STRIVER

Summary Report 9.6

Innovative Technology and Institutional Options in Rainfed and Irrigated Agriculture

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

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Contents

1. Introduction

1.1 Objective

The objective of this Task Report on innovative technology and institutional options in rainfed and irrigated agriculture is mainly to feed into WP4, concerning Stakeholder processes and interactions and WP10, the overall policy recommendations in respect of IWRM practices. It is expected that in WP4, presentation of these options will lead to a greater awareness of their need and implications of their use, make for greater acceptability and the more acceptable among them can also become part of the scenarios exploring alternative pathways of water use in the basins. Given the importance of agriculture in the Tungabhadra basin, it is also expected that it will be greater relevance in that basin.

1.2 Scope of Report (In terms of Region and Scope of Technology and Institutional Options Covered)

However, the task report concentrates on technology and institutional options in rainfed and irrigated agriculture and does not deal with industrial and urban water uses and also does not deal with drinking water and sanitation issues in rural areas. Firstly, all these sectors vary greatly in their technical and institutional aspects and it would be virtually impossible for a single group to deal effectively with all of them together. Secondly, in the Tungabhadra basin and to an extent in the Tagus basin as well, a very large proportion of water use is accounted for by agricultural use and the livelihoods of a very large number of people in the basin are affected by it. Innovations therefore will have the greatest impact on water use as well as on livelihood assurance. Thirdly, even with this restricted focus the field is still very large, and therefore within the ambit of the scope described above, the innovations considered in detail are those that are concerned with crops and institutions accounting for the largest water use. Fourthly, this task report is not a full fledged review of technological and institutional context of rainfed and irrigated agriculture within the basins, but concentrates mainly on promising innovations that potentially have good scope for water saving, IWRM and wider acceptability.

1.3 Structure of the Report

The report is organised under seven broad sections. Section 1, the introductory section, primarily deals with the objective of the report as well as its scope. Section two briefly outlines the policy and technology background or contexts in both the basins. Section three talks about the various stakeholders and actors involved in developing innovative technology and institutional options in both the basins. Sections four and five deal with promising options in irrigated and rainfed conditions respectively in the two basins. In section six we do a broad assessment of various promising technological options in terms of impact on water use and pollution, in terms of acceptability and support that is required to upscale these, and in terms of IWRM using MCDA.

2. Brief Policy and Technology Background

2.1 Tungabhadra Basin

The Tungabhadra basin may be divided into Upper and Lower catchments, Canal and Tank irrigated areas and into Karnataka and Andhra Pradesh.

2.1.1 Upper and Lower Catchments

The Upper catchment falls almost exclusively within Karnataka state while a substantial portion of the Lower catchment as well as the command area of the terminal Tungabhadra dam near Hospet falls in Andhra Pradesh. The portions also differ in relief and topography. The Lower catchment comprises mainly plains while the Upper catchments have a rolling topography broken by small and often narrow valley plains along the streams. The Upper catchment generally has a higher rainfall while the Lowe catchment generally is semi-arid.

2.1.2 Canal and Tank Areas

There are four major irrigation projects in the Tungabhadra basin (The Bhadra reservoir, the Upper Tunga reservoir, The Tunga anicut and the largest of them, the Tungabhadra reservoir near Hospet) and seven medium irrigation projects (Gondi anicut on the Bhadra, Hirehalla project, Narihalla project, Singatalur lift irrigation project, Hagaribomanhalli project, Kanakanala project and the Rajolbanda diversion scheme). An area served by major and medium projects through canals is called canal irrigated area and all the smaller tanks and areas served by the smaller reservoirs and tanks is called tank irrigated area. Technically speaking, tank irrigated areas are also served by canals, but they are much smaller and do not show the branching into distributaries and minors that the larger projects show. Because of their larger size and the degree of branching of the canal system major and medium projects have and need different institutional and technological considerations. A very large portion of the canal irrigated area lies in the Lower catchment and most of the tank irrigated area lies in the Upper catchment. There are also two types of tanks in the basin: purely rainfed tanks which harvest water from its immediate catchment and balance tanks which, apart from harvesting water from its own catchment are also replenished by the canal water from the reservoir.

