Towards improved management of living aquatic resources in watersheds of the Dry Zone, Sri Lanka

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Abstract

Livelihoods in the Dry Zone of Sri Lanka have traditionally revolved around paddy cultivation under village tanks. In recent times water-use strategies have responded to a range of demographic and environmental pressures. This has implications for the sustainable management of natural resources, especially living aquatic organisms. The impacts of such change need to be understood at the level of the watershed rather than for individual communities and tanks, the current focus of most dry-land development in Sri Lanka.

Watersheds of Northwest Province are highly complex. Understanding requires a holistic approach, which considers hydrological, biological, social and economic factors. In addition to the well-recognised constraint of seasonal water availability, a range of resource flows which move in both upstream and downstream directions, are critical in determining levels of aquatic productivity. Many of these flows depend on seasonal spill events that link successive tanks within cascading systems. This includes migration routes, which permit the natural recruitment of fish stocks. Rehabilitation initiatives that increase the storage / irrigation capacity of tanks often have negative impacts on these resources flows, yet rarely do planners consider such trade-offs.

The fundamental concept of the 'Purana Complex (PC)' as the smallest logical sub-component of the watershed for intervention is introduced. Within PC boundaries discrete community groups bound by longstanding ties of kinship and caste, control access to private and commonly held natural resources. PCs in uppermost reaches of watersheds are distinguishable by the highly seasonal nature of their tanks, poor physical infrastructure and their lower wealth / caste status relative to lower watershed communities. Such areas are also often buffer zones between as yet uninhabited hinterlands and settled areas where cultivation potentials are further restricted by wild animal incursions. Consequently these groups exhibit greatest dependence on exploitation of the natural resource (NR) base, including fisheries for subsistence purposes. This often includes exploitation of less seasonal tanks in lower PCs, where fisheries are of less significance to local livelihoods. Such low-level 'poaching' is generally well tolerated, but potential for conflict exists where development interventions obstruct hitherto free access to these resources. Existing conflicts in NR management and resolution mechanisms are considered at a range of micro (within watershed) and macro (with outside institutions) levels.

Poor understanding of such functional boundaries has undermined the sustainability of many dry-land development initiatives. We argue that a situation methodology based on these insights can help to target the most relevant groups with a view to improving the equitable distribution of benefits and subsequently the all-round regeneration of the NR base within watersheds.

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1 Background

Results presented in this paper are part of an ongoing DFID/CARE funded participatory research program, commenced in August 1998. The principle goal of the program is to generate new knowledge that can enhance the capabilities of marginalised rural groups to integrate and benefit from living aquatic resource production in small-scale farmer managed irrigation systems. An over-arching goal is to increase the productivity of increasingly scarce water resources in draught-prone rainfed uplands. Under the dynamic conditions of change currently experienced in the rural sector of Sri Lanka, there is a pressing need for such research to inform development interventions which aim to support sustainable livelihoods.
Recent development in aquaculture in SE Asia has related to intensification of production systems with little relevance to the poor and often with negative environmental impacts. The emphasis here is on broad, flexible, low risk approaches to improved management that are most relevant to the livelihoods of the poor.

2 Introduction

Despite Sri Lanka's favourable location within the Semi Humid Tropics (SHT) in the path of two monsoons, a major part of the island experiences extended periods of seasonal water deficit restricting rain-fed cultivation to a period of no longer than 150days. In this respect, rural populations in the 'Dry-Zone' of Sri Lanka face similar livelihood constraints to those living in more extensive drought prone uplands of the Semi Arid Tropics (SAT), which are characteristic of large areas of peninsular India. In both areas farmers have traditionally harvested water in small-scale irrigation systems to extend growing seasons and cope with the highly erratic availability of rainwater.

In Sri Lanka, as in many parts of India, watershed management exists mainly in the form of ancient community managed cascade tank systems, under which traditional collective water management practices have become progressively eroded.
In response the Indian government currently spends some US$300 million per year (Barr 1998), on integrated watershed management incorporating small-scale farmer managed soil and water harvesting devices implemented in participation with community-based institutions. Based on NGO pioneered models that have emerged over recent decades, such intervention is part of a belated response to a widespread neglect of many once highly sustainable traditional small-scale NR management systems. The focus on large-scale developments, particularly in irrigation, during the post-colonial period has contributed to such neglect.

In Sri Lanka vast investments have been made to rehabilitate village tanks over the last two decades, though in contrast to the situation in India, neither the State nor development community in Sri Lanka have adopted watershed development models. Instead focus here invariably remains on physical improvements at the village or household level. This restricted view has negative impacts on natural resource flows at the wider watershed level, which remain poorly perceived. This paper aims to highlight the nature of such linkages: socio-economic and biophysical, which impact on aquatic production and who benefits and looses.

3 Methodology

The project adopted a highly participatory and iterative research framework, incorporating the following components:

1. In-depth situation analyses; to identify representative research areas and beneficiaries, followed by assessment of the priorities, needs, resources of target groups and identification of researchable constraints.
2. Participatory research agenda; formulation of research hypothesis based on above findings and implementation of 'farmer led trials' with participatory monitoring framework. Identification of appropriate technologies.
3. Extension and dissemination; through production of extension materials in collaboration with farmers, local grass-roots development and National Agricultural Research organisations throughout whole project cycle.

Findings presented here relate mainly to the first stage. This situation analysis which resolved from national, regional, watershed and finally village level, included assessment of natural, social, physical and financial capital assets (which the programme aims to develop), transforming structures (institutions) and process (laws/incentives), trends (climate change and economic liberalisation) and shocks, which are fuelling rapid change within rural society. Together these factors shape livelihood outcomes (DFID 1997). A range of PRA techniques including key informant interviews, group focus and priority ranking and scoring techniques, we applied to these ends.

Early on the Purana Complex (see section ??) was identified as the basic community sub-unit defining resource access and hence relative poverty. Secondly it became apparent that a watershed-scale approach would be required to understand existing patterns of aquatic resource management and appropriation.

Having identified suitable research areas (see section ??) watershed boundaries, drainage, land use and access boundaries, were mapped and triangulated through interpretation of 1:50,000 ordinance survey maps, focus group meetings and farm walks. Mapping was followed by semi-structured and systematic data collection focussing on the Purana communities and individual tanks comprising each watershed. This yield spreadsheet over-lays detailing: water management (during current maha (major) and yala (minor) cultivation seasons), historic trends in cascade hydrology and tank rehabilitation, land and livestock holdings and NR access patterns (within and out-with the watershed), community characteristics (demography, caste/kinship patterns, livelihood strategies) and outcome of current collective fishing activities. A concurrent marketing survey investigated consumer perceptions, local, regional and national markets, demand and supply for inland fish and it's substitutes.

In the second 'participatory research' phase community-managed trials are focussing on low-input fisheries and enhancements under collective and co-management systems. In the absence of obvious commercial options, these trials are focusing on conflict resolution in NR management and aim to build social as well as human and physical capital. Trial monitoring incorporates stratified household survey based on wealth ranking including farmer-derived indicators of success and failure. A second round of trials will also asses potential for scaling-up village level interventions to the watershed level.

4 The research area

At the field level, a screening process based on water availability and health-related poverty criteria resulted in selection of eleven cascade systems incorporating 76 tanks and 19 separate communities, divided amongst two adjacent research areas located in Anamaduwa and Giribawa Divisional Secretariats of North West Province (see Fig 1 and Table ??).

Both areas are located in the Lowland Dry-Zone, which covers some two thirds of the islands land area. Conditions here are characteristic of the dominant dry-zone agro-ecology. Reddish Brown Earths (RBEs) dominate and the terrain is gently undulating (2-4% slope) with rocky outcrops. The two areas differ in their rainfall distribution and natural resource profiles. Annual rainfall decreases in a North Easterly direction, which, along with it's superior physical infrastructure favours Anamaduwa over Giribawa (See Table ??). Large residual forest areas in Giribawa bring both benefits and constraints. Benefits include potential to extract biomass, whilst marauding wild animals (elephant and wild boar) impose severe limits on cultivation, particularly in upper watershed areas. Both areas benefit from close proximity to recent large-scale irrigation developments.

