STRIVER TECHNICAL BRIEF

Strategy and methodology for improved IWRM
- An integrated interdisciplinary assessment in four twinning river basins

TB No.1

Land use change and water resources in the Tagus and Tungabhadra basins

Land use has a large effect on the water cycle of river basin, affecting the availability of usable water and other aspects related to water quality and quantity. Thus, an estimation of the effect of future land use changes on the water cycle should be part of any integrated water resources management plan. In this technical brief we analyze the recent changes in land use in the Tagus and the Tungabhadra basins, and their effects on the availability and management of water resources.

The STRIVER Technical Brief series translate the results from the EC FP6-funded STRIVER project into practical and useful information for policy makers and water managers

Land use change and water resources in the Tagus and Tungabhadra basins

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Abstract

Land use has a large effect on the water cycle of a river basin, affecting the availability of usable water and other aspects related to water quality and quantity. Thus, an estimation of the effect of future land use changes on the water cycle should be part of any integrated water resources management plan. In this technical brief we examine the recent land use changes in the Tagus and Tungabhadra basins, and their influence in the availability of water resources. Despite significant land use change in the headwaters which added to the effects of a reduction of precipitation in the last decades, it was found that the Tungabhadra reservoir system had large resilience and no effect was apparent in the series of water storage. In the Tagus basin, on the contrary, the regulation capacity is close to its maximum with respect to the total water available, and the system is much more vulnerable to alterations in the water cycle.

References

Gallart, F. and Llorens, P. 2001. Efectos de los cambios de uso y cubierta del suelo en los aportes del río Ebro y su evolución futura. In: N. Prat & C. Ibáñez (Eds.), *El curso inferior del Ebro y su delta.* Barcelona, 51–57.

Beguería, S., López-Moreno, J.I., Lorente, A., Seeger, M. and García-Ruiz, J.M. (2003). Assessing the Effect of Climate Oscillations and Land-use Changes on Streamflow in the Central Spanish Pyrenees. *Ambio* 32(4): 283–286.

The complete technical report on which this policy brief is based can be found as:

Beguería, S. 2008. Land Use and Land Use Change -Implications for Water Resources and Water Use in the Tagus and Tungabhadra Basin. STRIVER Project Task Summary Report 9.3.

Introduction

Land use has a large effect on water use, as well as on water resources quality and quantity. The relationship is twofold: on one hand, land use exerts a major control on water use; but it also has great potential for modifying the hydrological cycle within the river basin, thus affecting the availability and timing of water resources. The effects of land use change on the water cycle can have a magnitude equivalent to those of climate change. The interaction between land use and the water cycle is relatively well known, although it is often ignored in water resources management plans. For example, in Spain this issue was not included in the National Water Management Plan (Plan Hidrológico Nacional) of 2001. However, it is well known that land use change has been very important in Spain during the last decades of the past century, with a conversion of farm land to natural vegetation in the mountain areas, and there are many studies relating these changes to observed decrease in river runoff, specially in headwater areas (Gallart y Llorens, 2001; Beguería et al, 2003).

Land use change in the past decades in the Tagus basin

The analysis performed in this work task has confirmed the importance of land use change in the last decades in the Tagus (Spain-Portugal). In the case of the Tagus, the increase of the urban cover has been the most significant land use change in the Spanish part; whereas in Portugal the increase and densification of the natural vegetation cover has been predominant. A general process of abandonment of the marginal lands for agriculture and pastures has also been observed in the headwaters of the Tagus River in Spain, and some new irrigated areas were built in the valleys of major tributaries (Fact box 1). The time series of satellite derived vegetation index (NDVI) has also revealed a decrease of the vegetation activity around the Madrid area, contrasting with increased vegetation activity in the headwaters at the Iberian Range and the Portuguese areas (Figure 1).

Land use change in the past decades in the Tungabhadra basin

In the Tungabhadra basin, farmland and pastures predominate in most of the basin, except for the dense forests on the headwater areas in the Western Ghats region, to the South-East of the region. According to municipal land use statistics, a trend towards a denser and more abundant forest cover has occurred during the second part of the 20th Century, most specially in the headwaters of the river at the Karnataka state (Tables 2 and 3). The time series of the NDVI vegetation index confirmed this result, revealing an overall increase of the vegetation activity in the basin, which was most evident in the headwater areas (Figure 2).

