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Present Status of Research and Development onClimate Change Mitigation and Future Needs in the Sugarcane Sector in Sri Lanka

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Abstract: Changing rainfall pattern and shiftingmonsoonal weather are critical climatic factors affecting sugarcane production in Sri Lanka.The scarcity of water to fulfill theirrigation requirement coupled with prolonged drought have severely affected the sugarcane production.A shift of fauna, flora, and microbial population with changing climatic conditions,leading to a change in the biodiversity in sugarcane ecosystem would increase insect pest, disease and weed incidences in sugarcane plantation. Weakened plants due to drought, stress are more vulnerable to pest and disease attacks in addition to the retarded growth and yield. Even though the changing of planting and harvesting schedules of sugarcane minimizes the impact of drought, complete adaptation of the crop for such adverse climatic and soil changes is limited in the present context. Hence, development and selection of appropriate sugarcane varieties for different sugarcane-growing environmentsand soil conditions, and improvement of the management practices would help mitigating the impact of changing rainfall pattern, drought and soil degradation on sugarcane production in Sri Lanka. Mulching reduces soil erosion andover-heating by preventing incidence of direct sunlight on the ground, and conserves soil and moisture in addition to supplying of plant nutrients to soil.Conducting regular surveys to find out existing pest and disease situations and emergence of new pests and pathogens in sugarcane plantations would help identifyingthe potential threats and adopt control measures accordingly.In addition, intensive extension and training program has to be carried out to convince the farmers about the risk of future climate change, drought and water scarcity and its impact on their farming.

Keywords: adaptability, climate, drought,productivity, sugarcane

INTRODUCTION

Sugarcane (*Saccharum*hybrid spp.)has been cultivated in Ampara and Trincomalee districts in the Eastern Province andin Moneragala andBadulladistricts in the Uva Province of Sri Lanka. Itis proposed to be expanded in Batticaloadistrict in the Eastern province and inKilinochchi districtin the Northern Province where theagro-climatic and soil conditions are different to those in the traditional sugarcane-growing areas(Anonymous, 2010).The adaptability and the productivity of currently-cultivated sugarcane varieties under different climatic conditions aremainly dependent on the availability of soil moisture, particularly in rain-fed cultivation which gives about 60% lower cane yield of irrigated sugarcane in Sri Lanka (De Silvaand De Costa, 2004; Ariyawansha, 2014).Soil moisture deficit and the scarcity of water for irrigationwhich occur due to prolonged drought for aboutfour months from June to September in dry zone adversely affect the sugarcane production in Sri Lanka (De Silva, 2007). It cannot be totally overcome by changing the date of planting because the duration of the crop is about 12 months. Thestudies in Sri Lanka have also revealed thatin agronomic and physiological performances of sugarcane reduced with the reduction of rainfall in the dry zone of Sri Lanka (De Silva and De Costa, 2004; 2009; 2012; De Silva*et al*., 2011).However, short-term water stress could be reduced by agronomic practices such as correct land preparation, changing time of planting and harvesting and mulching. Use of drought tolerant varieties is the best way to overcome the yield losses due to drought(Yadava, 1993).Hence, studying the current changes in climate and soil conditions in all sugarcane-growing locations and the evaluation of different sugarcane varieties under varying climatic and soil conditions in different agro-ecological regions of Sri Lanka is very important to develop and introduce better varieties for different sugarcane-growing conditions to improve the productivity of sugarcane in Sri Lanka.

The scientific analysis and projections on climate change have indicated the rising of atmospheric temperature and occurrence of unpredictable monsoon rains, extreme weather events such as floods and more frequent severe droughts (MMDE, 2015). The erratic rainfall pattern and the shifts in monsoonal weather due to climate change,which would intensify the water scarcity and prolonged drought are considered as more critical climatic factors for future sugarcane production in Sri Lanka.Increasingatmospheric carbon dioxide(CO_2) concentration and resulting increase of air temperature and global warming (McCarthy *et al*., 2001)have a positive impact on sugarcane production as sugarcane prefers a high air temperature range of 30 °C for germination and 35°C for vegetative growth (Gascho and Shih, 1983).Further, sugarcane growing t doubled air CO_2 concentrationtogether with high temperature increases crop growth and stem juice production,utilizes water more efficiently and would perform better in sucrose production than plant grown under ambient CO_2 and near-ambient temperature combination (De Souza *et al*., 2008; Vu and Allen, 2009a; Vu and Allen, 2009b). Thus, there is an enhancement of growth, yield and sugar content of sugarcane when growing atdoubledCO_2concentration and high temperature combinations, which will be expected in the future. Rising global CO_2might not have the same effects on different cultivars and plants grownunderdifferent environments and management conditions (Allen and Vu, 2009; Chaves and Pereira, 1992;De Souza *et al*.2008; Vu *et al*. 2006). The predicted rising atmospheric CO_2 and temperature, and erratic changes in rainfall patterns in the future would affect interactively the sugarcane production in Sri Lanka. Therefore, development and introduction of better varieties and altering management practices to maximize the benefits and/or minimizing adverse effects of climate change would be useful to improve the productivity of sugarcane under futureclimatic conditions in Sri Lanka.