5 Bio-physical aspects

5.1 The inland fresh water resource

Sri Lanka has inherited an extra-ordinary and unparalleled water resource in the shape of man-made reservoirs dating back to antiquity. Whilst there are no natural lakes, there are 103 distinct river basins. Fish production in these systems is limited due their rapid flow over steep gradients and the seasonal nature of many of the basins. Whilst major 'system tanks' benefit from trans-basin transfers and relatively assured water supplies, small tanks arranged in cascading sequence within micro-catchments are rainfed and exhibit highly variable seasonality ranging from 3 – 12 months.

Estimates vary widely, but one of the more authoritative sources, the Survey Department of Sri Lanka (1985) has recorded 18,378 tanks island-wide. These are organised into some 3,500 small tank cascade systems (STCs), with from 2-25 tanks per system (Sakthivadivel 1996). This figure probably underestimates the smallest, least accessible tanks (<3ha), inclusive of which the true number of tanks is likely to extend to some 30,000 (Ref ??). Located almost exclusively in the dry-zone, this artificial resource is estimated to cover some 3% of the total land area (De Silva 1983) giving Sri Lanka one of the highest densities of small reservoirs in the world (Sugunan 1997). Ranging from around 80ha to <1ha, the great majority of tanks are below 12ha in extent, and very shallow ranging from 1-4m depth at full supply. Some 9,000 of these tanks are estimated to be operational (supporting communities of more than 25 households - DAS 1996). With a total of 4,242 recorded tanks, North West Province has the highest tank density in the country (DAS 1996).

Although a relatively small number of large-scale systems cover more surface area, and support larger areas of farmland, most farmers continue to depend on smaller seasonal tanks. However extensive investment in large scale-irrigation over recent decades (see Fig 1), has reduced the primacy of village tanks in the livelihoods of farmers in this traditionally rain fed area

5.2 Small Tank Cascade systems

The principal functions of small tank cascade systems have been described as

- Ensuring equity in water distribution in below average rainfall years.

- Regulating spill flow volume to prevent bund breaching and soil erosion.

Although historical evidence indicates a good appreciation of the need for water and catchment management at the community / individual tank level, planners continue to have poor understanding of the need for hydrological balance at the watershed level. As population and command areas have been expanded and rainfall levels decreased, such latent deficits have become exposed and uncoordinated rehabilitation efforts will often simply shift water deficits downstream. This has reciprocal negative impacts on upstream aquatic production through loss of migration routes. Despite recognition of a need for cascade level approaches since the mid 1980's (Kariyawasam et al 1984 & Madduma Bandara 1985), most rehabilitation still continues to take place on a tank-by-tank basis.

5.3 STC Classification and hydrology

Individual tanks can be classified according to their position within a cascade system and their seasonality. Axial tanks (located in the main axis of an STC) receive drainage and spill waters from one (first order axial) or more (second order axial) tanks higher in the cascade and tend to be better endowed than radial tanks, which receive waters only from their own micro-catchments (see Fig ??). Based on field observation we produce the classification of seasonality shown in Table ??. Radial and axial tanks are most likely to fall within the first and last two categories respectively. Irrigation therefore tends to be increasingly supplemental and yields lowest (typically by a factor of 0.5) in upper watershed areas where there is the greatest concentration of radial tanks. It is important to note that many farmers interpret drying as water availability for irrigation, when often, adequate dead storage remains for refuge of aquatic animals; plant and animal. This is conveyed in our definition.

Table ?? Classification of seasonality (based on survey data)

Seasonality class	Description
1. Highly seasonal	Completely dry every year
2. Seasonal	Completely dry at least once every 5 years
3. Semi-seasonal	Completely dry more than once per 5 years.
4. Perennial	Have not dried in recent memory (other than for rehabilitation purposes).

Sakthivadivel (1996) produced a classification of STCs according to form and size (see Tables ?? and Fig ??). Cascades in the research area fall exclusively into the small (Anamaduw area) and medium categories (Giribawa area). Large systems are more prevalent in terrains with lower gradients such as the neighbouring North Central Province though are also associated with lower drainage density.

Table ?? Classification of STC by size (Source Satkthivadivel 1996 and field data).

Class	Watershed area (ha)	No. Axial Tanks	Approx No. Households
Small	<1,000	2-4	300-500
Medium	1,000-2,000	4-8	500-1,000
Large	2,000-3,000	8-12	>1,000
Very Large	>3,000	>12	NA

Aside from the quantum and distribution of rainfall, the hydrological endowment of STCs can be said to be superior when they are;

- Linear or only slightly branched in form,
- Gently sloping on their main axis (2-4% slopes)
- Catchment area to length ratio is greater than 1.5
- Underlying geology/soils are relatively impervious

These predisposing factors are principal reasons for the high density of tanks in both project areas.

These classification techniques were combined with the following information to yield a simple system of hydrological assessment, derivable from PRA exercises and through interpretation of 1:50,000 survey maps

1. ratios of catchment, storage capacity and command area
2. assessment of cropping intensity (ratio of area harvested to that planted)
3. spill frequencies of individual tanks.

Such an analysis can be particularly useful in predicting wider cascade-level externalities (including those on aquatic production) that may accompany tank rehabilitation whilst avoiding the need to make costly and time consuming hydrological measurements. Based on such assessment, cascades in Giribawa and Anamaduwa were classified as surplus and deficit systems respectively. This difference is due principally to orographic rainfall effects enjoyed by Anamaduwa by virtue of it's proximity to the lee of the hill country.

With respect to aquatic production the temporal and spatial distribution of seasonality and spill events with STCs are of greatest relevance.

Tank rehabilitation interventions which increase storage capacity will have little relevance in deficit systems.

To some extent the impact of such poor awareness has been lessened as early rehabilitation strategies focusing on restoration of abandoned and non-working tanks has changed to lower cost maintenance of working tanks. Particularly bund, sluice and spill maintenance, rather than capacity enhancements (desilting and increasing of bund height).

5.4 Impacts of seasonality and spill characteristics on aquatic production.

Tank seasonality and spill frequency are the hydrological factors that have the greatest impact on fish production through their effect on seasonal carry-over of broodstock and migration routes for juvenile stock recruitment respectively. Tank seasonality is itself a function of numerous interdependent factors including rainfall, tank rehabilitation status, irrigation strategies and upstream hydrological endowment. In good rainfall years, spill events are most frequent and of greatest volume and duration during December and January. Such events are consequently less dependent on irrigation strategies as most communities commence releases only after the NW monsoon rains have abated.

By contrast secondary spill events (generally far fewer and shorter in duration) which occasionally follow the SW monsoon during April are much more dependent on irrigation strategies, particularly those of the previous maha season. A poor NW monsoon results in farmers delaying cultivation until further water storage takes place during the SW monsoon. In addition to a dramatic reduction in total spill events, this can result in a greater frequency of yala spill events as observed during the 1999/2000-cultivation year, where, against a background of low NW monsoon rainfall, only 2 maha spill events were recorded from a total of 92 tanks, whilst 4 tanks spilled during the subsequent yala season. Non of the latter tanks had been used for cultivation during the maha season and thus retained a substantial residuum of maha rainfall - see Table ??). The data also revealed a marked difference between the two research areas. All but 1 of the spill events during both seasons, took place in the 'wetter' Anamaduwa research area (See Table ??). Other than the generally longer duration of spill events in lower axial (A2) tanks, no significant difference was found between the different tank types in terms of spill frequency. No tank spilled on more than one occasion.