Fact box 1

Land use change in the Tagus basin in 2000 (percent variation with respect to 1990). Source: CORINE Land Cover 1985/1990 and 2000.

Land cover	Total Tagus basin	Spain	Portugal
Urban	+12.00%	+21.06%	+0.45%
Non-irrigated arable land	-5.00%	-5.55%	+0.60%
Permanently irrigated land	+6.00%	+7.89%	-4.81%
Vineyards	-1.00%	-4.02%	+3.29%
Fruit trees	-1.00%	-2.30%	+0.09%
Olive groves	+0.00%	+1.11%	-0.67%
Pastures	-1.00%	-1.88%	-0.19%
Complex cultivation patterns	+0.00%	+0.58%	-2.19%
Agro forestry	+2.00%	+3.77%	-0.08%
Broad leaved forest	-1.00%	-1.59%	-0.46%
Coniferous forest	-1.00%	-1.22%	+2.21%
Mixed forest	+0.00%	+0.51%	-1.70%
Natural grasslands	-1.00%	-1.39%	+0.15%
Sclerophyllous shrubland	-2.00%	-3.74%	-0.10%
Transitional woodland-shrubland	+7.00%	+5.70%	-1.16%
Bare rock	-6.00%	-11.35%	-0.45%
Sparsely vegetated areas	+0.00%	-0.48%	-0.86%
Burnt areas	-31.00%	-55.55%	-0.81%
Water bodies and courses	+2.00%	+3.78%	+0.07%

Hydrological analysis

Increase of the natural vegetation surface and activity causes an increase of the 'green water', or water consumption by the ecosystem to maintain the ecological status. As a consequence, there is a reduction of the 'blue water' or water in rivers and lakes and in the underground which can be used by humans. On the other hand, reduction of the forest cover and urbanization is known to increase (in some cases dramatically) the runoff coefficient, hence promoting the production of 'blue water' but also increasing the probability and severity of floods. In the case of the two basins analyzed in this study, the effects of land use change at the basin level are difficult to discern due to the interaction of effects of opposite sign, and to the lack of appropriate data in some occasions.

In the Tungabhadra basin, in addition to an increase of the vegetation activity in the headwaters, a negative trend in the annual rainfall was observed (fact box 3). Both things are expected to have had a negative effect in the runoff production and the river discharge. However, it was not possible to prove this hypothesis due to the lack of river discharge data. On the contrary, the analysis of reservoir storage time series revealed no impact of either land use change or climate variability, showing a stationary time series only subject to natural year to year oscillation. These

Fact box 2

Land use change in the Tungabhadra basin between 1950 and 2005, Karnataka districts (percent change with respect to 1950)

	Bellary	Chikmagalur	Davanagere	Raichur	Shimoga	Sta
Forest	−3.5%*	+8.1%*	+0.2%	+1.2%*	+18.2%*	+1.6
Not available for cultivation	+2.0%*	−0.2%	+1.3%*	−3.0%*	−1.9%*	+2.5
Permanent pastures	+0.0%	−17.3%*	−1.6%*	−0.8%*	−5.3%*	−4.8
Miscelaneous trees	+0.0%	+1.4%*	−0.3%	+0.7%*	−5.5%*	−0.5
Cultivable Waste	−1.3%*	−2.1%*	−0.5%*	+0.0%	−2.7%*	−1.3
Fallow land	+5.2%*	−2.7%*	+4.0%*	+9.7%*	−3.8%*	+1.7
Crops	−2.4%	+12.9%*	−3.2%*	−6.4%*	+0.9%*	+0.8

*: change significant at the 95% confidence level

Land use change in the Tungabhadra basin between 1950 and 2005, Andhra Pradesh districts (percent change with respect to 1950)