PRESENT STATUS OF RESEARCH AND DEVELOPMENT ACTIVITIES RELATED TO CLIMATE CHANGE

Research on the climatic variability and climatic trends

The following analyseshave been carried outbythe Sugarcane Research Institute (SRI)to address the issues in changing climatic and soil conditions in Sri Lanka:

i. Agro-meteorological conditions of major sugarcane-growing areas in Sri Lankaevery year (SRI, various issues).
ii. Characterisation of rainfall in relation to sugarcane cultivation in Sevenagala(Ariyawansha and Keerthipala, 2010a).
iii. Temporal trends of climatic variables in Sevenagala and Pelwatte sugar mill areas of Sri Lanka (Ariyawansha and Keerthipala, 2010b).
iv. Characterisationof rainfall in relation to sugarcane cultivation at Pelwatte (Ariyawansha and Keerthipala, 2012).

A project on the identification of farmers' perception and adaption to climatic change and variability in Sevanagala area has been proposed to be undertaken in 2018.The automated weather stationsinstalled in Kantale and Kilinochchi in 2015and the manually-operated weather stations established inUdaWalawe, Sevanagala, Pelwatte andHingurana are maintained to collect daily agro-climatic variables for analyzing agro-meteorological conditions in major sugarcane-growing areas in Sri Lanka.Daily climatic data collected at the SRI, UdaWalaweis provided to the Department of Meteorology to meet the national requirements.

Changes of rainfall and daily ambient temperature during past 30 years in sugarcane-growing areas of Sevanagala and Pelwatte are described in below:

Rainfall: The mean monthly rainfall values in Sevanagala and Pelwatte for thirty years were classified into two groups,*i.e.*, 1984-1999 (16 years) and 2000-2016 (17 years), and these two groups were compared with paired T test at 5% probability (Table 1). The results showed that, total annual rainfall and total *Yala* and *Maha*seasonal rainfalls in both sites have not significantly changed in the longterm.

Table 1. Average total rainfall for year, *Yala* season and *Maha* season in two periods from 1984-1999 and 2000-2016 in Sevanagala and Pelwatte

Comparison parameter	**Mean (from 1984-1999)**	**Mean (from 2000-2016)**	**t-value**	**p-value**	**Significance**
Mean annual rainfall at Sevanagala	1389.7±22	1537.9±28	-1.445	0.158	not significant
Yala season rainfall in Sevanagala	523.8±26	550.7±38	-0.572	0.571	not significant
Maha season rainfall in Sevanagala	856.9±51	987.2±48	-1.721	0.095	not significant
Mean annual rainfall at Pelwatte	1503.4±65	1691.1±65	-2.019	0.052	not significant
Yala season rainfall in Pelwatte	479.2±34	539.99±42	-1.115	0.273	not significant
Maha season rainfall in Pelwatte	1024.1±48	1151.1±65	-1.581	0.123	not significant

Source:L.M.J.R. Wijayawardhana (unpublished data)

Wijayawardhana*etal.*(2015) determined the annual one-day and 2-5 consecutive-day maximum rainfall levels and the probabilities of their occurrencecorresponding to various return periods for the sugarcane-growing areas at UdaWalawe using daily rainfall data recoded from 1992-2014. The maximum rainfall expected to occur for one day and 2-5 consecutive days in UdaWalawe in every two-year intervals and probable maximum rainfall values for 5 consecutive days for different return periods (Table 2) could be used effectively in designing a drainage system in sugarcane plantations. Normally, rainfall beyond 50 mm/day is considered as a heavy precipitation (Liesl, 2009). Accordingly, except for one-day maximum rainfall values estimated for 2- and 5-year recurrence intervals, all rainfall events could be classified as “very heavy rainfall” events. All combinations (Table 2) have exceeded the level of “heavy rainfall” events.