2.1.3 Karnataka and Andhra Pradesh

Perhaps the most significant contextual factor is related to the fact that the Tungabhadra basin falls into two different states of the Indian Union, Karnataka and Andhra Pradesh. The two states are linguistically, culturally and historically distinct and since, water is a state subject, have somewhat different institutional contexts. All the three divisions described above show a broad mapping on to each other, although inevitably, there is substantial overlap. Thus we have a mapping of Upper catchment, Karnataka state and tank irrigation on the one hand and Lower catchment, Andhra Pradesh and canal irrigation on the other.

Canals account for up to 55% of the net irrigated area in the Karnataka portion of the basin. Paddy is the main irrigated crop. It occupies more than 20% of the gross cropped area in the basin. It accounts for almost 40% of the irrigated area, and given that it uses relatively much more water than other dry crops its proportion in irrigation water utilisation is likely to be much higher. Sugarcane and orchard crops are similarly crops that consume much more water than other crops and hence in what follows we shall concentrate on innovations in respect to these three crops.

In paddy areas, most of the irrigation is field-to-field and paddy is grown in the traditional way in which standing water is maintained in the paddy field for as long as is possible. Also there is very little crop rotation in the paddy areas, especially in the command areas of the major projects like the Tungabhadra project, as paddy is taken in taken in all the three seasons like khaif (monsoon season), rabi (winter season) and hot weather (summer seson). Canals are unlined and seepage losses are high. In the paddy area, the irrigation is from field to field and there are few continuous field channels. Well irrigation often supplements canal and tank irrigation and recharge from tanks and reservoirs is an important component of well recharge in most areas. Command areas have been extended in many cases and also reservoir live storages and inflows have reduced making for long rotation periods and are not presently conducive for close control over the timing and quantum of irrigation water delivery. The use of drip and sprinkler irrigation is increasing, especially drip irrigation systems in orchard crops and in sugarcane, yet their capital intensive nature means that they are not affordable to the majority of farmers.

2.2 Tagus Basin

The Tagus basin is divided between two countries, Spain and Portugal. Spain is the Upper riparian state and Portugal is the lower riparian state. Unlike the Tungabhadra basin, the rivers in the Tagus basin are highly regulated and there is substantial power generation as well.

In Portugal, industrial and urban use is high and as compared with the Tungabhadra, the agricultural use is low. Because of its highly regulated nature, most of the water use is centrally served by surface irrigation systems between 45 and 90 per cent according to the region. Sprinkler systems form a significant proportion, up to 35% according to region. Localised systems, in contrast with Tungabhadra, are small in proportion up to 15% for most regions, except for a few in which they may account for between 25 and 40%.

The Spanish part of the basin may be classed as mainly semi-arid though analysis of rainfall patterns suggests that arid as well as wet regimes often alternate. Irrigation, especially at local levels started as early as the roman period and was controlled by local organisations or syndicates. From the 18th century and especially in the 20th century however, the basin was rapidly developed and dams and reservoirs as well as diversion schemes for urban and other supply have now come up. The river is now highly exploited and regulated. However, irrigated land is very small, only 3.5% of the basin. However, since the late eighties of the 20th century there has been a rethinking about dams and no new dams have been built and plans for two proposed dams have been abandoned.

3. Stakeholders and Actors involved in developing innovative technology and institutional options

3.1 Tungabhadra Basin (SOPPECOM and ZEF)

3.1.1 Government agencies

There are many different government agencies involved in technology development and dissemination. At the level of the Central government, the Indian Council of Agricultural Research (ICAR) is the premier institution which oversees agricultural research in the country. It is also the largest funder for the state level agricultural research. It includes research on irrigation as well as research on crop technologies and practices.

At the state level, in both Andhra Pradesh and Karnataka, there are research as well as extension activities carried out by different agencies. The main research activities are carried out by State Agricultural Universities (SAUs) in collaboration with the ICAR, and to some extent by the Water and Land Management Institutes (WALMIs) set up in both states (at Dharwad in Karnataka and in Himayatnagar in Andhra Pradesh) and the Canal Area Development Agencies (CADAs) for the canal irrigation areas of major and medium projects. These institutions are expected to be the main source of innovations.

