Working Paper 352

Land and Water Use Interactions Emerging Trends and Impact on Land-use Changes in the Tungabhadra and Tagus River Basins

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ISBN 978-81-7791-208-1

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LAND AND WATER USE INTERACTIONS: EMERGING TRENDS AND IMPACT ON LAND-USE CHANGES IN THE TUNGABHADRA AND TAGUS RIVER BASINS

Per Stalnacke, Begueria Santiago, Manasi S, K V Raju, Nagothu Udaya Sekhar, Maria Manuela Portela, António Betaâmio de Almeida, Marta Machado, Lana-Renault, Noemí, Vicente-Serrano and Sergio∗

Abstract

The paper provides a comprehensive analysis of the issues, current status and complex inter-linkages in land and water management, emerging trends and its impact in two river basins[1] - the Tungabhadra sub-basin in India and the Tagus basin in Spain and Portugal. The paper covers a wide range of issues including changing water demands affected by erratic hydrological cycles, frequent fires affecting forests, biodiversity and soil thus influencing the livelihoods of marginal communities. The paper also brings to the forefront the need for integrated water management in view of poor integration across and within sectors. Therefore, an attempt is made to understand the dynamics of rain fed and irrigated farming highlighting the technological and institutional options required for improving water-use efficiency. There is still a long way to go in both the basins before suitable integration can be achieved leading to an effective Integrated Water Resource Management strategy.

Introduction

Land use has significant impact on water resources in terms of quantity and quality. The emphasis on integrating land and water resource management appears logical because the type of land use and management has implications for water and vice versa. It eventually influences production, efficiency and livelihoods in a river basin. The relationship is mutually dependent: changes in land use not only have a major impact on water resources but also have great potential for modifying the hydrological cycle within the river basin. Most of the hydrological analyses emphasise very little upon the integration of land use. There is, however, experimental evidence of the importance of land use on generation of

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water resources (Bosch and Hewlett, 1982; Sahin and Hall, 1996; Beguería *et al.*, 2006). The concept of Integrated River Basin Management (IRBM) that explicitly recognises the inter-linkages between land and water resources management is relevant in this context. According to the proponents of IRBM (some call it as ecosystem approach that places human needs as the focus[2]), it takes the entire river ecosystem, including its terrestrial aspects, as the basic reference for sustainable management, while Integrated Water Resource Management (IWRM) tends to concentrate exclusively on water management[3].

In this backdrop, the paper provides a comprehensive account of the issues, current status and complex inter-linkages in land and water management and impact in two river basins, namely, the Tungabhadra sub basin (TBSB) in India and the Tagus basin in Spain and Portugal. River Tungabhadra, shared by the two southern states of Karnataka and Andhra Pradesh, is a tributary of the larger river system, the River Krishna. It originates in the Western Ghats with a catchment area of 71,417 km^2, of which 57,671 km^2 falls in Karnataka. The TBSB comprises two parts - the upper and middle catchment in Karnataka and the lower portion of the catchment in Andhra Pradesh. Prior to the construction of large dams and reservoirs, the downstream regions of Tunga and Bhadra (the two main tributaries of Tungabhadra) were mostly of arid and semi arid. The average annual rainfall in the catchment is around 1200 mm. Official statistics indicate that farm land forms the main land cover in Karnataka as of 2004-2005, accounting for more than 55 per cent of the geographical area while trees and groves, fallow land and cultivable wasteland account for 12.5 per cent. Forests and natural vegetation cover 16 per cent of the area, around 5 per cent permanent pastures and 11per cent is not suitable for cultivation or natural vegetation because it is speckled with water harvesting systems called tanks. The middle and lower portions of the basin receive low rainfall, prone to drought conditions, a sharp delineation between rain-fed and canal irrigated areas, and are served by the large dams built across the Tungabhadra. The cropland accounts for 38 per cent of the territory, with a higher proportion of fallow land (16%) and non-cultivable land (17%). Forests/natural vegetation covers 23 Per cent of the area.