Table 2. Variations of probable maximum rainfall for 2-, 3-, 10-, 20-, 30-, 50- and 100-year return periods for one and 2-5 consecutive days

Days	**Return period (recurrence interval) in years**						
	2	**5**	**10**	**20**	**30**	**50**	**100**
1- day max	95.8	117.7	132.2	146.1	154.4	164.2	177.7
2-day max	122.5	146.4	157.9	166.9	171.5	176.5	182.7
3-day max	142.9	167.7	180.7	191.5	197.2	203.5	211.6
4-day max	151.7	172.7	182.5	190.0	193.9	198.0	203.0
5-day max	163.2	187.3	203.2	218.8	227.5	238.2	253.0

Source: L.M.J.R. Wijayawardhana (unpublished data)

Table 3 shows the monthly probabilities of annual maximum rainfall received at Uda Walawe. The second inter-monsoon from September to October period had the highest probability of 54.5% to have the one-day maximum rainfall. However, the highest probability of occurrence of 2-5 consecutive-day maximum rainfall is 54.8%, in the 1st inter-monsoon period from March to April.

Table 3. Monthly probabilities (%) of annual maximum rainfall occurs at UdaWalawe

Month	**Annual 1 day**	**2-consecutive days**	**3-consecutive days**	**4-consecutive days**	**5-consecutive days**
March	0.0	13.6	9.1	9.1	9.1
April	0.0	4.5	4.5	13.6	13.6
May	0.0	13.6	13.6	9.1	18.2
June	0.0	0.0	9.1	13.6	0.0
July	0.0	4.5	4.5	4.5	0.0
August	18.2	13.6	0.0	4.5	9.1
September	36.4	9.1	4.5	4.5	0.0
October	18.2	4.5	13.6	13.6	13.6
November	4.5	9.1	4.5	4.5	0.0
December	4.5	13.6	9.1	9.1	13.6
January	0.0	9.1	18.2	9.1	22.7
February	18.2	4.5	9.1	4.5	0.0

Source:L.M.J.R. Wijayawardhana (unpublished data)

Temperature:The monthly average minimum and maximum temperature values in Sevanagala and Pelwattewere classified into two groups,*i.e.*, 1984-1999 and 2000-2016 (Figure 1).

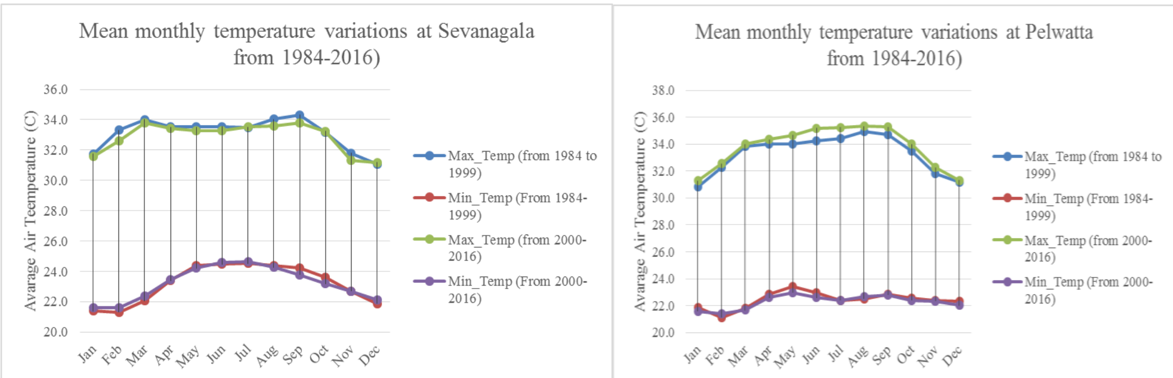

Figure 1. Mean monthly temperature variations in Sevanagala and Pelwatte (Source:L.M.J.R. Wijayawardhana, unpublished data)

The maximum and minimum temperature values between the twotime periods(from 1984 to1999 and from 2000 to 2016) in both Sevanagala and Pelwatte sugarcane-growing areas were not significantly different during past three decades (Table 4).

