Impact of climate change on culture-based fisheries in seasonal reservoirs of Sri Lanka and the resilience capacities of rural communities

Science and technology brief

A study was conducted in four districts in Sri Lanka where culture based fisheries (CBF) is practiced. This study involved hydrological modelling of small village reservoirs or reservoir cascade systems where CBF is practiced, together with a water balance to evaluate the filling pattern of the reservoirs in response to the long term rainfall and its variability. In this brief, guidelines for adaptation measure that can be undertaken by science and technology workers with institutional and policy support required to improve farmers' adaptive capacity has been suggested, based on scientific analysis and stakeholders' inputs.

CBF farmers in the study districts are already experiencing the effects of climate change such as changing weather patterns, increased frequency and strength of storms and increased and unpredictable rainfall. As they have low capacity to adapt to the changing situation, they need science and research support and technological development to find solutions to the problems they face, or will face, due to climate change.

Science and technology needs

- ANALYSE LONG TERM RAINFALL, TEMPERATURE AND EVAPORATION VARIATIONS: Long term variability of rainfall, temperature and evaporation needs to be analysed for the areas where CBF is practiced, ie. District Secretariat level, district level.

- SIMULATION OF RESERVOIR WATER LEVELS: Long term simulation of water volumes of seasonal reservoirs and those associated in the cascades should be combined with other models to predict reservoir filling patterns.

- PREDICTION OF WATER LEVELS IN CBF RESERVOIRS AT LEAST A FEW MONTHS BEFORE THE CBF CYCLE: Climate change has shifted the filling pattern of the seasonal reservoirs so that changes in stocking strategy are needed in culture based fisheries.

- STUDY THE FEASIBILITY OF ALTERNATIVE TECHNOLOGIES THAT CAN ASSIST TO INCREASE THE CULTURE PERIOD: Identify different technologies that can be employed by CBF fishers to increase the culture period. These technologies can be made available for selected farmers as a pilot project and study the feasibility and opportunities that those technologies provide in enhancing the culture period. One such approach will be to keep the fish fingerlings in cages until spilling of the reservoir is over. Fixing a barrier net across the spill to prevent escape of stocked fish is also feasible in some reservoirs.

- IDENTIFY IMPROVED WATER MANAGEMENT STRATEGIES THAT CAN ASSIST ALL THE WATER USERS TO SAVE WATER FOR CBF: Research is needed to different water management strategies that can assist in saving water in the reservoirs andthereby increase the culture period. CBF is still not recognised by the officials of the Agrarian Development Department at the regional level. Coordination between fisheries and agrarian authorities should be strengthened.

- STUDY THE IMPACTS OF TEMPERATURE INCREASE AND RAINFALL VARIATIONS ON BREEDING OF CARPS: Carp breeding is affected by temperature and rainfall variations. Thorough research is needed to identify the impacts of climate variability on breeding of carp varieties and other fish. Means to minimise these impacts also need to be studied.

Culture based fisheries and climate change

This brief summarises the results from the interdisciplinary study conducted within the Aquaclimate project in Sri Lanka looking at the impacts of climate change on culture based fisheries (CBF). The brief further provides guidelines for academia, researchers and technologists to support farmers for adaptation measures to address the climate change impacts on CBF in Sri Lanka.

Culture-based fisheries are essentially a form of extensive aquaculture, or a farming practice conducted in small water bodies (generally less than 100 ha) that would not be able to support a subsistence fishery due to a lack of adequate natural recruitment of suitable species (De Silva et al., 2006). Artificial water bodies, which are perennial or non-perennial in nature and built for irrigation purposes, can be used for CBF development (De Silva 2003). These water bodies are stocked with suitable species in pre-determined proportions. The stocked fish feed on natural food organisms in the reservoirs so that CBF is somewhat similar to extensive aquaculture without supplementary feeding (De Silva 2003). The fish are harvested after a growth period of 6-9 moths when the water level recedes. A selected community group, who will have ownership of the stock, prepare the water body for stocking, procure seed stock, and care for the stocked fish, in particular by keeping watch over the stock (De Silva *et al*., 2006; Amarasinghe and Nguyen, 2009).