The Tagus River is located in the central region of the Iberian Peninsula, and flows from East to West for more than 1000 kms (73% in Spain and 27% in Portugal), draining a total area of 80,100 km2 (69% in Spain and 31% in Portugal). It is one of the main water sources in Spain for urban (i.e., the city of Madrid) and agricultural purposes (the Tajo-Segura water transfer). About 15.5 per cent of the Spanish population lives within its basin. The Tagus River starts at more than 1500 m ASL, in the Albarracín Range, a massif belonging to the Iberian Range, mainly composed of carbonated and quartzite rocks, folded by the Alpine tectonics. The middle reach runs through the Tagus sedimentary basin, composed of sandstone and clay, and not affected by the tectonics. This basin is bound in the north by the Central Range with granite peaks that reach more than 2600 m ASL in the Gredos massif and to the south by the Toledo Mountains, a Paleozoic (mainly quartzites and shales) of moderate altitude (1600 m). Close to the Portuguese border the Tagus River runs through Paleozoic rocks (quartzites and shales) and enters into the Lisbon sedimentary Basin, composed of Miocene and Mesozoic rocks. The mouth of the Tagus River is in the Atlantic Ocean through the estuary of the La Paja Sea. The climate is of the Mediterranean type with strong continental influences. The average annual precipitation varies much in space and time. The headwater records about 1100 mm in average, but an important part of the middle reach (south of Madrid) records less than 450 mm. The headwaters of the tributaries coming from the right side (Gredos, Peña de Francia and Estrela ranges) receive more than 1500 mm. In Portugal, rainfall from the Atlantic Ocean explains an average annual precipitation of around 600-700 mm. Potential evapo-transpiration is estimated at more than 800 mm/year in the central and lower parts of the basin.

The paper focuses on changes in demand for water impacted by erratic hydrological cycles, frequent fires in the Tagus basin and unsustainable forest use in the Tungabhadra that are responsible for land degradation, expansion of irrigated agriculture activities in both the basins. This has further led to a shift in water use in the basins, and shifting livelihoods of marginal communities that are not adequately considered in water management decisions as observed in the TBSB. In the end, the dynamics of rain fed and irrigated farming and the technological and institutional options necessary for improving water use efficiency in the basins are discussed. The paper concludes by highlighting the need for improving integrated management of water resources in the basins. The basis of IWRM is that the different uses of water are interdependent and there is a need to consider the different uses of water together. Water allocations and management decisions consider the effects of each use on the others and are able to take account of overall social and economic goals, including the achievement of sustainable development. The integrated approach to management of water resources necessitates co-ordination of the range of human activities that create the demands for water, determine land uses and generate waterborne waste products. The principle also recognises the catchment area or river basin as the logical unit for water resources management. IWRM ensures coordination and collaboration among the individual sectors while fostering stakeholder participation, transparency and cost-effective local management.

IWRM is a complicated task, which involves many tasks besides hydrological considerations, such as the legal system, governability, equity issues etc. A complete hydrological analysis, however, forms the foundation of any IWRM plan, since it provides an account of the water resources available for human use and their regularity in time. In many cases, the hydrological analysis is reduced to a statistical appendix based on long term climate and discharge average values. Most hydrological analyses on which water resources management plans are based, consider only the average climatic and hydrologic conditions over a period ignoring important issues such as the climate and the natural variability of trends. Moreover, very often other important factors that are subject to variation, such as the land use, are ignored. Land use if often included in water management plans as a water demand, but other effects are ignored. There is, however, experimental evidence of the importance of land use on water resources generation (Bosch and Hewlett, 1982; Sahin and Hall, 1996; Beguería *et al.*, 2006). The case of Spain is a good example of this, since the effect of land use on water resources was not contemplated even when a new national water management plan (Plan Hidrológico Nacional) was implemented. However, it is well known that land use change has been very important in Spain during the last decades of the last century with the very significant process of converting farmland to natural vegetation. Studies relating these changes observed decrease in river runoff, especially in the headwater areas (Gallart y Llorens, 2001; Beguería *et al*, 2003). There is still a long way to go in both the basins before proper integration can achieve an effective IWRM strategy. The paper is based on data collected and analysed from primary and secondary sources in the basins within the scope of the STRIVER project and also information gathered from stakeholders' meetings.

