Farmer & River basin Management, Policy Perspectives on Adapting to Climate Variability & Climate Change in North Western Sri Lanka

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Introduction to Mahaweli System H

River Mahaweli: Mahaweli is the most important river in Sri Lanka, which winds its way downwards commencing from the central hills and reaching the sea in the North Eastern part of the country, in terms of its annual discharge and the magnitude of its river basin. It carries one seventh of Sri Lanka's total runoff and its basin spreads on country's 15 per cent of the land area. It has been impounded under the Accelerated Mahaweli Development (AMP) at five locations and they form five multipurpose reservoirs ie Kotmale, Polgolla, Victoria, Randenigala and Rantembe. They assist regulating seasonal Mahaweli river inflow to cater irrigation and energy generation demands of the country. Mahaweli diversions are then stored in several reservoirs located within the Mahaweli systems to be extracted as per irrigation demand.

Water management within Mahaweli sub divisions (-'Systems') pose a challenge at the field level as well as at the macro management level due to their physical & organizational complexity. Mahaweli Authority has the overall autonomy over development activities within a respective project area and also responsible for coordinating activities of the line departments and constituent agencies. Water Management Secretariat, a technically specialized unit of the Mahaweli Authority, recommends operating policies and prepares operating plans for the Mahaweli system. These operating plans are based on the irrigation and energy requirements.

The Irrigation Demand Model and the Acres Reservoir Simulation Program are the mathematical models that are used to prepare the operating plans. These models are also used to test various operating policies for the Mahaweli system.

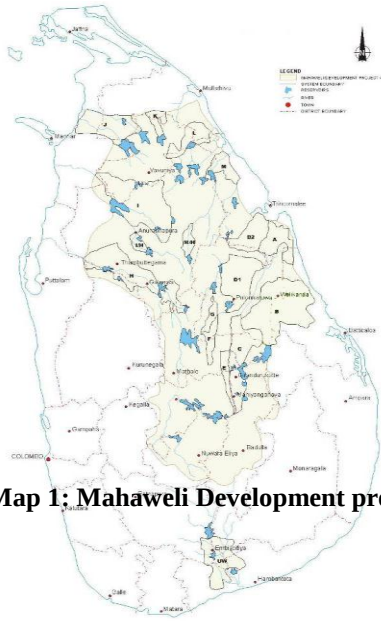
Paddy farming and the Mahaweli Project: Sri Lankan Paddy farming practices are based on deeply rooted traditions and beliefs. Post-colonial period saw a rapid development of large scale agro based human settlement schemes in the intermediate and dry zone of the Island. With the commissioning of multipurpose Mahaweli River development project in late seventies, the Island's total extent of land under irrigation increased to 483,000 ha with the inclusion of 102,898 ha. Mahaweli Project is also the largest ever undertaken human settlement program involving 166,269 farmer families. Previously established irrigation cum, settlement schemes were comparatively small scale and were scattered in the country. Thus they could not make any strong impact on the social, cultural or economic aspects of the macro society. But the magnitude

of Mahaweli project was considerably large and made an impression upon many facets of the society. Establishment of 23 new towns and 305 hamlets itself provide proof for it.

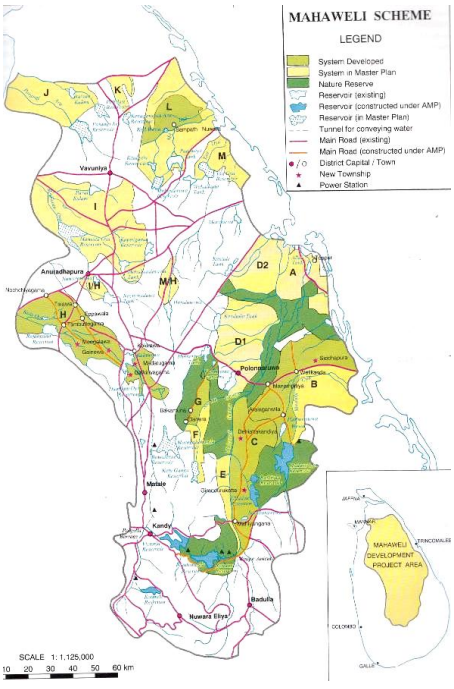
There are three types of settler families who have been allocated land in the system H area under the Accelerated Mahaweli Project (AMP); resettlers, new settlers, and evacuees. Each settler is given an irrigated allotment of one hectare (2 ½ acres) and a highland allotment of 0.2 ha (1/2 an acre) for the homestead.