Since the maha spill events upon which seasonal fish migrations are most dependent are largely independent of irrigation strategies, their overall frequency and duration can be expected to correlate closely to seasonal rainfall patterns. Unfortunately, although good rainfall records exist, the reliability of historical seasonality and spill data falls of rapidly beyond 4-5 years, being based exclusively on farmer recall. The last year when more than 50% of all tanks were reported to have spilled during the maha season was 1997. Analysis of historic monthly rainfall and rain-day[1] patterns indicates six similar or superior years since 1985 (see Table ??) when a similar or greater quantum of spill events can be expected to have taken. Only during 1 year 1993 (when 1238mm falling in 45 days between September to December), is their any likelihood that most or all of the tanks in Giribawa spilled. These observations correspond with wider reported climatic trends. Severe draughts associated with the failure of the NW monsoon have been shown to recur on average every 3-4 years in the Northern dry-zone, and inter-annual variability of rainfall is greatest during the maha season (Yoshino et al 1985).

The duration of spill events varies not only with season but also with cascade position and tank size. During spill years, lower axial tanks are likely to spill for fewer longer unbroken periods during the NW monsoon (often longer than 1 week). Smaller radial tanks (often in the most neglected state), tend to spill repeatedly for periods of 1-2 days, responding rapidly to high rainfall levels often earlier in the season.

Trends in tank seasonality or more difficult to assess because for reasons outlined above in addition to a tendency to equate 'dryness' with potential for irrigation rather than aquatic production. Residual dead-storage sufficient for the survival of fish is discounted by farmers and there is a range of species tolerance to reduced water conditions. However 83% and 94% of all tanks in the Giribawa area were reported to have dried completely since the last spill event with obvious implications for fish recruitment (see Table ??).

[1] As the field capacity of the dominant Reddish Brown Earth (RBE) soil type is high (150mm of rain must fall before surface run-off will occur), both total maha rainfall in the period prior to irrigation release (September to December) and the total number of rain-days during the same period are considered in the analysis (i.e. successive rain days are likely to increase the likelihood of run-off which Somasiri (1992) is responsible for two thirds of annual tank storage).

Rarely, if ever are impacts of tank rehabilitation on spill factors considered due their indirect impact on cultivation.

In the context of decreasing water availability the impacts of uncoordinated tank rehabilitation have even greater potential to impact on cascade spill characteristics and aquatic production. Smaller radial tanks in upper watershed areas are tend to be the most neglected, as they are considered least cost-effective to rehabilitate, or are ineligible for state funds effectively being in private ownership.
Ironically a reported shift in tank rehabilitation from complete refurbishment during the earlier part of the century to simple maintenance (i.e. spill, bund and sluice repair) has served to counteract the effects of poor planning. Although nearly all ? the tanks in the research area had benefited from some rehabilitation attention during the previous 10 years – only a handful had capacity increased through de-silting or elevation of spill height.

With respect to water management, particularly striking is the high levels of complete abandonment of cultivation in the Giribawa area, with only 41 and 14% of tanks being used to irrigate crops during the 1999/2000 maha and yala seasons respectively, reflecting both climatic and socio-economic trends referred to elsewhere in the paper.

5.4.1 Table ?? Historic rainfall patterns, Giribawa and Galgamuwa Districts 1985-2,000 and spill events (Source Department of Agrarian Services 2000).

	Giribawa		Anamaduwa	
	RF (mm)	**Rain Days**	**RF (mm)**	**Rain days**
5.5 Mean Annual	1037	58.5	1209	75
Min Annual	631 (1986)	41 (1995)	700 (1988)	NA
Max Annual	1564 (1993)	86 (1985)	1650 (1991)	NA
Co Var Annual	22.3%	13%	25%	NA
Maha % Total	66%	63%	60	NA
Yala % Total	25%	26%	28	NA
Mean Sept- Dec	596	32.4	NA	NA
Co-var Sep- Dec	58%	8.6%	NA	NA
Spill years? ▪ **Sept – Dec,** ▪ **RF > 700mm** ▪ **Rain Days > 40days**	1985 (761mm, 44d) 1987 (748mm, 36d) 1991 (937mm, 34d) 1993 (1238mm, 45d) 1994 (769mm, 38d) 1997 (784mm, 45d)		NA	

Note: Maha (NW monsoon) rains fall between Sept to Feb, Cultivation lasting 3-4 months variously falls between October to Jan depending on the onset of rains. Irrigation normally commences in January, farmers using rain for field preparation. Yala (SW monsoon) rains fall between March – June, cultivation normally begins in April also utilising residual maha storage.

Table ??. Tank water management and spill frequency 1999/2000 (source field data)

	Cascades	PCs	Radial 1	Axial 1	Axial 2	Total
5.6 Anamaduwa	**3**	**5**	**13**	**4**	**6**	**23 tanks**
Mean max waterspread (ac)			10.4	10.6	66.8	
Listed by survey Dept.			6	1	6	13
Fully de-silted No.			2	1	0	3
Tank restoration No.			2	2	3	7
Tanks maintained No.			4	0	3	7
Maha cultivation; No. Tanks			15 (94%)	2 (100%)	2 (40%)	19 (83%)
Yala Cultivation; No. Tanks			7 (44%)	0	4 (80%)	11 (48%)
Cultivated 2 seasons; No Tanks			4 (25%)	2 (100%)	3 (60%)	10 (44%)
Maha spill; No. Tanks			0	0	1 (1wk Jan)	1
Yala spill, No. Tanks			1 (2d Apr)	0	2 (2dy Apr)	3
Dried since last spill; No Tanks			15 (100%)	1 (50%)	3 (60%)	19 (83%)
5.7 Giribawa	**5**	**12**	**41**	**8**	**20**	**69 tanks**
Mean max waterspread (ac)			5.5	9.2	21.5	
Listed by Survey Dept.			9	6	15	31
Fully de-silted No.			2	1	1	4
Partial capacity increase No.			8	1	7	16
Tanks maintained No.			5	5	9	19
Maha cultivation; No. Tanks			11 (27)	5 (62%)	5 (42%)	21 (30%)
Yala Cultivation; No. Tanks			0	2 (25%)	6 (50%)	7 (10%)
Cultivated 2 seasons; No Tanks			0	2 (25%)	3 (25%)	5 (7%)
Maha spill; No. Tanks			1 (3dy Feb)	0	0	1
Yala spill, No. Tanks			0	0	0	0
Dried since last spill; No Tanks			41(100%)	5 (88%)	6	54(78%)

Note: First order Axial tanks (Axial 1) are those receiving spill and drainage waters from only 1 radial tank, second order (Axial 2) tanks receive water from more than 1 radial tank.

5.8 Resource flows:

The principal natural resource flows which impact on aquatic production and their interactions at the cascade level are shown in Table ?? An understanding of such flows is required if management of nutrients and stock recruitment at the individual tank level are to be improved. Whilst downstream flows are most closely linked with the seasonal hydrological cycle, upstream movements are a consequence both of hydrology and anthropogenic factors including livestock movements. As already stressed the increasing frequency drought has the greatest impact on aquatic production, through impacts on seasonality, spill events and other associated resource flows.

Farmer awareness of the factors shown in Table ??, their inter-relations and potential impact on different livelihood arenas were generally poor. For instance although all farmers were aware of the longer-term decreasing trend in water availability, both farmers and planners showed poor awareness of such uncoordinated development and water management on upstream and downstream resource flows, other than where impacts are obvious and highly localised (such as the inundation of an upper command area as a consequence of increasing the spill height of a lower tank).

By contrast, farmers demonstrated good awareness of aquatic ecology generally, including the impacts of seasonality and spill events on fish production. In this respect entrepreneurial youth will occasionally lease fisheries under smaller seasonal tanks for a modest price, such offers would be restricted to the seasons following a good maha spill event.