Land Use Change and Water Resources

In the TBSB, farmland and grazing lands dominate the landscape except for the dense forest patches in the headwater areas in the Western Ghats, to the Southeast of the region. According to municipal land use statistics, forest cover has increased in the basin (Beguería, S. 2008). In Tagus, the increase of the urban areas has been the most significant land use change. In Portugal the increase and densification of the natural vegetation cover has been predominant (Beguería, S. 2008). A general process of abandonment of the marginal lands for agriculture and pastures was also observed in the headwaters of the Tagus River and some new irrigated areas were built in the valleys of major tributaries. The time series of satellite derived vegetation index (NDVI) has also revealed a decrease in the vegetation around the Madrid area and increased vegetation in the headwaters at the Iberian Range and the Portuguese areas (Beguería, S. 2008).

Table 1: Land use change in the Tagus basin in 2000
(percent variation with respect to 1990)

Land cover	Total	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%

Source: CORINE Land Cover 1985/1990 and 2000

The analysis shows significant trends for all land uses/covers in Karnataka from 1950-2005. At the state level, the most relevant change was the increase of the crop and fallow lands and forests, at the expense of other land uses such as the permanent pastures and the cultivable waste. At the district level, Chickmagalur and Shimoga experienced an important increase in forested area (+8 and +18%, respectively). In Chickmagalur it occurred together with an increase in cropland (+13%). This increase in the two main land uses/covers in these areas occurred at the expense of the permanent pastures in Chickmagalur (-17%), and the pastures and tree plantations in Shimoga (-5 and -6%, respectively). Waste and fallow land reduced too.

Table 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	State
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 tree and grooves	+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 a 95% confidence level

Wasteland and fallow land decreased in size between 1950 and 2005 while net sown area increased. The reasons could be attributed to increased access to ground water resources through tubewells (Table 8). These wastelands and other uncultivable areas have been irrigated with groundwater. Fallow land is reducing due to increase in commercial and irrigation activities.

Increase of the natural vegetation surface is known to lead to an increase in 'green water', that is water consumption by the ecosystem to maintain the ecological status. Consequently, there is reduction in the 'blue water' or water in rivers, lakes and underground, which can be used by humans. This is compensated by the positive effect of forests in regulating the water cycle. On the other hand, reduction of the forest cover and urbanisation is known to increase the 'runoff coefficient,' leading to increased soil erosion and severity of floods. In TBSB, the assessment of the effects of land use change at the basin level was difficult due to the lack of appropriate data. In the TBSB, in addition to an increase in vegetation activity in the headwaters a negative trend in annual rainfall was observed. These factors are believed to have had a negative effect on runoff production and river discharge.

On the contrary, the analysis of reservoir storage time-series data revealed no impact of either land-use change or climate variability and showed a stationary time series only subject to natural year-to-year oscillation. These results suggest that in the TBSB, despite significant land-use change in the headwaters, which added to the effects of reduction in precipitation in the last decade, the Tungabhadra reservoir system showed resilience and no effect was apparent in the series of water storage. However, at the ground level, the Tungabhadra reservoir has steadily lost its water storage capacity over the decades. About 50 years ago, the capacity of the reservoir was 3766.161 Mm^3, now with accumulation of silt due to mining, dust, soil erosion and debris, the reservoir has lost its storage capacity by 849.51 Mm^3 of water. The rainfall in the areas has also decreased in the past few years resulting in the reservoir not filling up.

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

Competing Water Demands

Water allocation for different sectors is a challenging task with emerging new demands especially in the river basins that are trans-boundary in nature. As new demands arise, pressure increases on re-allocation of water across the sectors. In Tungabhadra which is a tributary of River Krishna that flows across three states – Maharashtra (26.8%), Karnataka (43.8%) and Andhra Pradesh (29.4%) - water sharing is based on the Krishna Water Disputes Tribunal Award (KWDT) 1976. Currently, water sharing between the three states is being renegotiated as the period fixed by the earlier KWDT for utilisation of the allocated water has expired. Available water is shared based on 75% dependability. Total available water for distribution is 2060 Thousand Million Cubic ft (TMC ft) that is allocated between Maharashtra (560 TMC ft), Karnataka (700 TMC ft) and Andhra Pradesh (800 TMC ft). Return flows are shared at 25, 34 and 11 TMC ft respectively and surplus water at 25, 50 and 25 per cent respectively. Evaporation loss is shared equally between Karnataka and Andhra Pradesh. Water sharing is highly politicised and, since the Krishna is a closed basin, any water re-allocation should be made within the existing waters. Hence, changes in the hydrological regimes due to shifting land use patterns, for example, introducing heavy water intensive crops like sugarcane or rice, in rain fed areas, increases competition for water between regions and sectors. Lack of integration between sectors is another serious problem that has not been addressed. Management is based on administrative and not hydrological boundaries resulting in various allocation, distribution and usage problems within and across sectors.