The Mahaweli Authority of Sri Lanka (MASL): The Mahaweli Authority of Sri Lanka (MASL) is a large river basin management agency which provides services for the farmers in its domain – these farmer account from up to a quarter to a third of the national rice production. Mahaweli charter offers not only irrigation and agricultural facilities to its settlers but a host of other facilities generally not enjoyed by other settlement schemes of Sri Lanka. Mahaweli Authority envisions "Harnessed Rivers, well-managed basins moved from agrarian to prosperous society and promoted economic development" which covers a wider aspect than conventional agro based settlements. Especially Socio Economic aspects of the farming community is being enhanced by direct intervention in Marketing, Social Development including gender issues, second generation problems of under-employment matters, introduction of Income generation oriented non farming activities. Early stages of the Project even had looked into the medical needs as well. Development of road network between the Systems has been a priority in the overall development plan. Accordingly 3,826 km of new roads were added to the national road network. The road network that connects System H, B and C has become an important trunk route in the national road map. Establishment of Dambulla Dedicated Economic Centre has resulted as a secondary development activity due to increase in the vegetable and other field crops in the System 'H' and its environs.

Inclusion of Uda Walawe project which was an existing scheme under the River valley's Development Board (RVDB), Padaviya and Medirigiriya Schemes into Mahaweli's fold are a result of the remarkable development that Mahaweli had achieved. Magnitude of individual 'Mahaweli System' is such that they are in par with the extent of a Government Agents division. A Block Manager division equals a Divisional Secretary's area.



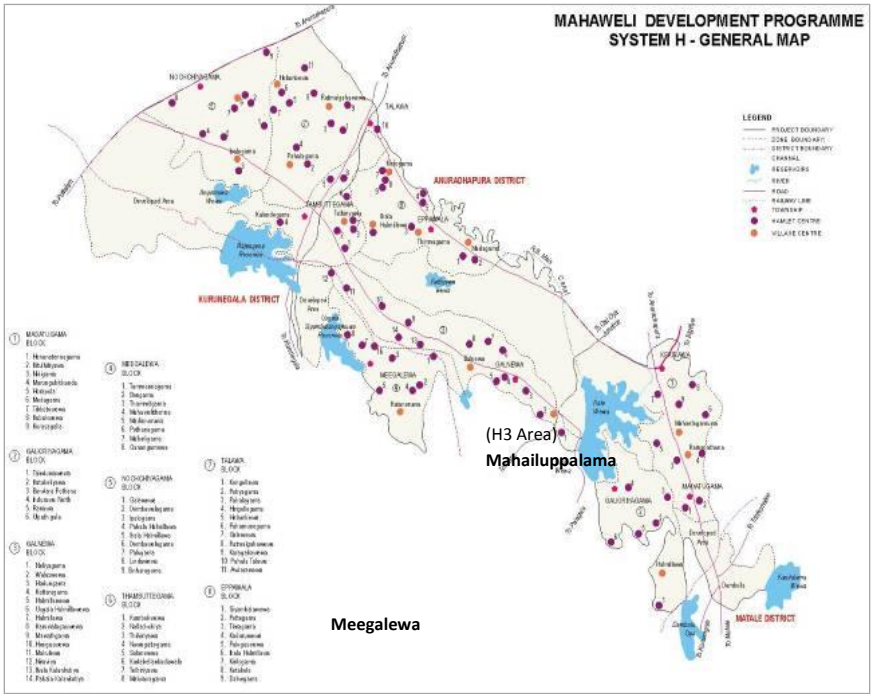
Map 1: Mahaweli Development project area



Source: Ministry of Irrigation and Water Management

Meegalawa

Meegalawa and Mahailupallama are two Block Manager Divisions under System 'H' which has been the pioneering phase of Mahaweli project, in the main seven systems. Meegalewa block comprises of newly developed 1 ha each paddy plots per family with individual outlets in a well laid irrigation network. It is located at the tail end of the Left Bank main canal under Kalawewa Reservoir. It is a block that encounters severe irrigation deficiencies towards the latter part of most of cultivation seasons. But a strong farmer organization is in operation.