In turn, these innovations are supposed to be carried to the fields of the farmers by the extension activities carried out by the Agriculture Department, the extension departments of the SAUs, as well as by the WALMIs and the CADAs. Of these, the Agriculture department has the most extensive reach with the extension worker at the lowest rung serving a few villages. The WALMIs and the CADAs are also expected to support the extension and training needs of the Irrigation department, especially those that have followed in the wake of the sector reforms.

3.1.2 Farmers

The farmers have their own organisations or sanghams but their strength and range of activities differs greatly. Both the states have enacted legislation to provide for transfer of irrigation management to farmers. While this has increased farmers' involvement and participation, it is still far from management transfer. Broadly speaking, while the reforms have in most places succeeded in transfer of management to the farmers at the lowest rung of the system, at the level of the minor, which comprises an area of the order of about 500 ha, there has been little transfer of control at the higher levels of distributaries, canals or at project level, lave alone involvement in managing and deciding wider allocations.

3.1.3 NGOs

In both states there is an active civil society initiative in the form of NGOs working in the rural sector, but more for agriculture than for irrigation. Irrigation, and within that, canal irrigation is not an area in which many NGOs are active, except for a few notable and important exceptions. As a consequence while there are many innovations in crop technology and practices being propagated by NGOs there is not much matching work on institutional innovations in the water sector.

3.2 Tagus Basin

3.2.1 Government agencies

In Portugal they are mainly a) COTR - Centro Operativo e de Tecnologia de Regadio (Operational and Irrigation Technology Center) and b) Regional Directorate of Agriculture and Fisheries

In Spain the state and semi-state organisations normally implicated are a) The State, through the Tagus Basin Administration Office, b) The Irrigation Syndicate and c) The Town and City councils

There are two levels of water management in the Tagus basin in Spain one so to speak at the basin level and another at the level of individual reservoirs and dams.

3.2.2 Farmers

In Portugal it is mainly the CAP – Confederação dos Agricultores de Portugal (Portuguese Farmers Confederation) that is involved.

In Spain, it is a) the local distributors and b) the farmers who are involved. There are also farmer associations who take on agitational tasks for new dams as well as price support and improvement in infrastructure.

3.2.3 NGOs

In Portugal it is mainly a) GEOTA – Grupo de Estudos de Ordenamento do Território e Ambiente, b) LPN – Liga para a Protecção da Natureza and c) QUERCUS – Associação Nacional de Conservação da Natureza.

In Spain it mainly the different organisations for ecological improvement and ecological concerns who are involved though they are not directly supposed to have a say or stake.

4. Promising Options in Irrigated Agriculture

4.1 Tungabhadra basin

In view of the fact that paddy is the main crop and that there is a system of field-to-field irrigation and therefore the lack of well defined field channels, most conventional solutions like lining etc., either do not work or involve great cost. More innovative solutions therefore need to be explored. In fact there are promising innovations in paddy cultivation technology and practices.

More crop per drop

By and large the technological innovations in the irrigated area has been mainly guided by the slogan of "more crop per drop" slogan popularised by International Water Management Institute (IWMI). Most of the water saving technologies like drips, sprinklers and various agronomical practices which help to improve the efficiency of water use all fall under this. Of late there has been also certain other type of articulations like "more livelihood per drop" which show the linkage between water saving and efficiency to improved livelihoods and not merely to increased production.

SRI and Aerobic rice

SRI, the so called System of Rice Intensification and Aerobic rice share a lot in common. The former is more controversial, since it claims to have a very large saving in water use and simultaneously increase yields to very high levels. SRI is now being actively propagated and experimented with by farmers' networks and civil society organisations (NGOs). A section of the research establishment is also in favour of SRI or SRI like practices as some of the agricultural universities are also involved in doing research and experiments on SRI and its propagation. The main innovation is to eliminate standing water and therefore create aerobic conditions. This is the main water saving component of the system. The research establishment claims that this must be combined with special varietal development to produce varieties that will withstand aerobic conditions better. This is also the main dividing line between the two. However, between them, SRI and Aerobic rice seem to have a great potential for water saving. Water use in paddy could be brought down by 40% or more. Given that paddy accounts for a very large proportion of water use in the basin, these could play a vital role in increasing production and livelihood support while greatly reducing water use. The Andhra Pradesh government is favourably disposed towards SRI and is in the process of making plans to encourage its adoption. Of course, SRI also involves costs, aerobic conditions tend to promote weed growth, while conventional practice maintains anaerobic conditions which suppress weed. Weeding costs therefore go up. Trade offs involved do need attention, though water saving is undisputed.