Table 4. Mean annual temperature variations inSevanagala and Pelwatte for two periods from 1984-1999 and 2000-2016

Temperature (°T)	Mean (from 1984-1999)	Mean (from 2000-2016)	t-value	p-value	Significance
Sevanagala Max. °T	33.1±0.29	32.8±0.28	0.599	0.555	not significant
Sevanagala Min.°T	23.2±0.36	23.2±0.32	-0.034	0.973	not significant
PelwatteMax.°T	33.3±0.40	33.8±0.44	-0.803	0.430	not significant
PelwatteMin. °T	22.4±0.17	22.3±0.14	0.543	0.296	not significant

Source:L.M.J.R. Wijayawardhana (unpublished data)

Research on the adaptabilityof sugarcane to diverse climatic conditions

Development and selection of varieties suitable for different sugarcane-growing regimes and a range of different soil and environmental conditions in different agro-climatic regions would help to mitigate the impact of changing rainfall pattern, drought and soil degradation. Research projects conducted since 2003 on the assessment of adaptability and stability of some sugarcane varieties in different environments in Sri Lanka could identify that varieties SL 7130, SL 88 116, SL 89 1429, SL 89 2227 and SL 97 1442are well-adapted to dry and intermediate zones of Sri Lanka (Ariyawansha, 2012, 2014; Ariyawansha and Perera, 2014; Ariyawansha*et al*., 2009).The results suggested that development of a cropping calendar to cultivate sugarcane in the different agro-ecological regions is important to obtain the maximum productivity of varieties by deciding the period for planting and harvesting. The SL 90 6237 has been identified as a well-adapted rain-fed sugarcane variety having higher plant and ratoon yields (De Silva, 2008). Currently,eight commercial sugarcane varieties,*i.e.*, Co 775, SL 71 30, SL 83 06, SL 88 116, SL 90 6237, SL 92 4918, SL 69 128 and SL 96 328 are being evaluated in seven locations,*i.e.*,UdaWalawe, Sevanagala, Pelwatte, Hingurana, Kantale, Kilinochchi and Bandarawela, representing six different agro-ecological regions to investigate the agronomic and physiological performance of different sugarcane varieties under current conditions in different agro-ecological regions to identify the cultivars with higher performance under current conditions of rainfall, temperature and soil in different agro-ecological regions in Sri Lanka.The same varieties are also being evaluated in 12 open-top chambers at the Sugarcane Research Institute, UdaWalawe, to investigate the agronomic and physiological performance of different sugarcane varieties under elevated atmospheric CO_2concentrations and air temperatures expected in the future and to identify the cultivars with high efficiency in water use and production of biomass and stem sucrose under elevated atmospheric CO_2 and air temperature and to give recommendations to develop varieties having better performance under future sugarcane-growing conditions in Sri Lanka.

Changing cultural and management practices of crop would help to mitigate adverse effects of changing climatic conditions on sugarcane cultivation. Mulching conserves soil and moisture byreducing soil erosion and increasing infiltration and supplyingplant nutrients to the soil. Low soil temperature under soil mulch decreases the rate of decomposition and enhances accumulation of organic matter in the soil. It helps to mitigate adverse impacts of drought and heavy rainfall occurring with changing climatic conditions on soil. Further, under rain-fed conditions, mulching plant and ratoon crops with a mixture of*Gliricidia* leaves and sugarcane trash significantly increased cane and sugar yields in plant and ratoon crops (De Silva *et al.,* 2012).The on-going studies include the varietal response of sugarcane to varying climatic and soil conditions under well-watered and water-stressed conditions in Sri Lanka and the response of physiological processes and parameters related to growth of sugarcane under elevated carbon dioxide and temperature.

Research on water management related to climate change

The scarcity of water and prolonged drought adversely affect the sugarcane cultivation (Shanmuganathan, 1990). As sugarcane is a crop that is planted and harvested seasonally, changes in the monsoonal weather pattern are considered as more critical climatic factors for its growth.Changing the planting and harvesting schedules of sugarcane and establishment of small ponds within the farmers' fieldsto collect run-off water for supplementary irrigation and maintaining the ground water at higher level are recognized as possible adaptationsto minimize the impact of drought (Wijayawardana*etal*., 2011; 2014). However, farmers may not allocate a part of their small land for establishing small ponds (Wijayawardhana*etal*., 2011). Therefore, this should be addressed at policy levels, which include implementation of compensation schemes. Skipping severe dry periods atthe highest water-demanding grand growth stage of sugarcane with changing the time of planting (Figure 2) and practicing alternate-row furrow irrigation instead of conventional every-furrow irrigation could have a significant potential to reduce the irrigation water demand in sugarcane plantations (Wijayawardana*etal*., 2014; 2016).