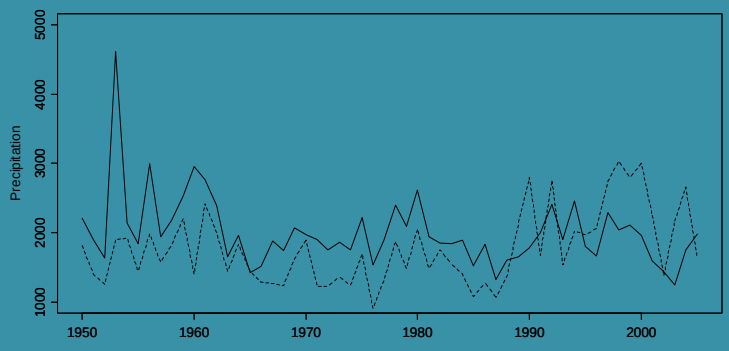
	Cuddapah	Kurnool	Mahaboobnagar	Stat
Forest	−2.8%	−36.3%*	−10.9%	+5.5
Not available for cultivation	+134.7%	+49.5%	−5.7%	+11.4
Permanent pastures	+23.5%*	−88.7%	−65.8%	−44.1
Miscelaneous trees	−46.7%	−79.0%	−27.0%*	−5.8
Cultivable Waste	−57.1%	−3.6%	−62.7%*	−57.5
Fallow land	−41.1%	+43.8%	+106.3%*	+32.6
Crops	−10.4%	+8.8%	−25.3%*	−4.7

results suggest that the Tungabhadra basin has a good resilience to changes in the water cycle, due to the fact that the regulation capacity has not yet achieved its upper limit. However, this conclusion is based on weak data, and it should be further confirmed by field analysis.

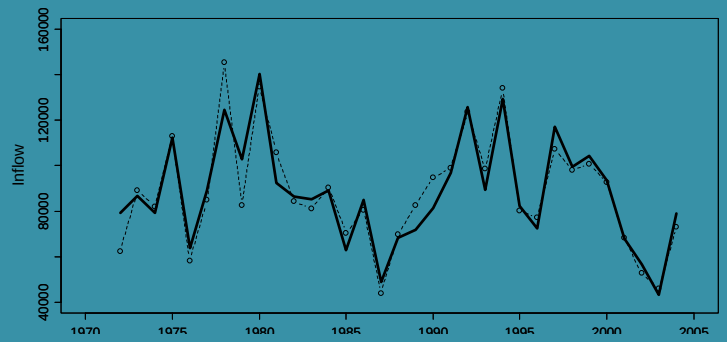
In the Tagus basin, on the contrary, the regulation capacity at the headwaters is very high (more than 100% of the annual water contribution). As a consequence, the system was much more sensitive to changes in the hydrological cycle. The analysis showed only a marginal effect of land use change on the river discharge, although the time series of reservoir storage showed negative trends.

Fact box 3

Time series of annual rainfall at Chickmagalur (solid line) and Shimoga (dashed line).



Rainfall-runoff modelling for the Bhadra reservoir. Top: time series of modelled (bold) and observed (dashed) inflow. The model was based on multivariate regression of the annual discharge data on the annual rainfall at several observatories, plus the annual NDVI for the upstream basin; a stepwise method was used to select only the significant variables. The model residuals show a slight positive trend, although it was not significant.



STRIVER

The STRIVER Policy and Techncal Brief series translate the results from the project into practical and useful information for policy makers and water managers.

The Briefs are also available online: www.striver.no

About STRIVER
STRIVER- Strategy and methodology for improved IWRM - An integrated interdisciplinary assessment in four twinning river basins is a three year EC funded project 2006-2009 under the 6th framework programme (FP6) coordinated jointly by Bioforsk and NIVA. The point of departure for STRIVER is the lack of clear methodologies and problems in operationalisation of Integrated Water Resource Management (IWRM) as pointed out by both the scientific and management communities.13 partners from 9 countries participate as contractual partners in addition to an external advisory board.

Title of project:
Strategy and methodology for improved IWRM - An integrated interdisciplinary assessment in four twinning river basins (STRIVER)

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Front-cover photo: Bird flying over a grassland in Hyderabad, India (Geoffrey Gooch)

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