Sugar cane

Sugar cane and orchard crops are the other most water guzzling crops after paddy. In both of them there are a number of possibilities. One set of possibilities is that drip irrigation systems of varying sophistication. The investment per system can vary greatly with the degree of sophistication of the system. However, even with the conventionally marketed systems, there are indications that if we consider the water saved as augmented supply, then cubic metre to cubic metre, drip system costs compare very well with the cost of augmenting water supply through conventional canal irrigation systems. This implies that if one social subsidies are acceptable for water supply augmentation they should similarly be acceptable for one time subsidies for drip systems, except that there should be proper institutional mechanisms that take the augmented supply to those in need of water rather than to those who already have access to water.

The other set of measures like changes in cropping pattern, agronomical practices and irrigation practices may not require heavy investments and external materials. The simplest of these is a change in the system of planting so that two rows are placed closer and each of these sets is spaced wider apart. Irrigation is then supplied in the wider alternate furrows between the rows. This reduces wetting by almost one-half and saves significant amounts of applied water. There has been also efforts to take more number of retunes per planting. Dr. Devangi Prafulla Chandra of the Devangi Agricultural Research and Extension Centre (DAREC) ad a progressive and a Food and Agriculture Organisation (FAO) awardee from the Shimoga area has been experimenting on sugarcane for many eyars and it is reported that eh ahs bee able to take up to 18 retunes. At the other extreme is the pit method is which the cane is planted in pits which cover about one-fourth or less of the area. Intercrop(s) is(are) taken in the empty portion nearly for eight months (two seasons) and the cane canopy is allowed to gradually cover the whole area. This results in great saving in water (some of the experiments on farmers fields have reported two-third water saving as compared to conventional method) without reduction in yield while the intercrop, if well, chosen provides incomes as well as nutrient. Between these extremes lie a number of options developed by practitioners and the SAUs all of which have a common principle of reducing the sugarcane area with denser plantation and taking advantage of the area thus freed for intercrops and organic supply of nutrients. All these techniques also involve trade offs, but there is a net increase in yield per unit of water and investment.

Orchard crops

Orchard crops are also suitable for drip systems. However, they may not show as striking a reduction in water use as in the case of sugarcane and therefore the cost of saved water may not be as competitive as in the case of sugarcane. There are however, other methods, mainly fertigation (irrigation + fertiliser application and hence fertigation) methods combined with pits which perform a function similar to that of drip systems but without the attendant requirements of filtering and pumping and elaborate permanently laid systems that drip (as well as sprinkler) requires. Since this system is one shared with rainfed systems with limited irrigation, it is discussed in the next section.

Utilising synergies between tank and canal irrigation

In conventional government thinking, tank and canal irrigation are, as a rule, seen as separate and independent systems. It is rarely that their synergies are acknowledged or utilised. One such example is the use of tanks as balancing reservoirs. Another example is the so called `system tanks' in Tamil Nadu which are tanks that are built as rainfed tanks but receive refilling from larger systems. Unfortunately, the latent synergy between tanks and canal systems is not taken into consideration here.

At present, tanks are suffering from lack of dependability. At the same time, larger canal systems are getting overstretched and the period between rotations is increasing so that farmers are losing control over the timing and amount of water application. If a system is devised in which tanks perform a dual function, that of harvesting local water (rainfed component) as well as receiving and distributing the water from larger reservoirs they can go a long way towards augmenting access, improving dependability and bringing closer control over timing.