5.8.1 Table ??: Small Tank Cascade hydrological resource flows and impacts on aquatic productivity

Resource flow	Downstream flows		Upstream flows	
	Flow description	**Impact potentials**	**Flow description**	**Impact potential**
Water	▪ Surface & ground water flows from rainfall, drainage and spill events.	▪ Tank rehabilitation can shift water deficits downstream, flood upstream command areas & modify spill events	▪ Bi-modal rainfall associated with two annual monsoons	▪ Erratic & decreasing trend leading to reduced cropping intensity & increased residual storage.
Organic nutrients	▪ Progressive movement grazing of cattle on lower (fallow) command & tank draw areas during dry season. ▪ Washout of nutrients with surface water during rains	▪ Increased primary and secondary aquatic production. ▪ Improved productivity of irrigated crops. ▪ High turbidity towards end of dry season due to livestock incursions	▪ Some cattle movements to upper watershed command & tank draw down areas during early dry season and to Jungle during rainy/ cultivation season.	▪ See downstream impacts
Inorganic: minerals, soil, silt	▪ Wash out with run-off from upstream, catchment, and command areas during rains ▪ Re-mineralisation of tank draw-down areas during dry season.	▪ Increased primary productivity and secondary aquatic production. ▪ High turbidity during rains ▪ Siltation and loss of tank storage capacity	▪ None	▪ NA
Inorganic: agri chemicals	▪ Inorganic fertilisers ▪ Insecticides & herbicides	▪ Increased productivity / eutrophication. ▪ Build up of pesticide residues in predatory species and aquatic bottom feeders.	▪ None	▪ NA
Encroaching weeds (Especially *Salvenia molesta*)	▪ Principle transmission during Tank spill events	▪ Loss of other aquatic productivity, enhanced siltation, loss of bathing amenity	▪ Transmission by water buffalo and Fishing gears	▪ See downstream impacts
Fish	• Migration during spill ▪ Stocking initiatives	▪ See upstream impacts	▪ Migration during spill ▪ Stocking initiatives	▪ Maintenance of fish populations in seasonal tanks ▪ Supplemented by occasional fish movements by farmers
Fish Disease	▪ Fish migration during spill events	▪ See upstream impacts	▪ Fish migration during spill events	▪ Losses of snakehead to Epizootic Ulcerative Syndrome (EUS) and market impacts.

6 Socio-economic aspects

6.1 Rural livelihood outcomes

Despite increasing stagnation, the agricultural sector continues to contribute to the livelihoods of some 65-70% of the population (Silva 2,000). Farming systems revolve around paddy cultivation under village tanks supplemented by shifting (chenna) cultivation (mostly draught resistant pulses) and some production of perennial crops in 'home gardens'.

Most farmers are locked in uneconomical paddy cultivation on miniscule holdings due to a combination of trends including: inter-generational land fragmentation (over 70% of farmers in study villages have access to <0.5ac of irrigated land), increasing frequency of drought and a rise in off-farm labour opportunities, opening of the economy and progressive withdrawal of state market intervention followed by the adoption of erratic and highly volatile trade polices with respect to agriculture in general (Silva 2000). These factors combined with a residual dependency culture and a cultural attachment to paddy cultivation reflected in paddy bias in government agricultural policy have resulted in farmers becoming highly risk averse. This has lead to a wide spread reversion to subsistence paddy cultivation or worse complete abandonment of cultivation in rain-fed areas (see Table ??).

For many 'rainfed' farmers seasonal agricultural labour or sharecropping under major irrigation systems, with their relatively assured water supply, larger holdings and yields, has come to be a primary source of agricultural income. Superior infrastructure including the development of service centres around major systems provides other employment opportunities. Although many households increasingly rely on remittances from relatives working abroad, the garment industry, security and armed forces, the availability of local off-farm labour options means that out-migration is less severe than in other regional dry land areas where it is the cause of severe community and household fragmentation.

Notes: Increasing diversion in opportunity between Major tanks and RF areas with respect to, agriculture, fisheries and service centres – Include in intro to livelihoods summary?

6.2 The contribution of inland fisheries and rural livelihoods

The predominantly Buddhist culture is accompanied by a tradition of low livestock holdings. This belies the importance of the fisheries sector. Although contributing only 2.63% to GNP (NARA 2000), locally produced fish products and imported dried marine fish account for more than 65% of total per capita animal protein consumption (NARA 2000) rising to an estimated 81% in rural areas (Nathaniel 2000). Compared to comparable rice-growing areas in SE Asia, poor families are much more reliant on purchasing fish than harvesting aquatic animals from rice fields and water bodies themselves. In rural areas demand is predominantly for locally produced, highly fresh and low-cost tilapias, whereas preference in urban areas is for more expensive marine varieties transported via a cold chain. There is unfulfilled demand for both marine and inland fresh fish (319,881 tons in 1998: NARA 2000) and rising imports of dried fish are required cover this deficit.

The abundance of shallow reservoirs and the introduction of the exotic tilapia some 50 years ago has lead to the emergence of a commercial inland fishery where before there was only a small-scale subsistence fishery. Tilapias have proved superbly adapted to the countries artificial shallow lacustrine environments, successfully occupying a niche left vacant by a depauperate indigenous, mostly riverine fauna. *Oreochromis mossambicus* dominates the fishery whilst later introductions of *Oreochromis niloticus* has lead to widespread emergence of hybridised tilapia populations. Prior to the 1950's, much of the catch emanated from the seasonal tanks, where fishers were attracted by the low effort required to harvest stock during the dry-season, using simple locally available gears and mud-fishing techniques.

Perennial tank fisheries: Undoubtedly the emergence an efficient artisenal gill-net fishery in perennial tanks has helped to keep pace with the demands for fresh fish from a rapidly enlarging rural population. Only perennial tanks support full-time professional fishing communities and it is estimated that 90% of all commercially available inland production originates from only 74 of the largest reservoirs in the dry-zone. Tilapia in turn represents an estimated 85%-95% of this production. These fisheries also support extensive networks of 2-wheeler vendors, required to supply fish to a dense but widely dispersed rural community. Opportunities for middle-men to dominate the market (as they do in the agricultural and marine fisheries sectors) are constrained due to relatively flat production, low prices and an almost complete absence of demand for inland fish in urban areas These characteristics result in a lack of product bulking opportunities, required for middlemen with greater capital resources to exploit scale-economies. Alongside the professional cadre, a new brand of fishermen / vendor / farmers is emerging as subsistence cultivators diversify their livelihood strategies through seasonal entry into the inland fisheries sector. The low overhead and risk required to enter the 2-wheeler sector make this a particularly attractive seasonal option. The sector however is male dominated with opportunities for women limited to the sale of dry-fish at weekly markets.

As increasing pressure is exerted on both agriculture and fisheries under large-scale systems, the need to manage the resource more efficiently and sustainably will become increasingly critical. At the same time as the agricultural sector has suffered from stagnation there has been a rapid and unregulated increase in the number of entrants into the commercial fishery. This is attributable to the open access nature of the resource, low entry costs and the highly favourable marketing conditions for small-scale participants, all pre-conditions that are in sharp contrast to the agricultural sector. Despite the negative impacts of intensified fishing activity on indigenous bio-diversity, so far, the tilapia fishery appears to be highly resistant and adaptable to these unregulated fishing practices. A scourge in India and elsewhere, due to it's low consumer popularity and perceived negative impact on other fisheries, in the Sri Lankan context the tilapia has been called the 'miracle fish'. The seasonal compatibility of the tilapia fishery with other components of rural livelihoods and the availability of substitutes is shown in Fig ??.

Seasonal tank fisheries: Information regarding the current production status from this resource is extremely scanty, in large part due to the exclusion of seasonal tank production from commercial markets as a consequence of negative consumer perceptions associated with soapy/muddy off-flavours. Due to concentration effects Such tainting tends to be inversely proportional to tank size. Furthermore the smaller mean size of fish, particularly stunted tilapias, which have come to dominate production in seasonal tanks are more severely effected (Murray et al 2000). The larger snakehead (*channa striatus)* is less affected by this problem, but it's marketability is also restricted by recurrent outbreaks of an ulcerative disease introduced into the country in the mid 1980's. This air-breather is second in importance to tilapia in the seasonal tank fishery in terms of volume and value. Consequently the bulk of production from the seasonal tank fishery which harvested on a highly seasonal basis, is retained almost entirely for immediate or future household consumption after drying.