With the introduction of small scale, individual and community lift irrigation schemes across the main river and its tributaries, the problem of water scarcity was further accentuated. Conflicts between Karnataka and Andhra Pradesh are generally related to increasing the storage capacity and water use in the upstream part of the basin. In lean years in terms of rainfall and river flow, comparatively less water reaches Andhra Pradesh. Access to water is a pre-condition in this farmland area with 80 per cent of the population depending on agriculture for a livelihood. Irrigation is provided through canal systems and in rain fed regions, farmers extract ground water through bore wells. Although the area is ideal for semi-arid crops, water intensive crops like paddy and sugarcane are cultivated. The spread of water-intensive crop cultivation throughout the basin has dramatically altered the water sharing balance, leading to major conflicts between demand for water for cash crop cultivation and staple food production on the one hand, and the demand for irrigation, industrial and drinking water needs on the other. Hence, there is a significant difference between farmers with access to land and irrigated water and those without access on the ground that the former can obtain higher income. This inequity is reflected in conflicts between head-end/tail-end (upstream/downstream) users.

Water allocation is given priority to drinking water followed by irrigation, industries and environment. Land-use for urban settlements and industries is also increasing the demand for water. In tourist and pilgrimage places, the floating population has added to the increase in consumption of water. About 20-40 per cent is not accounted for. Unregulated use of fertilisers/chemicals and effluents from mining areas, industries and urban settlements have resulted in severe pollution problems. Runoffs from the agricultural fields have resulted in salinity in 52,000 ha, alkalinity in 8,345 ha and water logging in 35,850 ha, in the downstream of the command areas affecting.

During the last two decades, there has been an increase in the number of small towns and industrial areas with an increase in competing demands for water. While increased industrialisation and growing urban areas have facilitated improved standards of living for some, the same activities have caused pollution and land degradation, thereby increasing the conflict levels among water users. There has been a mismatch between the pace of development activities on various fronts and the provision of sanitation and water supply infrastructure in resource-poor sections of small towns and rural areas. Thus, the socio-economic aspects are of very high relevance in water use management because the differences in standards of living of various social classes influence water sharing. The Tungabhadra sub-basin is a politically sensitive basin and re-negotiations between the riparian states concerning water allocation are presently going on[4]. Conflicts within and across the sectors are common, apart from interstate disputes due to the trans-boundary nature of the river.

The river basin is important as a 'trans-boundary case' in Europe where there are a large number of such basins. It highlights the pure scientific challenge in terms of water use and allocation, management, pollution, land-use changes and effects of changes on the river basin. Close to the border between Spain and Portugal, the Alcántara reservoir shows the consequences of river regulation. The comparison between the river regimes before (1949-1969) and after (1969-1986) the construction of the dam shows a clear decrease of discharges from November to April and an increase from July to September. Continuously evolving economic, social, environmental and political pressures on the water resources, including pollution and water resource limitations, are posing threats to the basin environment, which increase external costs and exacerbate conflicting demands for this strategic resource from domestic, industrial, agricultural and food production sectors. These pressures can also impair the regulative and regenerative functions of ecosystems in the water cycle. There is an increasing demand for water for irrigation and urban supply. A total of 230,720 ha are actually irrigated (7.1% of the irrigated areas in Spain), and this figure may increase in the future due to the opening of new private wells. The possibilities of getting more groundwater are farfetched because only 6.9 per cent of the natural recharge is taken every year. Some of the reservoirs were constructed to store water for irrigation and located in tributaries. The volume of industrial waste is very low compared with other basins in North Spain. The location of Madrid, Lisbon and other cities in the Tagus basin gives great importance to the domestic use of water.