Map 2: System H map

Source: Mahaweli Authority of Sri Lanka, Ministry of Irrigation and Water Management

On the contrary Mahailuppalama block has distinct and prominent differences to those of Meegallewa block, where the latter is a well-planned entity. Mahailuppalama block is also denoted as 'H'3 area in the system 'H' overall plan. It comprises of

- Kagama - Kattiyawa peasant colonization scheme-established in 1943,
- Privately owned farm land and command area of small tanks
- Village expansion schemes and

Crown reservations that spreads over 50 square kilometers

Its main geophysical boundaries are Kala Yoda Ela (KYE), Kal Oya and the boundary of Eppawela Block in the newly developed Mahaweli area. The land mass enveloped between the said three main boundaries has different type's irrigation networks and agricultural practices. It has a net command area of 5,000 ha with 6,000 family units.

Maha season water Duty was in the region of 4 meters at the time when Mahweli Authority took over Mahailuppalama block from the Department of Irrigation in 1979. During this period new

settlements were being just begun to establish and no cultivation was being done in new areas. Hence excessive use of water was not a burden on the Kalawewa reservoir. As the new areas were being gradually brought uinder cultivation by new settlers, farmers of Mahailuppallama block felt the irrigation water scarcities. This led to voluntarily formation of farmer organizations to improve water manage practices. With the assistance of all stakeholders, seasonal water Duty in Maha was reduced to between 1.8m and 1.4m by 1985.

Formation of Farmer Organizations: Also formation of farmer organizations took place in the newly developed area as well. As a result, a strong farming community was established with healthy inter relationship amongst farmer leadership, located at different parts of the country. A few seasons of cultivation in a command area within a Distributory or a Field canal strengthened the interaction among them. They realized that if they are to achieve satisfactory targets and materialize their aspirations they have to work in harmony. Such action has brought the farmer organizations to the level that they have reached today where entire system H is represented by about 4-5 farmer leaders with two Resident Project Managers at macro level decision making forums.
This has paved way for them to negotiate various types of common issues in not only irrigation and agricultural sector but in other areas such as land matters, rectification of deficiencies in infrastructure and common amenities etc. Therefore a regular and a healthy dialog continue between the farmers and the officials, at least in irrigation and agricultural matters.

Water Management in System H: KYE is an ancient contour canal starts from the right bank of Kalawewa and flows northwards meant to deliver water to Anuradhapura region from the Kalawewa reservoir. The catchment area of the Kalawewa Reservoir is 57,024 ha and the active storage is 117 miilion cubic meters. The command area is 38,462 ha, divided between the left bank (LB – 1, 146 ha) and right band (RB – 26, 316 ha); (Raby Namika, 1989). This was restored in 1886 and renovated in 1940. This is now terminated at the 16th Mile post near Mahailuppallama hamlet centre by an end regulator structure.
Kala Oya is the main drainage canal that flows thru the entire system 'H'. 'H'3 area is fed by water delivered along KYE. 'H' 3 command area of 5,000 ha is divided among privately owned lands (40%) and the early irrigation cum settlement scheme Kagama-Katiyawa (60%). Privately owned paddy lands lie in the upper reaches of KYE and in the proximity to KYE. Also some of these lands are fed by a twelve minor village tanks. They are fed by KYE in addition to surface runoff it receives from its small catchment. Thus water stress in these areas is minimal against the situation Kagama- Katiyawa schemes. Farmer organizations representing these lands do not function satisfactorily. Ownership claimed by Individual families of these minor tanks very often create tense situation among the stakeholders. Many a instance they fail to resolve farming problems without resorting to litigation.

Farm land belongs to Kagama- Katiyawa schemes are located at the tail end of Distributory canal no. 13 and 15. Necessity to share the meager quantity of water received by them due to much unlawful action of the farmers in the head end of the canals create a situation for stronger ti4s between the farmers. Thus there exist vibrant farmer organizations.