Another way of looking at this is to see it as eliminating the minor level (and to some extent the distributary level as well) of canal irrigation systems. All deliveries are then made to local water bodies (read tanks, or ponds) which are the units of local distribution. If it is recognised that water may be drawn either through the tank channels or through tank seepage, this will make for an effective delivery system. As an alternative seepage could be intercepted and put back into the local storage and restricting access to that through tank channels. Combined with some principle of minimum water assurance, this could greatly widen the access to water without and improve water use efficiency at the same time.

However, it is not necessary to combine all the elements described above. Each of these has a significance on its own and it is possible to start simply with integrating tanks into canal irrigation. However, it does need a corresponding institutional reorganisation as well. The concept of a water user is no longer as simple nor as centrally defined as that of water user in a central supply based system that defines the term based on a centrally determined command area. The institutional innovation would require an institutional integration of village or local watershed with a centrally defined system or allocation that would require incorporating a two-way flexibility.

Innovation Agricultural Practices in the Basin: The Case of Dr. Devangi Prafulla Chandra

Developing indigenous technical knowledge in agriculture and rural areas helps to find the solutions to the local problems using material easily available within the locality, which is cheaper and environment friendly. Here is a profile of one such person who is continuously innovating new practices and technology in agriculture.

Dr. Prafulla Chandra is a 75 years old innovative farmer from Shimoga. Total size of his farm is 45 acres and crops grown are Sugarcane, Coconut, Cocoa and Paddy. He is a recipient of several state, national and international awards for his contribution to agriculture. He has also participated in many international workshops.

Some of his achievements are

1. Slurry Bleeding: Is an innovative method of applying liquid form of organic manure directky to plants through sprinkler irrigation. It includes digested slurry of gobar gas, human excreta and domestic animal excreta and urine. It helps in efficient water management and to reduce the labour and transportation costs.
2. Sugarcane Ratooning; Sugarcane Ratooning means planting the cane once and cutting the crop and allowing rge sugarcane to grow again from the cut stalks. Dr. Prafulla Chandra is practicing sugarcane ratooning form 1969 and has harvested 39 crops from ratooning. After the sugarcane harvested, the trash along with lime is applied uniformly throughout the field. This helps in efficient utilization of organic waste, helps to reduce nutrient cost and to reduce labour cost and time.
3. Invention of New Areca Nut Boiler and Driver: Fuel used here is areca nut leaves. It consists of rectangular vessel and requires very little heat. This invention has helped save thousands of hectares of rich forest wealth from being used as fuel by areca nut growers every year in Malnad area in South Karnataka
4. some of his other innovative practices and ideas include 1) use of Toruleena plants on the bunds and roadside to reduce evaporation losses; 2) use of mixed crops and intercrops helps to maintain soil fertility; 3) use of sewage and animal waste in agriculture helps fulfil nutrient demands of the plants; and 4) use of low cost technologies for effective energy management.

4.2 Tagus Basin

In Spain, though the Tagus river basin is abundant in water in relation to need the scope for change in irrigation use is limited by numerous constraints that range from domestic and water needs of the urban areas, particularly Madrid to the transboundary agreements that stipulate that a minimum flow be maintained in the river at the Portugal boundary especially in the dry period.

The proportion of farmers has been decreasing and now stands at about 8% of the population though it varies from as low as 2% to around 40% in a few areas. Interestingly, large centralised properties which is the trend show very little diversity while small farms which are mainly engaged in subsistence production show much more diversity in produce.

After 1986, when Spain joined the European Union there have been profound changes in Spanish agriculture, with a number of factors that have made for consolidation of properties and their concentration and modernisation, quotas to the detriment of the smaller farmers, but also greater aid for rejuvenation, industrialisation, commercialisation as well as human power upgradation. Now up to 44% of agricultural income is provided by EU subsidies.

Spanish farms have been acknowledged to be over irrigated, with high degrees of nitrate pollution and other effluents. Recently, awareness of these factors has led to an increase in sprinkler and drip irrigation leading to water saving and reduction in pollution.