The occurrence of water use conflicts and the changing scenario during the last decades (climate and land-use/plant cover changes) obligates the introduction of delicate adjustments in water management, including an improved shared protocol of discharges and uses of water by Spain and Portugal. A "Convention on Cooperation for Portuguese-Spanish River Basins Protection and Sustainable

Use" was approved by both countries (INAG, 1998) to define the framework for bilateral cooperation in sustainable use and management of the shared water resources and protection of freshwater and groundwater. A Commission must define the necessary flow regime "in order to guarantee a good water status, the current and the foreseen uses" (Maia, 2000). For Portugal, it is evident that a more intensive use of water resources in Spain has led to a decrease in the mean flows, an increased irregularity in the flow regime (especially with longer and more frequent dry periods), a degradation in water quality and changes in sediment transport (Henriques, 1999).

Overall, the Tagus Basin faces a number of complex strategic problems, given the opposite concerns between water and landscape conservation and increasing water demands in a scenario of global change. It is important to note that (1) the Tagus River still maintains relatively well preserved riparian landscapes, which need a certain flow (and flood) regime, (2) the Tagus Basin has many reservoirs with different purposes (irrigation, urban supply and hydropower production), (3) irrigation is the purpose of many communities and farms, increasing the pressure over the water resources, (4) more than 6 millions inhabitants depends on the discharge of the Tagus River and tributaries for their water needs, (5) changes in water resources would affect directly the complex management of reservoirs and will increase the use of water within and out of the basin, and (6) any change in water management in the Spanish part of the Tagus basin will affect the quality and quantity of water resources in Portugal, thus influencing possible uses in the lower reaches and the price of water.

Forest Fires

Fires caused by both natural and manmade factors are serious problems in the Tagus river basin and of a lesser intensity in the TBSB. However, it is still a concern, causing damage to forest vegetation, biodiversity and environmental quality. In the TBSB, no reliable records on occurrences and extent of burnt areas are available. Fires may have severe effects on the land and hydrological behaviour such as increase in soil erosion resulting from increased surface runoff and degradation of water quality due to increase in the sediment load and nitrate concentration. These effects will depend both on the land surface (e.g. type of soil and land use, surface slope) and on the rainfall characteristics (e.g. regime, seasonality, rate). Some of the most common measures to prevent fires include awareness campaigns, forest monitoring observatories, suitable land management practices (including opening of firebreaks) and the use of remote sensing images to locate hot spots.

On an average, the burned area per year in the Portuguese part of the Tagus basin is about one-and-a-half times larger than the area in the Spanish part (about 46000 ha versus 29000 ha). The number of fires per year in the former is more than two-and-a-half times the number in the latter (3700 versus 1500). Taking into account the total area of the basin of 80600 km^2, 31 per cent is located in Portugal (24800 km^2) and 69 per cent in Spain (55800 km^2). Hence, in relative terms, the fires are a major problem in Portugal.

The occurrence of forest fires in TB basin is mostly anthropogenic either intentional or negligence. The most common reason for fires are the local herders who want to create new pastures for their cattle, collectors of minor forest produce for visibility, Honey collectors to smoke out bees and also *dhoop* collectors (Viteria indica). The head loaders destroy vegetation to create new pathways to facilitate collection and encroachers set fire in order to clear the land for cultivation. Tribes set fire to facilitate collection of minor forest produce. However, no reliable record of areas affected by fire is available. Specific areas prone to fires are identified in the basin. However, in the TBSB, various afforestation programmes initiated are by Social Forestry, Farm Forestry, Compensatory Afforestation and Joint Forest Management organisations with specific interest to protect forests.