There are legal provisions under the *Agrarian Development Act* of 2000 for the Farmers' organisations to utilise village reservoirs for CBF development. This strategy is facilitated by the links between Agrarian Development Department and National Aquaculture Development Authority of Sri Lanka (NAqDA).

Culture-based fisheries in Sri Lanka are mainly developed in non-perennial reservoirs due to their extensive availability and high biological productivity. Non-perennial small reservoirs, which are referred to as seasonal tanks, are often less than 20 ha at full supply level. These tanks usually dry up completely during July–September and fill during the inter-monsoonal rains in December–January. Their highly productivity relates mainly to the change in environmental conditions from a terrestrial phase during the dry season to an aquatic phase during the wet months (Amarasinghe, 2006).

The water retention period in non-perennial reservoirs is 7–9 months. As such, these reservoirs should be stocked with fish fingerlings in January–February. Fingerling rearing, fry rearing and induced breeding of fish should be conducted at a time so that fish fingerlings are available in January–February (Amarasinghe, 2006).

Aquaculture committees are set up under the farmers' organisations. These committees are responsible for the management of CBF in village reservoirs. Fingerlings needed for the CBF are produced in the fish breeding centers of NAqDA. Fry-Fingerling rearing is done through community participation in net cages in major reservoirs and in CBO-owned mini-nurseries (Amarasinghe, 2006).

Accordingly, there are four major steps for sustainable implementation of CBF (Amarasinghe, 2006). They are:

1. Induced breeding of major carps in state owned fish breeding centres.

2. Rearing of post-larvae to fry stage in cement ponds under controlled conditions in state-owned fish breeding centres.

3. Rearing of fry to fingerling size in earthen ponds owned by villagers (also in state-owned fish breeding centres) and net cages installed in perennial reservoirs through community participation.

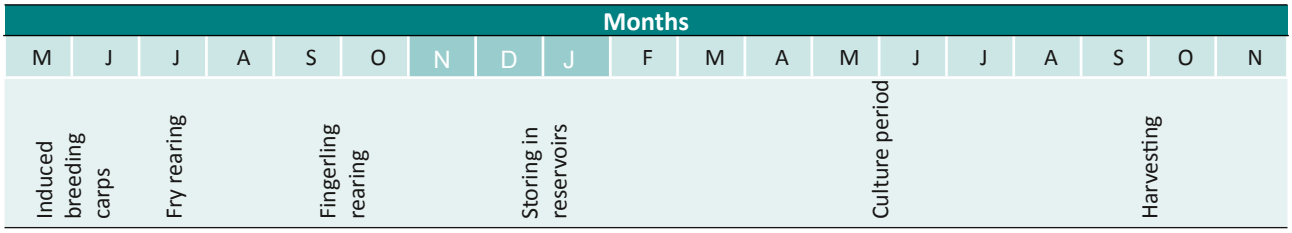
4. Stocking of fish fingerlings in non-perennial reservoirs and harvesting after a growth period of 7–9 months for marketing.

It is evident that noticeable changes on a global and regional scale are proceeding in climate. The observed changes include an increase in air temperature, regional monsoon variation, frequent droughts and a regional increase in severe storm incidence in coastal states. This may have impacted on the inland aquatic resources and their fisheries (Vass *et al*., 2009).

Rural Sri Lanka stands on the agriculture-based economy with a long history of over 2000 years. The living example of the agricultural economy is the unique irrigation system developed by the forefathers of the country. CBF is a secondary use of existing water resources benefiting communities in the rural areas. The unique feature of CBF is that it is not a competitor with traditional paddy cultivation and as such, it has become increasingly popular among the rural farmer communities. The rural agriculture activities and CBF in Sri Lanka are based on the two rainy seasons during April-May and October-December. When the development of CBF is carried out in seasonal reservoirs, one of the major requirements would be to make available fish fingerlings for stocking at the correct time coinciding with reservoir filling following inter-monsoonal rains in October-December (Figure 1).