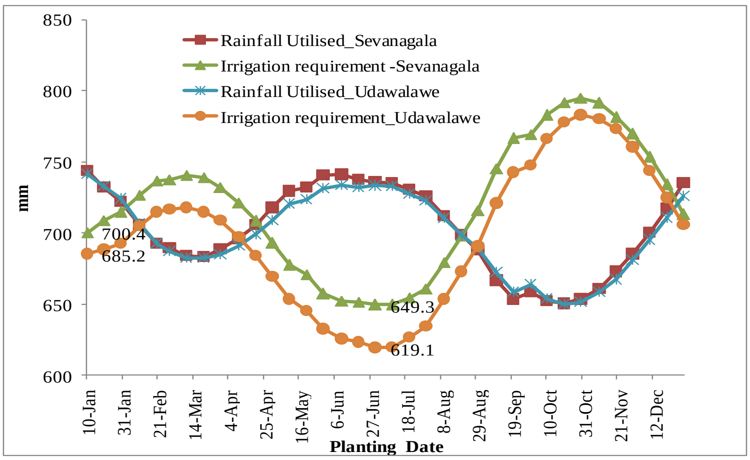

Figure 2. Changing pattern of rainfall utilization and irrigation requirement with changing the time of planting of sugarcane in UdaWalawe and Sevanagala (Source:L.M.J.R. Wijayawardhana, unpublished data)

Research conducted at UdaWalawe confirmedthat the alternate-row furrow irrigation technology saves irrigation water by 37-39% without reducing the attainable yield (Wijayawardana*etal*., 2016). Thus, it could be a worth option to save limited irrigation water in major irrigation schemes as well. However, some of these adaptations should be addressed at policy levels in order to save irrigation water.

Research on the pest and disease managementrelated to climate change

A shift of fauna andflorapopulationwith changing climatic conditions causeschanging bio-diversity in sugarcane ecosystem and increasing pest and disease incidences in sugarcane plantations. Therefore, regular surveysto find out the existing pest and disease situations and emergence of new pests and pathogens in sugarcane plantations help to identify potential threats and adopt control measures accordingly. Smut and white leaf diseases are the most devastating and fast-spreading sugarcane diseases in all sugarcane-growing regions in Sri Lanka. Different strains of smut disease and the relationship between the incidences of sugarcane white leaf disease and the population dynamics of its vector in different regions of Sri Lanka have been identified (Thushari and Ariyawansha, 2014; Chanchala*et al*., 2014). The weed spectrum in sugarcane fields dominated with annual grasses and broad leaved weeds about several decades before has now been changed to the spectrum with more perennial species (Witharama *etal*., 1997; Anonymous, 2014). Regular screening of herbicides and introduction of integrated strategies to control abundant and problematic weeds in sugarcane plantations helps to keep them under control.

FUTURE RESEARCH AND DEVELOPMENT NEEDS

The future researches for mitigating the impacts of climate change on sugarcane should be focusedon (a) development and identification of high-yielding sugarcane varieties with tolerant toabiotic and biotic (drought, salinity, alkalinity, pest and disease)stresses, well-adapted to adverse and diverse climatic conditions, (b) devising new methods and identifyingmaterials for soil moisture conservation under different field conditions and (c) improving the cultural practices for controlling soil erosion, soil and moisture conservationfor optimizing agronomic and crop management practices.Future studies on those aspects should be focused on to develop crop management strategies to conserve soil and moisture, protect crops from extreme climatic conditions such as excessive heating, drought and flood. Planting with zero/minimum tillage, changing cropping pattern and cropping system, development of integrated sugarcane-based farming systems would be effective to mitigate the impact of climate change on sugarcane. Schedules of land preparation, planting, irrigating and harvesting should be changed to maximize the utilization of available rainfall and to minimize the soil erosion and irrigation water requirement. New methods should be developed for runoff water harvesting. Regular monitoring of the dynamics of pests and their natural enemies, diseases and their causal agents and strains and weeds population in different agro-climatic regions of sugarcanegrowing should be continued. Weed management studies should continue while emphasizing on preventing the development of herbicide-resistance weeds and those problematic to the growing crop. In addition, intensive extension and training programs to convince all officers and farmers in the sugarcanesector about future risk of climate change, drought and water scarcity, their impacts on their farming and the importance of saving of irrigation water at national scaleis essential to make a comprehensive model forthe whole sugarcanesector for decide on policy directions to minimize the climatic risks.