Earlier expectations that there would be more intensified agriculture near the cities and would progressively decrease with distance has been belied. In fact now there is a reversal of the strategy that ruled for most of the 20^{th} century and is giving rise to a policy in favour of small farms with the objectives of a) the stabilisation or even growth of the local population, through the increase in the number of local employments, b) the increase of productivity, c) the improvement of work conditions (increase in the size of plots by concentration, construction of new pathways improving accessibility to the fields),and d) water saving by using new irrigation systems and training of local population.

5. Promising Options in Rainfed Agriculture

5.1 Tungabhadra Basin

The promising options in rainfed agriculture rest on an approach towards integration of rainfed and irrigated farming through the concept of limited but assured quantities of applied water being made available strategically to the rainfed areas. The synergetic system of tanks and canal systems is capable of providing this kind of limited service on an assured basis to a very large area from the cumulative water savings available from the options that have been described above for irrigated areas. As said above, this also requires that there are adequate mechanisms to ensure that the water saved goes to rainfed areas in a dispersed manner. What follows is premised on such strategic but limited quantities of water becoming available to the rainfed areas.

5.1.1 Changeover to a Biomass Based System\

In many areas it has been adequately demonstrated that a biomass based system (in which biomass recycling takes care of major nutrient replenishment either through a livestock system or through compost) can maintain its productivity sustainably if sufficient moisture availability is assured to maintain the minimum biomass production in the system. This is evident from farming systems developed by the Agriculture Man and Ecology Groups in Karnataka, Low External Input Sustainable Agriculture (LEISA) techniques in many countries, by Prayog Parivar in Maharashtra, by Shri Renke (who heads the nomadic tribes commission of the central government) on his farm (he has shown that it is possible to provide substantial livelihood assurance for the poor on small plots of land of the order of 0.12 to 0.15 ha per household along with assured water of about 1000 m^3) as well as agriculture practiced by many local farmers. However, there also trade offs involved here which need to be noted. Most of this experience shows that sustainability is attained after a minimum regeneration of native productivity lost through chemical practices is regained/enhanced through regenerative addition of biomass to the system. In this initial period, there is a need to forgo biomass harvesting in favour of recycling.

This initial period of recuperation along with the requirement of limited but assured quantities of applied water is the major constraint on the replication of these techniques on a wide scale, especially on the lands of the poorer farmers, who do not have the staying power to forgo production during this period. For this reason we see most of this experience being confined to bigger farmers, and precisely on that count being dismissed as suitable only to big farmers. However, if combined with an institutional and policy package it is possible to realise the potential of these techniques on a large scale and extend its adoption to small and marginal farmers as well.

This package combines elements of schemes already offered by the various state a governments as well as the central government. What is important is that during the initial gestation period in which it is necessary to forgo production (at least a substantial portion of it) almost the only input needed by the land is labour and limited assured water. Limited amounts of water can be made available locally through water savings if options similar to those described above are adopted. During this period, of two to three years, it is possible to provide employment support through schemes like the National Rural Employment Guarantee Scheme (NREGS) or the state REG schemes. Since the plots can be as small as 0.12 to 0.15 ha per household, even the landless may be provided land through forming small pools of land presently lying uncultivated for various reasons. Women and disadvantaged sections could be given preference in these allotments of land and allocation of water.

As we have remarked earlier, it is not necessary that all the elements of the package are brought together at one go. However, unlike the options described for the irrigated areas above, for these areas there is a need for a critical minimum package. Based on Shri Renke’s experience it may be said that 1000 m3 of applied water/yr, and a three-year employment support would allow poor farmers to develop at least 0.12 to 0.15 ha of their land to levels of sustainable productivity that would require very little external input and provide them with substantial livelihood assurance. Incorporation of women and landless into the scheme would expand the social security and amity within the basin considerably.

5.1.2 Integrated Watershed Based Development Approach

Since the late 80s and early 90s micro watershed (of areas about 500 to 1000 ha) based development approach ahs been gaining currency in India especially in the rainfed and drought prone regions. Today it has become the flagship rural development programme which aim to combine the improvement of the ecological conditions with improved livelihood options for the rural population. It has components like soil and water conservation measures to reduce run off, in situ resource (water and soil) conservation measures, surface storage structures, vegetative barriers, soil amelioration measures, land use and cropping changes combined with various agronomical practices, etc., to improve the micro agro-ecological conditions and improve productivity and thus better livelihood options. It is reported that more than 500 million USD is spent annually on watershed programmes in India. Till now the average per ha cost norm was Rs. 6000/ha (about 135 USD/ha) and now it is being increased to Rs. 10,000/ha (about 227 USD/ha). There are various types of innovations – both technological and institutional – taking place in this sector and there is lot of academic writing on this in India. Though the watershed development programme offers a good opportunity for integration of rainfed and irrigated and improved productivity and livelihood opportunities, the studies indicate that apart from a few notable examples and models, the average performance has been much below the potential.