Traditional Practices: A positive approach among the farmers could be observed whenever they confront with difficult situations. Though in the beginning certain sections of the farming

community resorted to violent and destructive action as solutions for their problems with passage of time they commenced acting with restraint. Accordingly seasonal water scarcities are well addressed and make positive attempts to resolve them amicably. Bethma (Voluntarily curtailing cultivable extent as per seasonable water availability) and Thattu Maru (Voluntarily forego cultivation under an entire Distributory canal and let the others utilize available waters in a particular dry season and then apply it vice versa when a similar situation arise in another season). These are strong ancient traditions practiced by farmers successfully to negotiate cultivation during water deficient seasons alleviating confrontations among farmers.
But such practices cannot be implemented in Meegalewa area where water issues are made by a larger and complex irrigation network starting from Kalawewa. Village level farmer organizations cannot undertake the implementation of Bethma or Thattumaru since water issuing is decided at the macro level.
Agricultural Manpower*:* Inclusion of younger generation into conventional farming has posed many setbacks. Thus high seasonal agricultural labour demand has further increased crop prices. Meager margins of agricultural profits are further decayed by ever increasing labour costs. Accordingly providing pipe lines may provide a long term solution for this. Cost of cultivation of cash crops during dry seasons discouraged due to heavy labour costs could be reduced by Drip or Sprinkler assisted agriculture in a pipe line system.

Marketing Strategies*:*Framers request strong government oriented marketing strategy to be implemented for agricultural produce, especially for the imports. Subsidies and protectionism is anticipated against imported agricultural commodities and to have the balance tilted towards the grower. Request is made to the revival of Economic, Industry & Entrepreneurship Division of Mahweli Authority that was terminated in 1998. Farmers prefer a filed level guidance at selection of crop mix, crop insurance, forward trade agreements that safeguard sales etc.

Introduction of modern farm power machinery & implements:Farmers appreciate recent introduction of various machinery for harvesting that saves labour component although overall expenditure increases. Farmers prefer to explore feasibility of sprinkler irrigation for paddy during rotational water issues and introduction of crop diversification and inter cropping to enhance income potential.

Post-harvest activity*:* Post-harvest activities amount to 10% to 20% loss of crop especially in vegetables. Also seasonal price variations of vegetables fluctuate to extreme low levels where the gross income reaches less than 10% of average farm gate price when the markets floods with the same variety. Hence guidance is essential to direct the farmers.

Impact on Health Sector*:*The International Water Management Institute conducted a malaria research project from 1994-2004 in the Huruluwewa water shed. This indicated the spread of malaria depends on the proximity to the main conveyance system ie. Yan oya, that delivers water from Bowatenna to Huruluwewa. However during extreme dry periods saw a complete reduction of it. Intermittent water issues create a water stagnation giving rise for vector propagation. Climate forecast should address this issue.

Energy Requirement*:*Present agricultural practices mainly require energy for post-harvest activities only. Large scale Lift Irrigation schemes in the Island are now almost defunct. But agro

wells drip and sprinkler irrigation will make a heavy demand for energy. In addition to this enhancement of farmer's living standards along with transportation would increase the demand for energy further. Establishment of more agro based industries within Mahaweli systems would create another major consumer of energy. It has been argued using cost–benefit analysis that the AMP is a success. The benefits from hydropower and irrigation had exceeded the cost of the project by 1997 (Liyanagama 2000). Such analyses are useful in showing the benefits for hydropower and agriculture.

***Agro Products Marketing**:*Mahaweli Authority has strong limitations on interfering in marketing of agro produce of its farmers. Within the larger frame of seasonal cultivation meeting decisions, farmers are free to grow any variety of their choice, except for paddy. Market forces are allowed to operate freely. However reactions of the market forces are felt within the River Basin making a secondary thrust upon irrigation water.

Therefore

- implementing seasonal variation in the type crops and
- Allocating specific crops for different systems should be considered as a suitable alternative to the present practice.

Ongoing water management and ongoing adaptation to climate change

Institutions, Constraints, Responses to Climate Change: Posing the question on 'climate changes' (and thereby the water) was received with mixed reactions by many a farmer. They responded differently but reactions were evenly spread across a Likert scale. The underlying main theme of the responses to questionnaire was "come what may, let's face it" attitude. Based on this attitude there extreme responses among the two sect of farmers. Response of farmers under formal irrigation network was more rigid and negative than the 'stand-alone' small tank farmers who had flexible and positive attitude towards the envisaged scenario. It was explicitly visible at Meegalewa. Over 50% viewed it as a problem of MASL and should be handled by them. They belonged to the first generation Mahaweli settlers. A majority among the second generation was ready to accept alternatives as challenges. But they would prefer a firm statement or a well-defined plan of action. Explanation on the difficulty of evolving an elaborate solution or a detailed course of action at this stage was an obstacle for further negotiations with them. However this could be considered as encouraging.