The time of the onset of the rainfall as well as the duration also alter the traditional crop calendar of farming. Similarly, it can be expected that CBF calendar would also be affected by changes in rainfall patterns. In the recent decades, the rainfall has undergone changes and as a result, water scarcity and excess water have become a recurrent problem in crop production in Sri

Figure 1. Correct timing of culture-based fisheries in seasonal reservoirs of Sri Lanka. Rainy seasons (N, D, J) are shaded. Adopted from Amarasinghe and Weerakoon (2009).



Lanka. Further Jayawardena *et al*. (2005) have shown the decreasing trend of rainfall in 13 rainfall stations over recent 50 years. Changes in rainfall pattern were also observed in Kerala, India as a result of climatic change (Pal and Al-Tabbaa, 2009).

Science and technology

CBF farmers face difficulties in adapting to even a small change in weather pattern as the water stored in a seasonal reservoir is used for many other uses. The water use by CBF is considered as a non-consumptive use usage but it is not given priority in water management but rather agriculture is given priority. Short term gradual climate changes and rapid changes or long term continuous climate changes are difficult scenarios for farmers to adapt. Therefore, farmers need to be assisted by scientific research and technology development to find solutions that will allow them to adapt to the predicted future climate changes.

There is a need for scientific research to understand the underlying biological processes that are affecting productivity changes due to climate change, physical processes that influence reservoir filling and drying patterns and water management variations due to climate change. Research on subjects such as the effect of temperature on breeding and fry rearing, temperature effects on the reproductive performance of brood stock and quality of fingerlings produced, effects on pond primary productivity due to variable climatic conditions, filling patterns and drying patterns of reservoirs, enhancing the culture period employing other culture practices, water resources sharing among competitive uses and socio-economic issues related to changes in culture practices are important. In addition, there is a need for scientific research to better understand climate change and its potential impacts on CBF to provide technical guidelines to decision making groups such as farmer/fisher organisations, NAqDA and related services and the Agrarian Development Department.

Adaptation technologies need to be cost effective, environmentally sustainable, culturally compatible and socially acceptable. The technologies also need to be implemented through widespread technology transfer supported by effective institutions, both formal and informal. Funding will be needed to be identified to pay for necessary research and technology development.

Even if new technologies are devised, and are suitable for local conditions, it may be difficult for the poorer farmers to adopt them. A national strategy for adaptation needs to be devised, assessing and identifying the communities and reservoirs that are at the greatest risk.

Major challenges to culture based fisheries in Sri Lanka

Frequent fluctuation of reservoir volume

Frequent fluctuation of water levels in seasonal reservoirs in the recent past can be observed from most of the selected reservoirs for this study. Figures 2 a and b show the changes of volume of Wawewgma Wewa reservoir in Hambantota district in the period of 1961-1970 and 2001-2010, respectively. Graphs indicate the frequent drying off of the reservoir in recent decades.

Increased drawdown of reservoirs

Figure 3 indicates comparatively high drawdown of water level from 2001 - 2010 compared to the 1960s. Among the all reservoirs the drawdown volume has been increased compared to the volume in the 1960s. Although the drawdown volumes of the reservoirs have been increased, reservoirs in Anuradapura and Kurunegala have less drawdown compared to reservoirs in Hamabamtota District. Several authors have revealed that the reduction of rainfall over the country in recent past (de Silva 2009; Ranatunge *et al*., 2003). Eriyagama *et al*. (2010) indicated that the reduction of annual rainfall over the country from 1961 to 1990 compared to the period of 1931 to 1960 was 144 mm. As such an increased drawdown of the volumes in reservoirs would be expected with the climate change scenario.

Shifting of drawdown

Shifting of the drawdown period can be observed from the reservoirs in the last decade compared to the 1960s. Figure 3 indicates the forward shifting of drawdown in the period of 2005-2010 in Wewegama Wewa reservoir in Hambantota District. This shifting was observed in most of the reservoirs in the sample. The shifting of drawdown is a potential risk on the duration of the culture period of the stocked species in non-perennial reservoirs. Highly shifted drawdown periods can be observed in the Wewegama Wewa reservoir in Hambantota District

Figure 2. Fluctuation of reservoir volume of Wewegama Wewa reservoir in Hambantota district. (a) and (b) indicate the fluctuation of reservoir volume from 1961 to 1970 and 2001 to 2010.