5.1.3 Utilising Small Sources and Micro Irrigation Practices

Most rainfed areas would require the effective utilisation of small sources and there is a need for suitable technological options for this. Some of these are described below.

5.1.4 The 5-percent pond

It has been shown that a farm pond on 5 per cent of one's land will provide for adequate protective irrigation for the rest of the land for the kharif crop in most areas except for the semi-arid and arid regions, where a larger area may be required. These farm ponds can also be built from employment support schemes. Built strategically, these farm ponds can function both as rain water harvesting structures as well as buffer storages for allocations and refilling from local systems.

5.1.5 Low Lift Treadle Pumps and the Like

The IDE treadle pump is an example of a small pump that does not operate on electricity or fossil fuel. For the kind of limited water application foreseen for rainfed areas, they are handy equipment for the poor farmers. They will help greatly in providing water to small patches of cultivated land. Combined with the farm ponds above they can become very good supports for the livelihood systems of the poor.

5.1.6 Fertigation through Pots and Pits

Limited water application can be efficiently utilised for limited water applications in dryland horticulture. A drip like system with efficient delivery of fertiliser and water together has been demonstrated in the Konkan area. The system consists of a set of pits at a strategic distance from the tree (typically two or four in number according to canopy size). The pits are filled with composted and compostable slow composting material and soil at the bottom of the pit, a pitcher with a hole at the bottom and a wick or a loose cloth fitted into it is placed on top of the compost-soil mixture so that the mouth protrudes. The top of the pit around the pitcher is filled with stones and boulders. The pitcher is provided with a lid. The pitchers are periodically filled. The system acts like a drip system but needs no heavy inputs or energy source for pumping not does it need filtration. The stone filling acts as a stone mulch to prevent evaporation. It is possible to provide precise quantities of fertiliser through the water.

5.1.7 Farmers

Most of the rainfed areas were not cropped land and many of those areas were dependent on tree cover or pastureland or fodder trees. At present it is not possible to incorporate trees into the agricultural system in rainfed areas because of the pressures of food security. However, if substantial livelihood assurance is made possible through 0.12 to 0.15 ha of land per households, many households (the general landholding in rainfed areas tends to be higher than this) will be able to combine agriculture with horticulture-silviculture which is acknowledged to be a more stable system.

Dr. Renukacharya, a retired Professor of University of Agricultural Sciences, and who is also an innovative farmer now, has developed a model dry land farm near to Davanagere with integrated farming system, which integrates agriculture, horticulture, forestry, sericulture, apiculture, animal husbandry and orchard and water augmentation.

5.2 Tagus Basin

Cereals, vineyard 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 mechanization, reduction of the in-fallow period and a moderate incorporation of other crops or varieties are the changes observed and can also be considered as the main and best present and future options for a stable agricultural system.

The Agrarian Policy of the European Union also provides other options by subsidizing some crops or activities in rainfed agriculture. It is necessary to take into account that such an Agrarian Policy has several purposes: (a) to reduce the surpluses in certain crops such as cereals or wine, and increase the production of those crops with deficit or good prices in international markets, (b) to improve the quality of other products, and (c) to improve the quality and sustainability of the environment. For these reasons, rainfed agriculture in the Tagus basin is conditioned by some political and economical measures

6. Assessment

6.1 Assessment of options in Tungabhadra basin (SOPPECOM and ZEF)

6.1.1 Assessment in respect of impact on water use

All the options above have an impact on water use. There will be substantial water saving in present agricultural area and it is expected that saved water would become available to the rainfed areas. The exact impact on water use will be worked out on the basis of the modelling being carried out on water use in the basin as part of the modelling exercise in WP7. Data on water use collected through household surveys in the basin shall be combined with the data from the model.