Rain Fed and Irrigated Farming

Agriculture dominates land use in both Tagus and Tungabhadra basins that are semi-arid in nature. Currently, irrigated agriculture has replaced the traditional farming methods. In TBSB, both rain fed and irrigated farming coexists, with the latter expanding as new irrigation projects are commissioned. Coming to understand the existing policies and programmes for rain fed and irrigated agriculture, with an eye to the question whether IWRM is addressed, of particular interest is whether there is 'integration' discernible or vice-versa. Situation analysis indicates that the main finding in the TBSB that irrigated and rain fed agriculture are largely treated in isolation with very few signs of 'integration' between these two domains of agricultural water use. Also, within each domain policies and programmes tend to be narrow in orientation, focusing on one or limited number of aspects of water resources management. It was apparent that the concept of IWRM has made very little headway in practical terms in the TBSB. There are, however, a number of smaller-scale initiatives that could serve as a starting point for more integrated approaches. For instance, for sustainable use of fragile lands much of the effort devoted to increased productivity of rain fed agriculture revolves around land-use planning for integrated use of different types of land. Watershed development is the vehicle to promote improved land use principles. However, several problems plague the concept of improved land use, and various steps are needed to solve them. The furthering of integrated approaches to water resources management would require an alignment and mobilisation of such local momentum and creativity. Such a process, which would be characterised by 'out of the box' thinking in government policy, and widespread participation of the rural population in the planning and implementation process of rain fed and irrigated agriculture policies and programmes, may take some time to emerge. Thus, evidence suggests that the diversity of rain fed agricultural systems may require location-specific approaches to soil and water management.

The Tagus basin is way ahead in the development of water uses. This means that there are competing uses and users and, in principle, there are institutional frameworks within which negotiations should take place. The European Union policy makes it mandatory to have an integrated approach to water resource management. Nevertheless, many of the conflicts are unresolved – the challenge in this basin is not to advocate IWRM as a concept but to make it a practice. The major challenge for irrigated agriculture is to increase water-use efficiencies to satisfy other water needs, including the ecology. An additional issue is the depopulation of rural areas as a result of declining economic prospects in agriculture. This requires a linkage between water resources management approaches and the broader issue of rural development, with participation of the inhabitants of the rural areas. In this context, improved strategies need to focus on improved accountability and sustainable water management on public irrigation perimeters for optimal use of land and water.

Technological Innovations in Rain fed and Irrigated Agriculture

Technological innovations have an important role in expanding access to water, improving water use efficiency and ensuring sustainable water use. Improving water use efficiency is important because new demands for water can be met through re-allocation of water saved. With respect to irrigated agriculture[5] there are quite a few promising options in the TBSB. Paddy is the most important irrigated crop and accounts for a very large portion of irrigation followed by sugar cane and orchard crops. In this context, the most popular innovations in paddy are System of Rice Intensification (SRI) that saves water and increases yields and Aerobic rice. Water use in paddy in TBSB could be brought down by 40 per cent or more with these practices and/or varieties. However, SRI has not been promoted through government programmes in the basin but mention is made in the newly set up National Food Security Mission document with minimal financial allocation as a possible way of augmenting food production.

For sugar cane and orchard crops, drip irrigation systems of varying sophistication and inversely varying costs can bring about large water savings. If we consider the water saved as augmented supply, drip system costs compare very well with the cost of augmenting water supply through conventional canal irrigation. Assistance may also be justified if proper institutional mechanisms ensure that water savings are used to augment supply to farmers who do not presently have access to irrigation. Orchard crops are also suitable for pit systems. Another set of measures comprises low investments and low external input changes in cropping pattern, agronomical practices and irrigation practices. For sugarcane (a) ratooning or planting in two alternate rows and supplying water through the wider furrows (b) pit method where the cane is planted in pits that cover one-fourth or less of the area with intercrop(s) taken in the empty portion before the cane canopy closure. It gives almost same yield and reduces water use.

In the Tagus basin, the number of farmers has been decreasing (currently 8% of the population) in the Spanish side. Spanish farms have been known to be over-irrigated with high degrees of nitrate pollution and other effluents. Recently, awareness of these factors led to an increase in sprinkler and drip irrigation leading to water saving and reduction in pollution. There are emerging policies in favour of small farms for a) stabilisation or even growth of the local population, by increasing local employment opportunities, b) increasing productivity, c) improving work conditions and d) saving water by using new irrigation systems and training the local population.

The promising options in rain fed agriculture in the TBSB rests on its integration with irrigated farming through limited but assured quantities of water for minimum biomass production in a biomass based system[6]. However, they require an initial period of recuperation and support for the poorer farmers who do not have the staying power to forego production during this period. During the initial period, support is possible through schemes like the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGA) or the state REG schemes, access to small plots of land and small quantities of water. The augmented water access could come from Integrated Watershed Based Development Approach.

