics and to discriminate between climatic triggers and grazing pressure as driving forces for vegetation changes.

Fig.3b shows us slow changes of the species composition in the fenced plots of test site Tichki (TIC). Palatable but defenseless species like *Veronica rosea*, *Scorzonera laciniata* or *Vicia glauca* show a steady increase in individual numbers under **exclosure conditions** whereas none of these species shows a change in biomass or number outside the fences. Permanent gramineous species like *Helictotrichon sedenense* (TIC, TZT), *Stipa parviflora* (IMS, BSK, TAO) or *Stipagrostis obtusa* (TRL) show similar dynamics at all testsites north of the Jebel Sarrho. **Grazing pressure** has apparently caused major vegetation shifts in the northern part of the study area, while we don't find comparable processes along the southern part of the test site transect (ARG, EMY, JHB, IRK). **Climatic trigger events** have a major impact on regeneration (and die off) events.

Seedling numbers of *Alyssum spinosum* at test site Tichki show strong interannual variations according to late summer/early autumn precipitation (Fig.3c). At different absolute levels, seedling dynamics inside and outside the exclosure show **parallel trends**.

Fig.3d shows the fate of the 2002 *Alyssum spinosum* seedling cohort over the following years. Ongoing monitoring activities and trend analyses shall allow us in the future to formulate modelling algorithm which describe vegetation responses on climate or land use changes. Abundance of **sensitive indicator species**, seedling establishment and structural vegetation parameters of dominant species (as height and cover) will serve as **response indicators** for scenario evaluation.

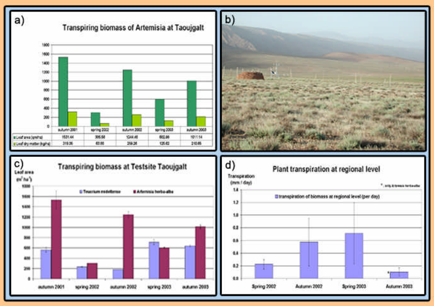

Fig.5: Estimation of plant biomass and transpiration at testsite Taoujgalt

5. Waterbalances as a Function of Plant Water Consumption

Transpiration rates of dominant plant species at IMPETUS testsite Taoujgalt were carried out in the years 2001 – 2003 by **gas exchange measurements**. Transpiration rates were extrapolated to regional scale by biomass measurements. Dominant plant species are *Artemisia herba-alba* and *Teucrium mideltense*. The biomass measurements showed that *Artemisia herba–alba* is the prevailing species with a biomass maximum in autumn (flowering time) (Fig.5a). Water consumption of *Artemisia* at leaf scale is less than *Teucrium* (maxima 4.2 l /m2 leaf area x day versus 7.8 l/m2 leaf area x day), but due to its predominance at **regional scale** the water consumption of *Artemisia* is higher. While the *Artemisia* biomass responded instantaneously on the singular precipitation event of 1. April 2002 (48 mm), this influence was seen in *Teucrium* in 2003 (Fig.5b).

Water consumption of the dominant plant species ranged between 0.2 and 1.2 mm per day (Fig.5d), which is about 70% of annual precipitation (data for 2002) at this area and can locally be higher, especially in autumn (up to 125 %). This indicates that plants have at least partially access to lateral water supply or ground water recourses.

4.Modelling Biomassdynamics

The spatial **ecosystem model** SAVANNA is used to describe vegetation dynamics under grazing conditions. Different functional vegetation units are distinguished to simulate plant growth and competition for nutrients and water, as well as biomass intake by herbivores and herd dynamics.

As a first approach the model was calibrated for steppes of high valleys at the southern High Atlas slopes. Dominant species are *Artemisia herba-alba* and *Teucrium mideltense*, which were parameterized by **transpiration and biomass measurements** carried out in the years 2001 – 2003. Actually, measurements of biomass and plant growth are carried out for codominant species such as *Adenocarpus bacquei*, *Stipa parviflora* and *Stipagrostis obtusa*. Maps of soil and vegetation parameters constitute the **spatial base of SAVANNA**. Additional soil data completes the input parameter database. Explicit herd data, concerning sheep's, goats and camels, was provided by Moroccan counterparts at ORMVAO.

Model results indicated an underestimation of root (leaf-) water uptake and reproduction rates for *Artemisia herba-alba*. The consequence is a high mortality rate during the hot summer season. The modelled population density of *Artemisia herba-alba* overestimated real values in spring by 10% and was 23% too low in the flowering season in autumn (Fig.4b). On the other hand, the biomass calculated by SAVANNA was too high (Fig.4c). **Further simulations** take into account the strong dependency between semi-arid plant population dynamics and their adaptation to low precipitation rates and soil water resources. Once finished the **model calibration**, model output of standing biomass for dominant species will serve as response indicator for scenario evaluation.

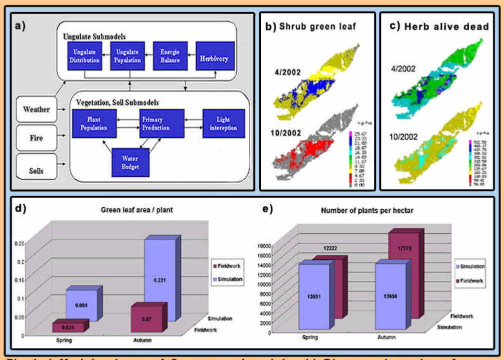

Fig 4.a) Model scheme of Savanna submodules b) Biomass dynamics of green leafed shrubs (model output) c) Herb biomass in autumn (model output) d+e) Simulated and observed leaf area and plants per hectar

RESULTS

- **Rangeland vegetation consumes between 20 % (southern Drâa area) and 70 % (High Atlas) of precipitation.**
- **Steppes in the semiarid north show severe degradation.**
- **We find no evidence for large scale degradation in the south.**
- **Future change processes are likely to affect particularly the semiarid parts of the study area.**

CONCLUSIONS

- **Agriculture constitutes the principal water consument in the Drâa area.**
- **Minor changes in production system might help to buffer changes in water availability due to climate or land use change processes.**
- **Stakeholder should invest in water saving techniques rather than optimize rain water harvesting at the expense of rural communities in the source areas.**

SCENARIO OUTLOOK

- **Scenario M1 would cause biodiversity losses, reduced pastoral productivity, intensified run off events and higher total erosion.**
- **Scenario M2 would result in a higher vegetation cover, significantly reduced run off and slightly to considerably enhanced infiltration.**
- **Scenario M2 would increase the transpiration losses in the northern part of the study area up to 30 % while we do not expect changes in the south.**
- **Scenarios M1 and M3 would not affect the urban water supply, but biological resources and rural water supply might result affected.**
- **Climatic change scenarios of reduced precipitation might reduce absolute transpiration losses but aggravate the water supply.**

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