Water Storage - (Return period of floods and droughts): Surface water Storage facilities play a paramount role in a model for finding solutions in confronting challenges of the envisaged climate effect. In the backdrop of a probable rainfall distribution change major thrust would be imposed upon it. However Impact upon sub surface water availability in the form of confined and unconfined aquifers may not affect significantly from the stakeholder point of view. Therefore concern was focused on reservoirs.

All major irrigation schemes in the Island have dedicated reservoirs that act like an irrigation buffer. Having utilized seasonal rainfall mainly for initial land soakage and land preparation work, the storage reservoir manages the rest of the growth period water requirements. Hence infrastructure development arresting seepage and other water losses could provide a solution to a great extent.

Feasibility of increasing storage capacity was an issue raised by a several groups. Assuming the available storage of a reservoir at the FSL (full supply level) is adequate to provide 50% of rotational water issues in a Maha season, then 5% increment in the storage capacity would

relieve water stress of a 5% of the command area. It is observed that seasonal water scarcities occur in the final or the penultimate water issues. Hence a further study in this direction may prove useful.

***Storage Reservoirs**:* In contrast to this there are a few irrigation schemes that operate without a dedicated reservoir. Minipe and Elahera schemes are significant in this regard. Absence of a reliable source of mid-season water supply in these schemes create irrigation crisis and thereby loss of crop very often. Both schemes were established in 1940s and 50s and some solace has been provided after establishment of new Mahaweli development reservoirs in the upstream. But the fact remains that only under catastrophic situations such decisions are taken to release water for these schemes. Hence a future climate change and an uneven seasonal rainfall will make a heavy thrust upon these projects. Therefore dealing with such unique situations should receive prioritized attention of the authorities. Ground water may provide a solution in a crisis like this but the feasibility has to be explored further.

***Ground water Distribution Network**:* Conventional distribution networks pose many difficulties presently. It is seldom one would find concrete lined Distributory or Field canals except at locations with heavy seepage or at drainage crossings. Losses thus incurred by unlined canals could be improved by providing piped filed canals. Irrigation Block No. 404 in Thelhiriyawa Administration Bock of Mahaweli system 'H' has piped distribution network. This system is still being used even after three decades of operation. Seepage and management losses are at a minimal. Pipe line operates under a pressure head. Though no improvement has so far being done for this network it is suggested that during a Yala or a drought season Drip or Sprinkler irrigation network outfit could be coupled to this. Distribution by pipelines may not be possible in all locations but such could be provided at water scarce canal tail-ends.

***Ground Water harvesting**:* Agricultural wells are a widely spread source of water for agriculture in the dry zone of Sri Lanka. Especially vegetable cultivation in system M/H has been greatly assisted by ground water harvesting. In situations where regular seasonal water supplies failed farmers resorted to dig shallow wells to extract water as a supplementary source. But when the Mahaweli supplies continued to fail agro wells became a successful alternative. From 1998 to 2001 number of Mahaweli Authority assisted agro wells increased to 148 in an area of 10 square meters. During drier periods intensity of extraction of water was rapid. Certain wells in Palugaswewa Provincial Secretariat's division in Huruluwewa Resident Project Mangers area had agro wells located in the close proximity of each other that extraction of water from only one was possible among a cluster of a few. This kind of high density in a limited catchment led to suspension of Mahaweli assisted Agro well project. However it does not discourage individuals excavating wells of even larger capacities. This could be considered an adoption to situation as a short term solution but does not appear to be suitable in the long term.

But the future trends in climate may create a tendency to increase ground water extraction. Hence introduction of a legal approval for excavation of agro wells is needed.

***Reduction in Seasonal rainfall**:* Farmers propose introduction of improved long term paddy varieties or olden day varieties such as Kalu Heenati etc. to be recommended for cultivation. Cultivation of 4 to 4 1/2 month varieties was approved in Kanna meetings until early eighties. They are confident that such long term varieties would survive extreme cases as envisaged in various model studies. The situation changes under village tanks and farmers need autonomy to make seasonal decisions. But they are silent on the question of supplementary water supply in a

mid-season crisis. Hence such standalone schemes are to be considered separately. However farmers feel that in a situation where a net seasonal rain fall reduction is to be anticipated then a major shift in the cultivation pattern has to be evolved.

Likely water scenario in the next decades

Challenges to Water Management practices: More often than not seasonal cultivation calendar arrived at the Water Panel held at the beginning of the season with the participation of all stake holder representatives of the country's Major Irrigation system, are changed even before the season begins. This is due to a conflict between the farmers insistence for adaption of traditional cultivation calendar and officials decisions based on weather forecast for a particular season. Water Panel had been in operation for nearly three decades.