6.1.2 Assessment in Respect of Impact on Pollution

All the options described above result in a reduction in external input, including that of chemical fertiliser and pesticide, especially in the rainfed areas. The situation in respect of exact impact is similar to the above and estimates will be worked out on the basis of the WP7 model and the household survey data.

6.1.3 Assessment of acceptability and support needed

Options have been chosen with a view to wide acceptability and the support needed has been specified at each point. However, these will be put forward in the stakeholder meetings and the follow up meetings and an estimate of their acceptability and needed support will be worked out on the basis of these discussions.

6.1.4 Assessment in Respect of IWRM

Most assessments tend to use a single criterion that they try to optimise. However, the trend is towards a recognition of the multifaceted and often multi-valued nature of assessments. After the above estimates are worked out, a composite multi criteria decision analysis will be attempted.

6.2 Assessment of options in Tejo-Tagus basin (TT Partners)

In spite of the large promising options for irrigated lands in the Tagus basin, some problems remain to solve, which can be a direct or indirect source of conflicts. One of the main issues is related to the planning of water concessions to satisfy the water demand for different uses, since irrigation must compete with other industrial and urban water uses. Usually concessions for irrigation are overestimated, partially due to the inefficiency of the irrigation systems.

There are major irrigation challenges in the Tagus basin. They are related to the quantity of water, mainly as a consequence of the frequent water scarcity during the dry years, but also with the water the water quality, since there is a specific problem related to water quality once the river crosses Madrid and in some areas (Vega del Tajo) agriculture strongly depends on water quality (“scientific agriculture”).

A large effort is being developed to improve the efficiency of irrigated lands in the Tagus basin, and one of the priorities of the Tagus management plan is to increase the irrigation efficiency (at present it oscillates between 0.6 in some public non-modernised irrigated lands and 1.0 in some private irrigations highly technified). Thus, there will be priority to the concessions that saving water and the sustainable use of subterranean water resources. The improvement and consolidation of the present irrigated land is also a priority with the purpose of increasing their competitiveness, favouring the reuse of water and developing a strict control of the water use for each exploitation.

Improving the efficiency of irrigated lands should also include the use of crop varieties better adapted to the climatic conditions and the development of education programs conducted to the establishment of modern irrigation techniques and the improving of the applied research regarding to soil-plant-climate relationships and the crop production in the basin.

Although several uncertainties remains for the agriculture in the future, the irrigated lands go beyond a simple economic sector, being highly necessary to maintain an ecological/integrated agriculture based on the implementation of agro-environmental measures that include the participatory and integrated management and the support to local communities, in order to avoid rural abandonment

6.3 Twinning Aspects

Ways to integrated of the intensively irrigated with the rain-fed and the suitable technological, institutional and policy options for the same could be an important area for twinning across the two basins. The problem of highly intensively irrigated areas co-exists with raindfed agriculture in both the basins. There are fragmented efforts at developing technological and institutional innovations in both the basins that need to synthesised and brought together as part of an integrated strategy that can bridge the compartmentalisation that exists today between irrigated and raindfed. experimenting with different components

7. Conclusion

Suggestions in respect of promising options (Input for D9.3)

- Support for SRI and Aerobic rice
- Support for drip systems in sugarcane and orchard crops provided the saved water is made available for reallocation to rainfed areas
- Support for water saving low cost fertigation methods for orchard crops
- Progressive integration of tank and canal irrigation (melons on a vine concept)
- Allocation of 1000 m^3 of water and employment support for three years per household for transition to sustainable systems for the resource poor
- Support for farm ponds for between 5 and 10 per cent of farm area according to agro-ecological zone
- Support for systems or utilising small sources
- Progressive integration of landless and women

Suggestions for IWRM (Input for WP10)

- Integration of tank and canal systems
- Integrated tree-agricultural crop systems in rainfed areas

Suggestions for Twinning (Input for D9.1)

- Ways to integrate the irrigated with the rain-fed and the suitable technological, institutional and policy options for the same