Stocking programs: Various attempts have been made to harness the high potential productivity of the seasonal tank resource, most notably with the introduction of fisheries enhancement programs based on regular stocking with fast growing exotic carps during the 1980's. These trials focussed on larger semi-seasonal or minor perennial rainfed tanks (largely excluding a vast resource of more seasonal water resources). Although demonstrating good production potential, stocking initiatives have so far proved unsustainable due to problems assuring seed supply and the poor capacity of community based organisations to collectively manage enhanced fisheries. Whereas government policy to the provision of seed has proved highly erratic for political reasons, the establishment of private sector networks is inhibited by an economic opportunity cost *vis a vis* the recent advent of a highly lucrative ornamental fish production sector. Any attempts to introduce initiatives, which rely on regular stocking, must also be able to compete cost effectively with the highly productive and self-recruiting tilapia fishery in perennial tanks. With average production levels between 250-300kg/ha/yr^{-1} (one of the highest levels anywhere the world) fresh prices remain uniformly low through much of the year. The truly low cost of fresh fish is reflected in the fact that it is even substituted by poorer farmers for more costly vegetables during the dry season.

Exotic Carps: Undoubtedly there exists a niche market for large fish in rural areas, which is in part filled by low levels of common carp production (the only exotic established in some larger reservoirs of the dry-zone). Consumer demand for some of the exotic carps is good (especially rohu), sharing consumption qualities with the highly popular and formally abundant *Labeo dussemiri*, an indigenous carp species. However whether significant production increases could be sustained in the absence of external support for seed provision remains open to question. Greatest potential exists in the larger semi-seasonal and perennial tanks (50 – 800ha) where catch effort remains acceptably low for numbers that could that could be realistically stocked and production levels may be high enough to make community based seed production strategies based on exotic carps (and tilapias) viable. This is the principle focus of current government and NGO policy towards the sector. There fast growth and relatively large harvest size may also be a means of offsetting the problem of off-flavours to some degree.

This research aims to understand the existing role and level of aquatic production in seasonal tanks and potential for enhanced or sustainable management based on this understanding reflecting an important knowledge gap.

6.3 Local tenure systems and resource access - The Purana complex.

Two principle forms of rural settlement were identified in the research area reflecting recent and more historic patterns of colonisation, which in turn are critical in defining natural resource access patterns.

Irrigation colonies: Development of major irrigation systems over recent decades aimed at relieving population pressure in the hill country has resulted in the establishment of 'irrigation colonies', often small the size of a small town, benefiting from good physical infrastructure. They are typical populated by heterogeneous kinship groups despite some attempts to resettle entire communities.

Purana Complexes: By contrast the more traditional settlements in the dry-zone are known as Purana (old or traditional) villages and are home to relatively homogeneous social groups in terms of caste, kinship religion and ethnicity. In a seminal study of a such a community near Anuradhapura (to the N of the research area) in 1954 Leach (1971) gives a detailed description of the customary rules based around caste and kinship and their role in creating social boundaries, which perpetuate inter-generational patterns of access to various resources including land and water. In the current study the oldest Purana villages (>150years old) tended to be established around the most reliable perennial or larger semi-seasonal (non-system) tanks. Traditionally farmers from these villages then typically extended irrigated cultivation to smaller seasonal tanks adjacent to their base tanks, often on a rotational basis. However with recent population increases, permanent settlement has progressively taken place under these radial tanks, though ownership of much of the irrigated land under these tanks (and therefore the primary control of water) often continues to reside with more affluent older farmers in Purana base-villages. Vertical colonisation within cascade systems is often constrained by existing settlement around the hydrologically better endowed axial tanks. In the current study a typical Purana community will have access to one very occasionally two larger axial tanks from 1-13 more seasonal radial tanks. We coin the term Purana Complex (PC) to describe these discrete social assemblages, sharing well defined spatial and temporal access to a range of natural resources centred around, water storage. Such a PC may cover a whole part of a catchment, depending on the catchment size and hydrological endowment.

Fig ? shows the Pahala Diulwewa Cascade System, within which three such PCs are identified. Demarcations are based around two castes, with the 2 lower PC's being of dominant and most ubiquitous Govi (cultivator) caste, whilst the Ihala Diulwewa PC at the top of the watershed of the low kumbara (potter) caste. In the case of two lower communities, subtle intra-caste demarcations continue prevent inter-marriage between the two lower communities although the precise nature of these distinctions is generally lost the kinship linkages persevere. Such a pattern is recurrent of the wider research area whereby of 19 PCs studied 5 are low cast (non govi) and only one benefits from access to a larger perennial axial tank. All the others are located in upper-watershed areas where they settled around seasonal or highly seasonal tanks. Residual lands of once extensive temple estates also tend to be located close to rocky (sacred) prominences in upper watershed areas. In such instances the tanks and lands underneath them are leased to villages by the temple. Both Ihala Diulwewa and one other low caste PC fall into this category. As these 'privately' owned tanks are not eligible for state sponsored rehabilitation they are often in the greatest relative state of neglect.

Also shown is a more recent irrigation colony under the recently rehabilitated Uriawewa system tank.

Despite the far reaching impacts of liberalisation and a widely held belief that the feudal Sinhalese caste system is in rapid decline, these caste demarcations were observed to remain deeply entrenched in rural areas. Although it was apparent that the rigidity with which indigenous village institutions enforce customary rules relating to caste as described by Leach have been relaxed or entirely lost, social taboo on intermarriage continues to be the norm perpetuating the community boundaries which are most critical to understanding natural resource access and ownership. Within the research areas, marriage usually takes place only within the Purana boundaries or between ancestral communities with whom kinship links are maintained.

6.4 Open Access and Common Property Resources.

For a resource the to be managed effectively and sustainably, the boundary of the management unit must be clear. This requires the definition of both spatial and social boundaries (i.e. who has rights and duties with respect to participation in different uses of the demarcated resource). Such clarification is critical when considering natural resources, which are held in common ownership. Village tanks, which are used for multiple purposes by a heterogeneous assemblage of different stake holder groups are an example of such a resource.

Over recent decades the debate around the commons has moved from a perception of open access resource appropriation and depletion expounded by Hardin in his seminal paper 'the tragedy of the commons' (1968) to a progressive recognition that that sustainable governance of Common Property Resources (CPRs) is often best entrusted to indigenous organisations (Ostrum 1994). The shift in thinking comes with the recognition of CPRs as a 'fourth property estate' (as distinct from private, public and open access estates) overlooked in Hardin's original model. This model viewed all of the commons as being Open Access, where individual self-interest leads to plunder and pillage of natural resources. Table ?? outlines some key distinctions between the Open Access and Common Property resources according to current thinking.

Table ?? The commons: open access and common property resources

	Open Access (Res Nullis)	**CPRs (Res Communis)**
Ownership	Common	Common often with usufruct (i.e. non transferable) rights
Management authority	Absent or Broken down	Social unit with defined membership and boundaries and some common interests
Management system	Free resource appropriation through self interest, 'capture and control'	Existing social system with shared norms & sanctionable customary rules
Incentives to participate in resource management	Non	Economic and non-economic
Participation	Heterogeneous social groups or individuals.	Relatively homogeneous groups with most individuals affected by

		operational rules (hence compliance)
Excludability	Non excludable	Excludability determined by membership of community and multiple use characteristics.
Subtractability	Free subtractability	Substractable only by members of community or group.
Conflict resolution	Local confrontation, External agencies	Low cost, local arenas
Multiple use	Uncoordinated	Activities in multiple layers with multiple rules.
Costs of co-ordinating resource use	High	Low
Management outcome	High user rates tend to deplete capital assets	Efficient / sustainable
Examples	***Perennial fisheries in major tanks***	***Traditional fisheries in seasonal village tanks***

Sources: Firth 1997, Bromley 1989, Ostrum 1994, De Castro 1998.