The other option is utilising small sources and micro irrigation practices - (a) the 5-per cent pond, (b) low lift treadle pumps and (c) fertigation through pots and pits. The other important option is utilising synergies between tank and canal irrigation. In conventional government thinking, tank and canal irrigation synergies are not acknowledged or utilised. Currently tanks suffer from lack of dependability while large canal systems are overstretched and lack control over the timing and amount of water used due to insufficient buffer. Hence, institutional innovation would require an institutional integration of village/local watershed with a centrally defined system or allocation that would require incorporating a two-way flexibility.

With respect to the Tagus basin, cereals, vineyards and olive trees have been the traditional trilogy in Mediterranean environments: cereals complete their vegetative period just at the beginning of the hot, dry season and both vineyards and olive trees have roots enough deep to resist intense droughts. This has been disturbed in irrigated areas. Increase in intensity, generalised mechanisation, reduction of the in-fallow period and a moderate incorporation of other crops or varieties are the changes and can be considered as the best present and future options for a stable agricultural system. The Agrarian Policy of the European Union also provides other options by subsidising some crops or activities in rain fed agriculture.

To summarise, highly intensive irrigated areas co-exist with rain fed agriculture in both the basins. Concerning the technological innovations and institutional options, there are fragmented efforts in both basins that impact largely on land and water usage. Hence, there is a need to synthesize and bring together an integrated approach that can bridge the compartmentalization between irrigated and rain fed agriculture for improved land and water management.

Livelihoods

In TBSB, fishery is an important source of livelihood next to agriculture. Improving the livelihoods of marginal communities and promoting economic growth is one of the basic principles of IWRM. However in TBSB, it does not find a place in water use and allocation management. The Fisheries Department (FD) prioritises revenues from fisheries over the welfare of fishermen as evident from the state's fisheries policy. The Department of Water Resources does not consult the FD while allocating water for various uses. As a result, fishery in the Tungabhadra has declined by almost half from 2000 to 2005 (GOK 2005). This is also due to inadequate development initiatives by the FD, pollution from industries and lack of integrated approach to manage water resources in the basin.

A number of policies and institutions already exist in TBSB to facilitate the entry of the poor into fishing activities. However, the policy needs to be implemented properly to ensure that the benefits reach local fishermen or their societies. A number of measures can be initiated at the local level, for example**,** improving the fisheries in the water bodies, customising training programmes and implementing government welfare schemes. Integrating water management with the needs of other sectors such as fisheries, will not only ensure livelihoods for marginal communities such as the small-scale fishermen, but also increase the water-use efficiency in the basin. Improvement of livelihoods is part of IWRM principles and attempts to implement IWRM will ensure the development of the fisheries sector in the region.

Conclusion

The hydrological consequences of land-use changes have indicated that the effects of land-use change at the basin level are difficult to discern due to the interaction of effects and lack of appropriate data in some cases. The interaction between different land-use and the hydrological cycle, which includes several aspects such as the annual availability of water, seasonality, protection against flooding, etc., should be considered carefully. IWRM is a complex process, which involves many aspects such as the legal system, governability and equity issues besides hydrological considerations. The Global Water Partnership (2000) defines IWRM "as a process that promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems". A complete hydrological characterisation, however, must be carried out at the early stage of any IWRM plan, since it is the only way to get an account of the water resources available for human use and of their regularity in time and space. Bringing some of the principles of IWRM into a water sector policy and achieving political support may be challenging because hard decisions have to be made. Reforms in water laws and water institutions could be required to implement appropriate policies. Innovative policies and technologies will have the greatest impact on water-use efficiency as well as on livelihood assurance. The contexts of the poor are diverse and need to be addressed in a holistic manner in future development programmes.