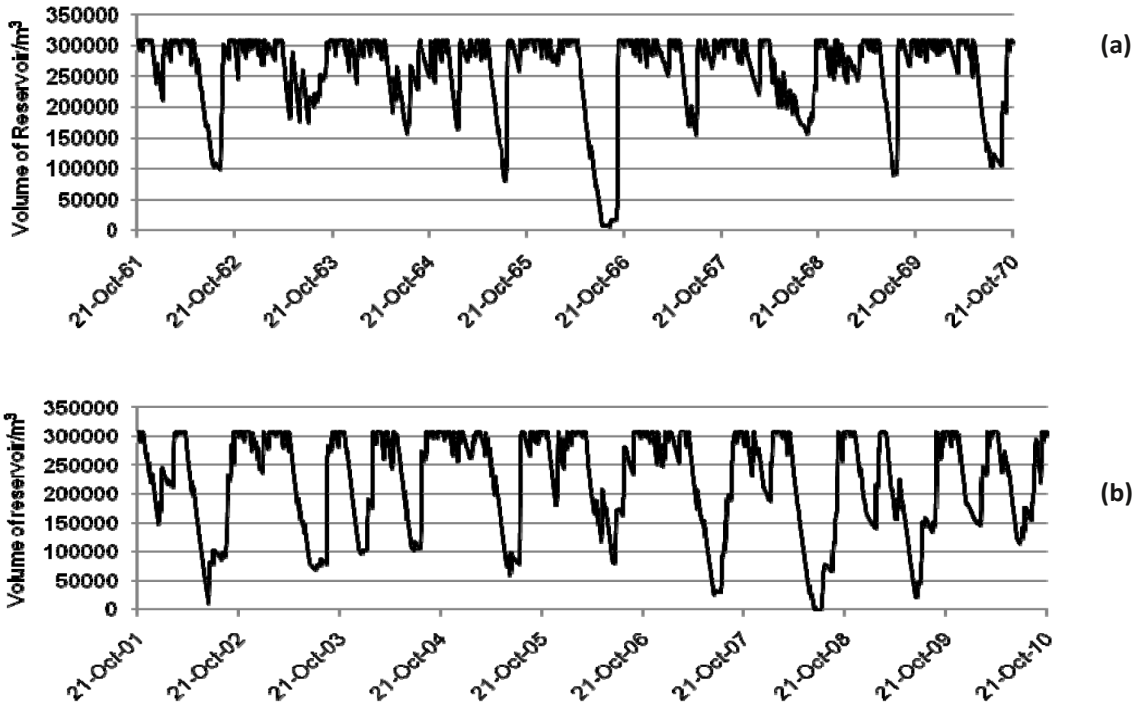
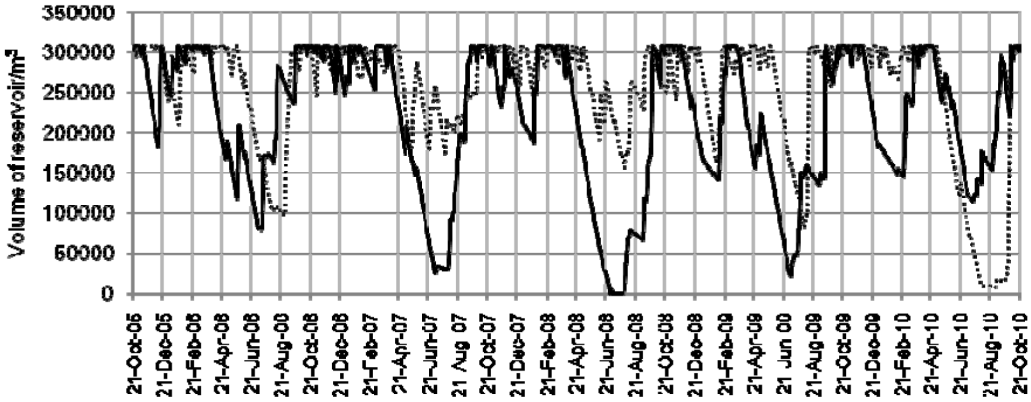


Figure 3. Increased drawdown and Shifting of drawdown period of Wewegama Wewa in 2005-2010 compared to 1965-1970. Dotted line indicates the fluctuation of reservoir volume in 1965-1970.