Property regimes are closely related to ecological and economic features of a resource, a fact which influences the cost/benefit balance of different forms of appropriation. Keeping this and the factors outlined in Table ?? in mind, traditional village tanks in rain-fed areas fall firmly into the CPR domain where the basic management unit is clearly defined by the PC community (see section ??). Levels of excludability to non PC members are largely contingent on the relative priority accorded to multiple water uses within the community and the interactions of different uses on each other (see section ??). Excludability also varies in both space and time as the relative importance of priorities shifts with water availability during the course of the year (see section ??). Overall responsibility for managing the water resource was traditionally entrusted by the community to the *vel vidane* (the hereditary irrigation head man) who, in return for a tithe on all harvests, was responsible for co-ordinating all collective activities associated with the resource. These included cultivation calendars, collective fishing including enforcement of seasonal bans and maintenance of tank and irrigation infrastructure, equitable distribution of seasonal fish harvest and conflict resolution (along with other respected titular village elders).

CPRs can also be defined then as 'private property for the group' where non-members are excluded from use and decision-making, whilst individuals within the groups have a range of rights and concomitant duties. Built in incentives, both economic and non-economic serve to re-enforce the system. For reasons outlined below, a clear distinction between CPRs from OARs is critical in understanding patterns of aquatic resource management in the current research arena:

The costs of mis-classification

It is a mistake to design development projects on the assumption that physical inputs are the most important factor. What has been overlooked almost entirely is the importance of social capital. Conveying of knowledge from one generation to another makes institutions survive over a long period of time (Ostrum 1994). Where CPRs have been mistaken for OARs, community based institutions, which may have endured for centuries have often been unwittingly destroyed by external institutions. This has often occurred in the guise of environmental conservation, where invariably more emphasis is placed on physical rather than social capitals

In Sri Lanka the *vel vidane* along with many other customary village institutions (see Table ??) were effectively abolished during three decades of experimentation with centrally planned economics, during which time responsibility for management of nearly all the countries irrigation resources, both large and small were appropriated by the state. The result of this action, along with other market interventions and the external imposition of farmer organisations, was to create a dependency culture bringing with it a loss of accountability for resource management at grass-roots level, a trend that has proved difficult to reverse. Furthermore, the rapid loss of these traditional systems, which together instilled an enduring sense of cultural identity, has fuelled a wider trend in eroding social cohesion. 'We are no longer a community' is a common response heard from farmers in rain-fed areas, despite enduring links of kinship and caste (see section ??).

The traditional CPR situation pertaining to fisheries under village tanks can be usefully contrasted with tilapia fisheries in perennial tanks, which fall squarely into the open access classification. This recently introduced resource has never been effectively incorporated into any existing social system and there has been an institutional failure to implement any new regime. It would appear that the resilience of the exotic tilapia to the gill net fishery is arresting rapid resource depletion as the number of entrants and intensity of fishing methods increases. Meanwhile the catches of indigenous species have declined dramatically the incidence conflicts including the destruction of gears and occasional physical violence increases.

The greatest threat to CPRs based on village tanks is the potential for degeneration into OARs bringing negative impacts to the whole range of water users and uses. Despite the bleak picture painted above, many customary traditions persist even under new institutional frameworks. The challenge becomes to understand which of these traditionally collective management practices have relevance to current livelihood strategies and trends and could be the basis of an evolution of stronger community institutions capable of sustainable resource management and conflict resolution both within and between neighbouring communities and local development institutions.

Development of community and co-management systems for the commons, in addition to recognising the role of local institutions, involves multiple resource use and the participation of different resource groups in a complex multi-dimensional political process i.e. this emphasises; the interaction between the resource users and the resource 'uses' rather than just between the users and the resource itself. This further underlines the need for:

- A shift from sectoral to a systemic view of resource appropriation
- An evaluation of resource sustainability in the light of institutional stability and
- An understanding of the structure of opportunities and constraints by which people make decisions.
- A definition of both the rights and duties contingent on different stake holder groups accessing CPRs.

These issues are developed further in the following sections.

Table ?? Traditional collective management activities and their contemporary status.

Collective management arena	Type	Traditional description / outcome	Contemporary description / outcome
Irrigation	Synchronised cropping	Field preparation, cultivation strategy and water delivery	Asynchronous management and emergency pump down becoming more common particularly under larger village tanks.
	Bethma	Temporary redistribution of lands under reduced cropping intensity, facilitating use of residual water storage - usually during the minor yala cultivation season	Cultivation increasingly likely to be abandoned entirely when storage levels are low.
	Catchment	Avoiding deforestation in the immediate catchment area, which could accelerate tank siltation.	Intensive use of catchment areas for both rainfed and irrigated cultivation – often with forestation remaining between upper watershed and lower tanks
Aquatic resources	Fishing bans	On nets - during the irrigation and dry season – to reduce seepage losses and loss of water quality for bathing.	Still widely honoured due to difficulties of fishing during the irrigation season and the high priority accorded by the whole community to bathing
	Collective fishing	1-3 days of activity on a set date towards the end of the dry season – with equitable distribution based on participation and social needs.	Still occurs due to the opportunity presented by decreasing water spread – but typically on an informal basis for individual gain, prompted by increased poaching rather than on date set by CBO
Socio-cultural	Shrimadana	A tradition whereby public works were undertaken in order to gain social and religious merit.	Still prevalent – but undermined by the introduction of modern welfare schemes (Samurdhi) which reward participation with payment benefits.
	Death donation society	Indigenous community based organisation providing Micro-credit for funeral costs	Still highly prevalent – one of the few traditional CBOs functioning efficiently
	Temple maintenance society	Indigenous CBO providing labour and materials for temple maintenance	Still highly prevalent and functioning.

6.5 Multiple use of water in STCs

Many factors other than the absolute availability of water in village irrigation systems, impact on the livelihoods of the poor. The highly variable temporal and spatial scale of water availability and it's multiple use / user characteristics means that there are always likely to be various stakeholders groups with competing interests. This is especially true in the case of water since it's use often involves externalities whereby secondary benefits and costs do not accrue to the resource user him/herself (Soussan 1998). Understanding the priorities accorded by different stakeholder groups to different water uses and their externalities, is therefore critical to determining the need for and predicting impacts of interventions. Table ?? shows the externalities which arise as a consequence of interactions between different resource users and uses, to which further detail is presented in Table ??.

Externalities

As the main consumer of water, the impact of irrigation on other uses is relatively well understood – more poorly perceived is the interaction between the subordinate functions. In addition to irrigation, villagers identified an additional six regular uses of water stored in seasonal tanks (Table ??). These uses exclude human consumption, generally relying on ground water sources instead. The implicit / hidden use for ground water recharge for this purpose or for micro-irrigation using agro-wells, was not identified by those questioned.

Forty-four households in two villages located in mid and upper watershed areas were asked to score the relative importance of the identified uses. A significantly higher priority was attributed to bathing and irrigation ($P < 0.5$ Friedman's test) than all other uses in both villages. Whereas the primacy of irrigation was to be expected, the high priority accorded to bathing was more surprising. This is reflective of a high socio-cultural significance attached to bathing in rural Sri Lanka, whereby all members of society (men, women and children) prefer to bath communally in a local tank, canal or river when the opportunity presents itself. This usually occurs at least twice per day; both in the morning and evening, either in family or gender groups.