Implementation Water Panels: Wherever exclusive storage facilities are available farmers tend to take the risk by themselves and adopt their own deviations from the water panels approved seasonal calendar. Legal action taken to discourage such activity has presently being gradually eased off and a more flexible attitude has been adopted by the officials. During early stages tendency for such action was performed by a few errant farmers, as officials saw it. But when the entire farmer organization resolve to such action it is difficult to strictly adhere to Water Panel decisions. This is very prominent especially in Yala seasons in Madatugama Block fed by Kandalama Reservoir, Galkiriyagama Block fed by Dambuluoya reservoir of system 'H' and under Huruluwewa reservoir in system 'M/H'. Farmers have been successful at more occasions and have strengthened their decisions. In the absence of a well-coordinated and a dependable agricultural insurance scheme farmers are of the view that losses are borne by them anyhow.

Urban Water Demand and Water Supply: But this scenario has to be changed since these reservoirs are being used not only for irrigation but for urban water supply schemes by the National Water Supply & Drainage Board as well. The urban water supply scheme for Greater Dambulla area extracts water from the DambuluOya reservoir and a certain minimum water level has to be maintained to facilitate operating the scheme. Presently it extracts 60,000 cubic meters per day and serves Galewela, Sigiriya, Kandalama and Madatugama towns located around Dambulla. A new railway track from Kurunegala is due by 2020 and development afterwards would increase the demand for urban water and would have a tremendous impact on the irrigation requirements.

Anuradhapura urban water supply scheme obtains water from Nuwarawewa reservoir and it receives Mahaweli diversions thru Nachaduwa reservoir. Similarly Tricomalee urban water supply scheme which receives water from Kanthale tank located at the tail end of Mahaweli diversion network initiating at the Polgolla barrage. In both instances conflicts erupt between the two water user sects in dry seasons. Urbanization in these areas have widened since the end of conflict in the north increasing the demand domestic water supply. Climate changes affecting the rainfall distribution shall not make an appreciable impact as the demand for domestic water supply is a linear in comparison to seasonal irrigation demand. But there is a strong uncertainty and an opposition among the farmers about the increase in the volume of the demand.

Even Habarana reservoir, a cascade in the upper reaches of Yanoya which is conveys Mahaweli diversions to Huruluwewa reservoir is involved in Habarana towns' water supply scheme. Tendency for such projects are in the rise in the Dry zone. Especially in the backdrop of widely spread Renal disease in the dry zone which has been suspected due to contaminated domestic

water consumption, the thrust for purified water schemes will be increasing. Farmer's suspicion for irrigation water deficiency appears to be justifiable.

Potential adaptation – planning and policy

New diversion projects: A new diversion project to water starved north western province is being developed and it will take off from Dambulu oya. Mahaweli Authority assures that savings envisaged in the Moragahakanda Kalugaganga project is utilized for this diversion and in no way it will reduce the present diversions to 'H'. It appears prudent to temporary suspended implementation of new projects until 2040-2070 water balance projection is complete.

Instead construction of new projects the existing projects should be rehabilitated along new guide lines deviating from conventional repair and restoration process that would take network backyards by three to four decades backwards. Accordingly existing schemes should be newly planned with fresh parameters capable of negotiating climate changes successfully. A new dimension in irrigation water issue system has to be evolved.

Future Adaptation: 75% of the farmers at selected locations across system 'H' are confident that they could successfully negotiate negative effects of climate envisage in 2040 and beyond with the assistance of the respective sector authorities. The rest needs monetary compensation and/ or subsidy for the loss of agro income. Majority of them have mortgaged their lands or have resorted to other income avenues. Hence the former groups of farmers' views are worth analysis and the main concern being that their due representation is necessary at decision making level. If a reasonable hearing is given to their views they are willing to adopt strategies proposed by the authorities. Introduction of other field crops from well drained RBE soils (Reddish Brown Earth), mainly chilies, in system 'H' in mid-eighties was an adoption strategy to negotiate water scarcities of the Yala season.

A community that had hitherto cultivated paddy in both seasons has moved to the extent that in System M/H, 100% of the area is cultivated with Soya Beans in Yala season under more advanced forward trade agreements. Accordingly water management institutions such as Mahaweli Authority should focus on institutional changes, enhance service.