(Figure 3), with a shift of one month in 2005 to 2010 compared to 1960s pattern.

Impacts of climate change on culture based fisheries

This creates uncertainty of water availability in reservoirs and stocking of fingerlings at the correct time was problematic due to non availability of water in reservoirs when fingerlings are ready for stocking. This issue also alters culture period (shortened culture period and/or inability of harvesting due to reservoir filling). Increased drawdown and the shifting of the drawdown period in seasonal reservoirs would impact on the sustainability of the CBF in seasonal reservoirs. Early draw down leads to shortened culture period causing marketing difficulties and low production. Frequent fluctuations of reservoir volume potentially create the stressful conditions to stocked fish species and may increase the mortality due to disease and increased vulnerability to predators and poaching. The frequent fluctuation can create intolerable water quality extremes causing massive deaths of stocked fish. Therefore, identification of strategies to improve the resilience of vulnerable fish farming communities to climate change impacts is important for the sustainability of CBF in seasonal reservoirs.

Science and technology needs

Analyse long term variations in rainfall, temperature and evaporation

Even though some trends on these parameters are predicted, it is necessary to do a detailed study to evaluate the variability and future trends of these climate parameters on a regional scale in relation to aquatic

resources management and CBF. This analysis will give an insight to the gravity of climate change so that all stakeholders in the sector will understand the issue of climate change on CBF. Such a study will pave the way to narrow the information gap between stakeholders so that it will divert the attention of the key players to the issue of climate change.

Simulation of reservoir water levels

This study should be conducted in all the agro-ecological regions where CBF is practiced as the climate change is expected to influence different agro-ecological regions differently. The trends in reservoir filling, drying, culture period and its shifts could be understood clearly for each and every agro-ecological zone so that localised adaptation measures can be suggested.

Prediction of water levels in CBF reservoirs at least few months before the crop cycle

If the reservoir water level that is expected during the culture period could be predicted before introducing the fingerlings, better decisions could be made about CBF in said reservoir. If the predicted water levels are not satisfactory for CBF, alternative means of releasing the fingerlings that are already reared could be sought out. In addition, measures that can help to increase the culture period could also be identified, i.e. introduction of cage culture. These sort of predictions can also help the decision makers to transfer the fingerlings to other reservoirs, eg. minor perennials, perennials or reservoirs in other parts of the country that are least affected.

Study the feasibility of alternative technologies that can assist to increase the culture period

Identify different technologies that can be employed by CBF fishers to increase the culture period. These technologies can be made available for selected farmers as a pilot project to study the feasibility and opportunities that they provide in enhancing the culture period. One such approach will be to keep the fish fingerlings in cages until spilling of reservoir is over. Fixing a barrier net across the spill to prevent escape of stocked fish is also feasible in some reservoirs.

Stakeholder consultative workshops in Batticaloa.

Identify improved water management strategies that can assist all the water users to save water for CBF

Research is needed to identify different water management strategies that can assist in saving water in the reservoirs thereby increase the culture period. As agricultural water usage is given the priority in reservoirs, more attention on increasing the efficiency of water usage, thereby reducing losses or wastage and enhancing the productivity of water can be sought through research. CBF is still not recognised by the officials of the Agrarian Development Department at the regional level. Coordination between fisheries and agrarian authorities should be strengthened.

Study the impacts of temperature increase and rainfall variations on breeding of carps

Thorough research is needed to identify the impacts of climate variability on breeding of carp varieties and other fish species at the breeding centres in Sri Lanka. Means to minimise these impacts need to be studied and adaptive measures have to be recommended and implemented.

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