During the dry season the bathing function is elevated to the highest priority for the great majority of the community. Under more seasonal tanks where irrigation is typically supplementary, risk of crop losses high and yields low, cultivation is increasingly abandoned to preserve water for dry season bathing, particularly where off-farm labour opportunities are available. Generally there is no exclusion to anyone wanting to participate in bathing even beyond PC boundaries. Villagers around the smallest seasonal tanks are most likely to take the opportunity of bathing in larger perennial tanks during the dry season, often travelling up to 6-7km to do so. Poorer families without means transport may continue to bath in shallow muddy pools of water almost until they run dry.

In contrast to bathing, the use of water for fishing was accorded one of the lowest priorities by those questioned. Although the introduction of tilapias has undoubtedly brought benefits to seasonal tanks, this is outweighed in large part by the simultaneous rise in the regular availability of low cost tilapias from perennial reservoirs, untainted by off-flavours. Other reasons include the highly erratic nature of fish production in seasonal tanks and perhaps a general reluctance to confess participation in fishing, a traditionally low caste activity.

The real importance of seasonal tank fisheries only becomes apparent when one considers the intensive seasonal nature of participation and the externalities associated with this activity (Table 2). Loss of water quality accompanying net-based fishing during the dry season is at the root of one of the most prevalent forms of natural resource conflicts. This takes place between the larger communities of bathers and small groups of mostly male youth who ignore informal fishing bans during the dry season (May to August). This is the period when both bathing priority and fishing activity are most intense as water coverage shrinks and catch effort decreases. Most fishing is undertaken by small groups of youth using gill nets and fish drives to minimise catch effort. This can cause massive elevation in water turbidity, which often persists for several weeks (see section ??).

Apart from irrigation and livestock watering, all other water uses are also subordinate to bathing. Most villagers take a cultural view that 'livestock have an equal right to life' and are therefore permissive of livestock watering even where it has negative impacts on water quality (particularly where water buffalo are concerned). As such activity is usually confined to littoral zone negative impacts increase as water areas recede during the dry season.

Although water related / livestock incursion conflicts are rare, conflicts between livestock smallholders and cultivators during the main maha cultivation season are commonplace. Loss of pasture and access to fencing materials means that cattle must be closely shepherded at this time as pasturalists risk forfeiting stock in recompense for crop damage. The remaining exposed tank bed area and jungle clearings become important areas for grazing at this time. Increasing levels of such conflicts and a reduced requirement for animals for draught has resulted in a general decrease in the number and size of already low holdings by regional standards.

Excludibitlity and subtractibility:
The consumptive use of water for irrigation is the most excludable, being base on access to irrigated lands in the command area. Although such access rarely extends beyond the PC, farmers settled around radial tanks are often excluded as ownership of irrigated land often resides with older farmers around the older settled base tank.
By contrast, despite their high priority, bathing and to a lesser extent livestock watering are the least excludible of all the water uses (see section ??) due to their fulfilment of a basic human/animal need and their relatively low subtractibility with respect to other uses. In this respect bathing and fishing can be perceived as mutually subtractable to each other based on their influence on off-flavours and water quality respectively. However the proxy benefits of bathing on fisheries management, through fishing bans and the reduced likelihood of pumping down dead-storage for irrigation, probably outweigh such subtracability.

Table ?? Multiple-use interactions of seasonally impounded water resources in livelihoods of rural communities, NWP Sri Lanka

Water use	1ry stakeholders details	1ry Stakeholder priority	2ry stakeholder details	Excludability	CPR Externalities		Realised Conflicts
Farmer Identified					**Cost**	**Benefit**	
Irrigation	Most HH in PC during main maha cultivation season Older farmers are main stakeholders	High or highest. Priority But primacy falling	Occasional sharecropping on degraded lands by non PC members	Access rarely extended to non PC members or extended family	Highly consumptive use of water can impact on all other uses. Downstream concentration of agro-chemicals	Downstream drainage flows and ground water recharge	See livestock and fishing.
Bathing	Most HH in PC	High & highest during dry season Relative importance rising	Neighbouring PC members during dry season	No exclusion from perennial tanks	Soapy off-flavours reduce commercial value of collective fish harvest during dry season	Socially cohesion Conservation of dry-season water for fish survival	See fishing
Livestock watering & tank bed grazing	Small group mostly poorer HH with small holdings. No's falling.	High dry season priority for small stakeholder group	Upper watershed livestock holders move downstream during dry season	No exclusion during dry season Limited access during cultivation season	Soil erosion Risk of Crop damage Transfer of encroaching aquatic weeds Loss of bathing amenity	Liquid asset during dry season Increased aquatic productivity	Livestock holders v cultivators
Other domestic uses (clothes washing etc)	Most HH in PC	High especially for mostly female participants	Non PC members during dry season	No exclusion	Soap inputs – see above	Social activity (women)	Domestic users v fish poachers
Brick making & tank bed ravel/ sand extraction	Small number of mostly poorer households within PC	Medium during dry season for variable stakeholder grp	Non	PC only	Increased percolation losses through tank bed excavation. Catchment deforestation	Individual only	Non detected
Cajun Retting	Small No. of HH within PCs	Med	Non	PC only	Potential to reduce water quality in bulk	Individual only	Non detected
Aquatic resource production / fishing	Mostly male youth and children for dry season collective harvest	Low but many seasonal recreational and subsistence participants	Poorer youth from upper watershed communities Regular fishing	No exclusion for hook and line. Net bans during dry season May-July.	Loss of water quality for bathing and livestock Transmission encroaching weeds on gears. Increased percolation loss	Improved village cohesion through collective activity	Highest Internal &external poachers v bathers

Notes: HH = Household. PC = Purana Community

6.5.1 Fisheries management in village tanks

Non commercial fishing activity in village tanks can be broadly be divided into two seasonal categories; collective fishing activity (July – August) and a period of more 'regular' sanctioned and unsanctioned activity concentrated around the two inter-monsoonal dry periods of retreating water spread (March to February and May to September).

In the past most fishing effort fell into the former category under a low output, but equitable and highly sustainable system of community based management based on customary rules, value based norms and taboos. Most traditional fishing techniques could only be practiced in shallow water restricting the time of fishing and concentrating effort in more seasonal tanks leaving deeper waters and perennial tanks as refuge areas. Under a village assembly headed by the irrigation headman, all able bodied men in the village were expected to participate on a specified date and a share allocated to those incapable of fishing, with benefits also going to the temple. Formal sanctionable fishing bans were imposed as water levels began to fall during the minor Yala cultivation season and taboos on taking fish struggling to survive in mud ensured the survival of air breathing species. External participation was effectively proscribed under this system underlining the traditional CPR status of the resource

Today the window and scope for unsanctioned fishing activity and associated conflicts has increased as more efficient imported gears (gill nets) displace locally produced shallow water and 'mud-fishing' systems (Fernando 1969). As net ownership is limited, gear owners out with PC boundaries are regularly invited to join in both unsanctioned 'poaching' and collective fishing - particularly in larger semi-seasonal tanks where 'mud-fishing' is less of an option but yields potentially high. This results in unnecessary dissemination of information regarding fishing activities inviting external participation, loss of production to the PC and further delimits local control of the resource for a variety of uses (see section ??). Much of the unsanctioned fishing activity takes place at night in order to avoid detection.

Former duties that were attached to fishing rights have moved from perfect to imperfect forms of duty. That is they are now more general and non-compulsive as a result of loss of effective CBO involvement as 'institutional duty bearers'. Residual vestiges of the traditional management system include dry-season bans on fishing (though only as result negative fishing externalities – see Table ??), and distribution of surplus collective catches though generally only to immediate kinship groups. The only direct efforts to manage fisheries in any of the tanks studied were restricted to limited movement of wild broodstocks or locally sourced fry (often with the assistance of bicycle vendors) to initiate re-colonisation of seasonal tanks. Undoubtedly the introduction of tilapias, which has proved superbly adapted to seasonal as well as perennial tanks has served to sustain productivity in the face of intensified exploitation which has contributed to loss of indigenous biodiversity (see section??).