Types of Information needed on climate change

Stake holders, with special reference to the farmers, accept that the Climate changes are a reality. Their traditional knowledge and experience make them believe that there could be water shortages in the next few decades. Hence implementation of recommendations based on results of a scientific approach would be easy. Therefore the following information has been requested by farmers irrespective of the location/ system.

Climate on Water

- Increase or decrease in the net seasonal rainfall
- Changes in the rainfall pattern
- Possible shift in cultivation seasons
- Temperature increases (thereby increased evaporation losses)
- Demand increase in urban water supply (stress on irrigation storages)

Climate on Agriculture

- Effect on paddy harvest

- Introduction of new varieties OR other field crops in Yala
- Groundwater extraction (Agro wells)
- Necessity to change fertilizer/agro chemical usage
- Impact on net crop water requirement
- Models sensitiveness to climate in different altitudes (300m to 1500 m)

Climate on Health

- Impact on rural domestic water supply – *stress on water (would?) increase chronic Renal failure among Sri Lankan agro community*
- Re-emergence of Malaria (?)

Climate on Socio-Economy

- Global demand for food Vs. harvest
- If global climate change would be sensitive to Agricultural productivity then the profitability of farming.
- Sri Lanka's adoptability strategies for Climate change and their compatibility with global strategies, such as protectionism.

Conclusion

Interdisciplinary stakeholder participatory programs can provide a forum to disseminate findings and recommendations of on effects climate change. Adaptation has been a continuing process for Mahaweli farmers hence shall not pose a difficult task. Traditional farmers of small village tanks and old settlement schemes are inclined to protest for adaptation. Special attention required aimed at them. Policy decisions should be evolved on a bottom up approach based on a vibrant dialog between all stakeholders to ensure the ultimate success of research work done by AgMIP etc.

References

- AgMIP guide for regional integrated assessments: handbook of methods and procedures, Version 04.
- Atlas on Population and Housing: Census of Population and Housing (2001). Dept. of Census and Statistics & UNICEF Sri Lanka.
- Delpachitra U. (1996). Nilwala Ganga Flood Protection Scheme; *Proceedings of the Symposium on Rehabilitation of the Nilwala Basin*. The Open University Review of Engineering Technology. Vol.2 No.1. pp 5-14.
- Dharmarathna, W. R. S. S., S. Herath, S. B. Weerakoon (2012). Changing the planting date as a climate change adaptation strategy for rice production in Kurunegala district, Sri Lanka. *Sustainability Science*, DOI 10.1007/s11625-012-0192-2.
- Dharmarathna, W.R.S.S. (2013). Adaptation measures to sustain the rice production in Kurunegala district under the impacts of climate change. Dissertation submitted in partial fulfillment of the requirements for the degree of masters of philosophy in the Department of civil engineering of the University of Peradeniya.

- First, Second National Climate Change Adaptation Plan.
- Hoogenboom. G., et al (2010). Decision Support System for Agrotechnology Transfer (DSSAT) Version 4.5. University of Hawaii, Honolulu, Hawaii.
- Liyanagama, B.S. (2000), 'Mahaweli Hydropower is Sri Lanka's Key to Development', Journal *of the Institute of Engineers, Sri Lanka*, 32(2), pp. 61–69.
- Mahaweli Water Resource Management Project, Studies of Operating Policy Options, Main Report. Water Management Secretariat, Colombo, Sri Lanka. Acres International Limited, Niagara Falls, Canada.
- Mahaweli Authority of Sri Lanka, Statistical Abstract, 2011.
- Mapa R. B., A.R. Dassanayake, H.B. Nayakekorale (2005). Soils of the Intermediate Zone of Sri Lanka, Morphology, Characterization and Classification. Special publication No 4, Soil Science Society of Sri Lanka.
- Mapa R. B, S. Somasiri, A.R. Dassanayake (2010). Soils of the Dry Zone of Sri Lanka, Morphology, characterization and classification. Special publication No 7, Soil Science Society of Sri Lanka. 2012.
- Navaratne C.M, Weerasinghe K.D.N., Jayasuriya. N. (2004). Rainwater Harvesting and Roof Runoff Coefficients. *Proceedings of the International Conference on Sustainable Water Resources Management in the Changing Environment of the Monsoon Region at Colombo, Sri Lanka*. Vol.II. pp 628-634.
- Panabokke C.R. (1996). The Geomorphologic Setting and Salinity Intrusion in the Lower Nilwala Basin; *Proceedings of the Symposium on Rehabilitation of the Nilwala Basin*. The Open University Review of Engineering Technology. Vol.2 No.1. pp 17-21.