Explanatory Notes

1. The present paper is based on a larger study supported by the European Commission - Sixth Framework Programme (FP6) STRIVER project, "Strategy and methodology for improved IWRM – An integrated interdisciplinary assessment in four twinning river basins, 2006-2009".
2. The Ecosystem Approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way (www.iucn.org).
3. http://www.bothends.org/strategic/RBM-ANA-Executive_Summary_Methodology
4. In fact the Krishna Water Disputes Tribunal gave its verdict in January 2011 and it created fresh tension amongst the three riparian states especially on the issue of raising the storage levels in the Almatti dam on the main Krishna river.
5. Technological innovations in the TBSB irrigated areas have been guided by the slogan "more crop per drop" popularised by International Water Management Institute (IWMI). Most of the water saving technologies like drips, sprinklers and various agronomical practices, which improve the efficiency of water-use fall under this category. Of late other slogans like "more livelihood per drop" have also been suggested which emphasise the linkage between water saving and efficiency to improved livelihoods and not merely to increased production.
6. Agriculture Man and Ecology Groups in Karnataka, Low External Input Sustainable Agriculture (LEISA) techniques in many countries, Prayog Parivar in Maharashtra, demonstrate many of these

References

Beguería S, J I López-Moreno, A Gómez-Villar, V Rubio, N Lana-Renault, J MGarcía-Ruiz (2006). Fluvial Adjustments to Soil Erosion and Plant Cover Changes in the Central Spanish Pyrenees. *Geografiska Annaler series A - Physical Geography,* 88A (3): 177–186.

Beguería, S, S Vicente-Serrano, I López-Moreno, N Lana-Renault, J M García-Ruiz (2008). *Land Use Change and Water Resources in the Tagus and TBSBs*. STRIVER Technical Brief No. 1

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.

Manasi, S, K V Raju, N Latha, U S Nagothu (2008). *Competing Water Uses in Tungabhadra Sub-basin, India*. STRIVER Policy Brief No. 5. (http://www.striver.no/diss_res/files/STRIVER_PB5.pdf)

Maria Manuela Portela, António Betâmio de Almeida, Marta Machado, S Manasi, K V Raju, N Latha, Nagothu Udaya Sekhar, Santiago Beguería, Lana-Renault, Noemí; Vicente-Serrano, Sergio (2008). *Fires and Reforestation – Current Status in Tagus and Tungabhadra River Basins*. STRIVER Report D. 9.2

Nagothu, S U and S Manasi (2008). *IWRM and Livelihoods: Fisheries in Tungabhadra sub-basin, India*. STRIVER Policy Brief No. 1. (http://www.striver.no/diss_res/files/STRIVER_PB1.pdf)

Nesheim, I, D McNeill, P Stålnacke, N U Sekhar, B Grizzetti, A A Allen, D Barton, S Beguería-Portugés, D Berge, F Bouraoui, D Campbell, J Deelstra, J M García-Ruiz, G D Gooch, K J Joy, N Lana-Renault, A Lo Porto, M Machado, S Manasi, D K Nhung, S Paranjape, M M Portela, A Rieu-Clarke, V S Saravanan, H Thaulow, S Vicente-Serrano (2008). *First IWRM Assessment Report for the Four Case Basins: Glomma, Tagus, Sesan and Tungabhadra*. STRIVER Report D5.1. 71p.

Nigel Ducley, Sue Stolton (2003). *Running Pure: The Importance of Forest Protected Areas to Drinking Water*. World Bank/WWF Alliance for Forest Conservation and Sustainable Use, UK.

Paranjape, S, K J Joy, S Manasi, N Latha (2008). *IWRM and Traditional Systems: Tanks in the Tungabhadra system*. STRIVER Policy Brief No. 4. (http://www.striver.no/diss_res/files/STRIVER_PB4.pdf)

Peter Mollinga, V S Saravanan, Rahul Pillai, K J Joy, Suhas Paranjape, Maria Manuela, Antonio Betamio, Marta Machado, Begueria Santiago. *Strategies for Rainfed and Irrigated Agriculture: TBSB, India and Tagus Basin, Spain and Portugal*. STRIVER Report D. 9.1.

Peter R Robichaud (2000). Forest Fire Effects on Hillslope Erosion: What We Know. USDA- Forest Service, Rocky Mountain Research Station, Moscow, Idaho

S H Schoenholtz (2004). Impacts of Forest Management on Water Quality. Oregon State University, Corvallis, OR USA. Elsevier Lda.

Sahin, V and M J Hall (1996). The Effects of Afforestation and Deforestation on Water Yields. *Journal of Hydrology,* 178: 293–309.

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