Different stakeholder groups undertake fishing for different reasons, though all are exclusively male and mostly youth between the ages of 15 to 30. Parents are generally keen to dissuade younger children from fishing for cultural reasons, though they will often participate in hook and line fishing surreptitiously. Older individuals display a tendency grow increasingly conservative with respect to participation for religious reasons, though most participated in their younger days. This can fuel inter-generational conflicts within PCs, where older members accuse youth of being work shy and more reluctant to participate in more labour intensive cultivation activities. Youth groups in turn feel disenfranchised through their relative poor access to productive cultivation resource and often-poor representation in village institutions.

Fishing for subsistence purposes is of relatively greatest importance to poorer low caste, upper watershed groups. Because of the generally high seasonality of their own resources they tend to exploit larger surrounding tanks in a wide radius. Fig ?? is a mobility chart demonstrating the relative importance of fishing seasonal tank three neighbouring PCs, 2 low and high cast. Very few of the high caste villagers in Pahala Diulwewa participate in regular fishing either in neighbouring or their own tanks and only 1/5 of households participate in collective fishing, this despite having access to a highly productive seasonal tank. By contrast 25 youth from the upper watershed village of Ihala Diulwewa participate in regular (>1/month during the season) sanction and unsanctioned fishing activity in a large number of tanks up to 6km from their village. Such subsistence activity is generally well tolerated at low levels when practiced by small groups away from periods of minimal waterspread.

In other villages, often high caste, disenfranchised youth participate in fishing less for subsistence and more for recreational purposes. This often involves larger groups who are often emboldened to fish during the day regardless of sanction and season, often trading some of their catch for illicit locally distilled alchohol, a potent combination often leading to violent confrontation.
The exclusion and these ‘free riders’ have proved a major constraint to stocking initiate
Transhumance strategies. NER (i.e. production levels) and management systems i.e. new approach called for.

Bund based techniques (such as hook and line), which do not involve tank entry, are well tolerated and even non PC members are rarely excluded, particularly from larger tanks. Though this technique is less attractive due to lower catch per unit effort compared to gill netting. Passive fishing with nets (i.e. gill nets set overnight) is rarely an option due to risk of net confiscation or destruction.

In smaller tanks, the resulting loss of water quality and bathing utility which accompanies livestock incursions and intensified poaching activity (often during the night), increasingly are the cues that initiate 2-3 day collective fishing episodes in the absence of effective community based management. Although large sections of the community still participate, as news of the event is rapidly spread by word of mouth, benefits are less equitably distributed (see section ??). Furthermore although the limited gains to be had from fishing in the most

In the smallest radial tanks this often corresponds with the period of useful water availability, tanks being reduced to muddy pools thereafter, whilst in larger seasonal tanks informal fishing bans are re-introduced once the incentive for poaching has been reduced.

7 Technical options:

Strategic/Watershed

Most farmers stress stocking initiatives should be undertaken only after the NW monsoon and the initiation of irrigation releases to reduce the risk of stock losses during spill events. Yet in seasonal tanks early season stocking strategies which exploit limited growth windows confer obvious advantages. All though it is impossible to predict the occurrence of spill events with any certainty results show that most tanks fail to spill in most years. Improved resolution and feedback of spill profiles to farmers, may allow them to make more informed risk management decisions.

If communities are prepared to co-operate in fisheries management at a wider watershed level then there may be potential for stocking strategic nodal (A2) tanks which could then exploit spill events for natural recruitment, through their good linkages with other tanks.

The most seasonal radial tanks are being abandoned for cultivation with the greatest frequency and are less constrained by other multiple-use functions, as they are often distributed around larger perennial community tanks in which most bathing activity takes place. As these many of these tanks are private and not valued by their owners for fish production it may be possible to promote fisheries leasehold arrangements with interested youth from poorer upper-watershed communities.
Rehabilitation: Fish friendly interventions must be integrated with other uses – principally bathing. Increasing dead storage rather than waterspread will be most relevant. Complete de-silting will crash production. Building smaller refuges in the deepest area under the bund could benefit – bathing and fish production (anti-predator,

Tanks should be viewed rather than an irrigation structure per se as a service resource to service diverse dynamic needs of a changing rural society with decreasing primacy of on-farm irrigated agriculture.

Smaller deeper areas for bathing and refuge for fish is a priority. Minimal hydrological impact

Semi-formal institutions more important in poor livelihoods
Then link up with external private sector trader networks to increase productivity without undermining new primary uses of livestock and bathing in top tanks.

Fish will keep water cleaner if livestock allowed to bath.

Private sector driving off-farm employment – allow people to live in watersheds without exploiting NR in watersheds as heavily.

Costing of value of increases for different functions.

Low value of existing highly seasonal tank fishery can be increased by low level inputs (see above) and linkage with external seed networks for early season stocking (later stocking of snakeheads).

8 Further research

Nutrient status: Longitudinal assessment of water quality and cattle movements
Migration characteristics by species (are tilapia less prone to migration).

Social / village based

9 Conclusions

Today national policy for food security and food self sufficiency is often equated with 'rice security' and rice production. What is less appreciated is that at the rural level, fish security is only second to rice security, true levels of consumption are almost certainly not reflected by government statistics.

Policy recommendations:
Turton and Bottral 1997 produced a typology of farming systems and development in Draught Prone Drylands according to which rain fed systems in the research area can be classified as transitional systems. These are areas with high and increasing population densities, declining rainfall from climatic change, high levels of labour migration out-with the watershed and a history of indigenous technologies. Recommended development strategies are evolutionary rather than the transformational approaches recommended for higher potential systems with more favourable water availability and good access to markets. Evolutionary approaches rely more on the development of indigenous technologies. Particularly with respect to water management. Farington and lobo also suggest that such an evolutionary approach is consistent with requirements for scaling up participatory watershed approaches which are beginning to shows signs of sustainability – but unrealistically slow lateral spread.

The general neglect of caste issues in the development community in Sri Lanka can be equated with a reluctance to become involved in the arena of CPR development to which the issue is of greatest relevance. This may be attributable to the often complexity of these multiple stakeholder systems and the potential that exists to enhance latent conflicts when they are poorly understood. The lack of such a focus is also reflected in the lack of meaningful dry-land watershed approaches in the country

Connect this with difficulties associated with community/social capacity based watershed management and lack of spread in reasonable time-scales compared to Indian govt programmes which stress physical interventions and have good coverage but poor sustainability.

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Technical options:

Watershed approaches?
Kerr and Sanghi (1992) conclude that SWC approaches should concentrate wherever possible on technologies that require minimal co-operation. This is mirrored by doubts over the watershed approach, which although logical from a water resources point of view, place heavy demands on joint action (Turton and Bottral 1997).

Micro-watershed approaches in India not only reverses environmental degradation; largely through improved re-charge of groundwater. Yet approaches to watershed planning and implementation which are both participatory and replicable have proved elusive. Most exhibit one or other of the characteristics

The difficulties involved are apparent that when one considers in India were the Govt alone spends some US$ 300m/yr on interventions at the micro-watershed level, the highly participatory approach championed by NGO's covers only 1% of the total area of watersheds covered in India.
Approaches have been sharply polarised between the highly participatory and apparently productive approaches typically adopted by NGO's and the approaches of the some govt depts characterised by wide coverage and an emphasis on physical planning. In many cases the latter exhibit insufficient accountability and particpation by local beneficiaries to ensure participation, whilst the former require long term face to face joint learning, higher costs per beneficiary and less significance in area terms (1% of total treated area). Hence are associated with real problems in scaling up in an acceptable time scale.

Information on organising around water as a CPR remains scattered (Turton and Bottral 1997)

Conflicts?
Many modern day farmer organisations are often poorly representative of local communities and remain woefully inactive, often only meeting once per year prior to the main cultivation season. Loss of local participation combined with increasing numbers of stakeholders in the resource have resulted increasing levels of conflict with respect to resource management, a trend particularly evident with respect to fisheries (see below).
Perfect and Imperfect Duty