- Rosenzweig, C., J.W. Jones, J.L. Hatfield, C.Z. Mutter, S.G.K. Adiku, A. Ahmad, Y. Beletse, B. Gangwar, D. Guntuku, J. Kihara, P. Masikati, P. Paramasivan, K.P.C. Rao, and L. Zubair, (2012). The Agricultural Model Intercomparison and Improvement Project (AgMIP): Integrated regional assessment projects. In *Handbook of Climate Change and Agroecosystems: Global and Regional Aspects and Implications*. D. Hillel, and C. Rosenzweig, Eds., ICP Series on Climate Change Impacts, Adaptation, and Mitigation Vol. 2. Imperial College Press, 263-280.
- Ruane, A.C., et al. (2013). Climate Change impact uncertainties for maize in Panama: Farm information, Climate Projections and yield sensitivities. *Agricultural and Forest Meteorology*. Volume 170: 132-145
- Raby, Namika; Merrey, Douglas, J. 1989. Professional management in irrigation systems: A case study of performance control in Mahaweli System H, Sri Lanka. International Irrigation Management Institute, Colombo, Sri Lanka.
- Sangakkara, U.R. and Nissanka, S.P. (2008). Food security in Sri Lanka – agronomic implications and potentials. *Journal of National Science Foundation Sri Lanka,* 36 (Special Issue2): 17-24.
- Seo, S.N.N., Mendelsohn, R. and Munasinghe, M. (2005). Climate change and agriculture in Sri Lanka: a Ricardian valuation. *Environment and Development Economics*, 10: 581–596
- Studies of Operating Policy Options – Main Report. Mahaweli Water Resources Management Project. (1985). Water Management Secretariat, Colombo, Sri Lanka; Acres International Ltd, Niagara Falls, Canada.

- T.Somasekaram, M.P.Perera,M.B.G. de Silva, H.Godellawatta, Arjuna's Atlas of Sri Lanka. Dehiwala,Sri Lanka, Arjuna Consulting Co Ltd.
- Weerasinghe K.D.N, Sabatier J.L., Attanayake W.S. (2000). *Water Balance and the Irrigation Need of Rice in Different, Agro-ecological Regions of Sri Lanka*, Proceedings of the International Conference on Challenges Facing Irrigation and Drainage in the New Millennium. Fort Collins, Colorado 2000.
- Weerasinghe K.D.N. (1996). *Soil and Water Management for the Improved Rice Production in the Acid Soils of the Nilwala Scheme, Southern Sri Lanka*. Proceedings of the International Symposium on Maximizing Sustainable Rice Yield through Improved Soil and Environmental Management Vol. 1 113-121.
- Weerasinghe K.D.N. (2009). Tank Base Irrigation and Paddy Ecosystems Development in Sri Lanka, *An Overview from Antiquity to the Present Proceedings of the Workshop*." From Environmental to Sustainable Science". Thinking the Shift and the Role of Asian Agricultural Science. Ibraki, Japan pp 152- 157.
- Weerasinghe K.D.N., Panabokke, C.R. Elkaduwa. W.K.B. (2000). *Agro-climatic Risk and Irrigation Need of the Nilwala Basin, Southern Sri Lanka*, Proceedings of the International Conference on Challenges Facing Irrigation and Drainage in the New Millennium. Fort Collins, Colorado.
- Weerasinghe, K.D.N. (1990). Agroclimatological risk and the irrigation need in dry regions of Sri Lanka) IRAT/ CIRAD, Montpellier, France.
- Wickremasinghe, S.T. (2006). Development of the national agricultural research system (NARS) in Sri Lanka with special reference to food crops sub sector: Issues related to science policy. *Journal of national Science Foundation Sri Lanka,* Vol. 34, No. 2, pp. 69-83.
- Zubair, L. (2002). El-Nino-Southern Oscillation influences on Rice Production in Sri Lanka, *International Journal of Climatology*, 22 (2):249-260.
- Zubair, L. (2005). Modernisation of Sri Lanka's Traditional Irrigation Systems and Sustainability. Science, Technology and Society. 10:2.