CONCLUSION

The erratic rainfall pattern and the shifts in monsoonal weatherwhich create severe drought with climate changewould significantly affectfuture sugarcane production in Sri Lanka.The main long-term sustainable adaptation optionfor cultivatingsugarcane under a changing climate is selection of varieties with higher yields and tolerance to abiotic and biotic stresses due to climate change effects. Main short-term adaptation options are improving efficient cultural practices and cropping systems and adhering to soil and moisture conservation practices which have been already recommended by the sugarcane Research Institute. Regular monitoring of pests, diseases and weeds in sugarcane plantations helps to face the impact of altering diversity of furan and flora under changing climatic conditions. Thus, a comprehensive research program including variety improvement, development of new technologies and/or improvement of existing crop management practices and continuation of studies on dynamics pest, disease and weed populations in sugarcane plantations are required.

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Effects of Climate Change on Livestock:Sri Lankan Perspectives

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Abstract: Livestock production has increased in Sri Lanka in recent years.The same trend would continue in the future. While providing vital protein for human population, livestock farming contributes to the greenhouse gas (GHG) emissions. Methane is the main GHG emitted by livestock.Emission factors for enteric fermentation in Sri Lankan cattle and buffaloes estimated using IPCC(Tier 2) method has revealed that methane emission from cattle, buffalo and sheep were 50, 49 and 3 kg head^{-1}year^{-1}, respectively, whichwere lower than the respective IPCC default values.According to the production systems, GHG emission is the highest in dry low lands (Dry Zone) and the lowest in wet low lands (Wet Zone). Several studies have been conducted to improve the productivity of livestock through better feeding and nutrition, which will ultimately serve as a mitigation measure to reduce GHG emissions. Adaptive measures on livestock housing; especially to tackle high temperatures, have been introduced and are successful in operation in the country. Sri Lanka should establish GHG measuring facilities for livestock.Further, the country should prioritize and facilitate research and development work on climate change and its effects on livestock production.

Keywords: Adaptation, methane, mitigation, livestock

INTRODUCTION

Crop and livestock are the major sub-economic sectors in agriculture in Sri Lanka, particularly for the rural population. In Sri Lanka, livestock sector contribute to about 0.6% of the gross domestic product (Anonymous, 2015),however, this may increase in the future as milk production has increased by 4% in the year 2014 and has shown an increasing trend over the recent years. This is mainly due to the increase in productivity of an animal and the number of animals. For example, cattle population has increased by 10% while buffalo population by 2% in 2015, compared to 2014(Anonymous, 2015).

The three main greenhouse gases (GHGs) are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Steinfeld*et al*., 2006). The animal agriculture sector accounts for approximately 9% of the total CO_2 emissions, of which animal product processing and transport accounts mainly for livestock-related CO_2emission, while the rest is from the crop agriculture sector (Koneswaran and Nierenberg, 2008). The livestock sector is responsible for about 35-40% of the annual global anthropogenic methane emissions, which are the results of enteric fermentation and farm animal manure (Steinfeld*et al*., 2006). Ruminants could produce 250 to 500 liters of methane per day depending on various animal and feed-related factors.This would lead to about 12% loss of the dietary energy in the ration as methane(Johnson and Johnson, 1995). In addition to the contribution by livestock to the global warming, the sector has in turn been seriously affected by the same. Rising temperatures could reduce roughage yields or destroy the harvest due to prolonged drought or heavy rains, which could lead to a feed scarcity and thereby lower productivity of the animals. Amount of milk produced by cattle and buffalo depends mainly on the type of breeds. Temperate breeds and their crosses could perform well in cooler climates and produce relatively higher amountsof milk compared to more heat-toleranttropical breeds. When temperature rises, vast animal-growing areas would become unsuitable for high producing animals, resulting in lower milk production.

In Sri Lanka, cattle and buffaloes are the main livestock groups by numbers while sheep, goat and swine remains as minors (Lokupitiya, 2016). Although the contribution by livestock to the national GDP is low, it is one of the major livelihood and income generator for a significant population in the country. Dairy cattle has multiple functions such as producing milk for household consumption, income and sales, male animals as mode of transport, cash income generated through meat, and their dung as a valuable fertilizer.

The importance and contribution of livestock to the livelihood of the people in Sri Lanka is significant both economically and socially, however, the impact of global warming on the sector in Sri Lankan conditions has been less documented. The objectives of this review is therefore, to compile statistics of GHG emissions by livestock, current research and development activities related to climate change, identification of gaps, and suggest future research and development needs.

Greenhouse gas emissions by livestock

Methane is the main GHG emitted by livestock (Knapp *et al*., 2014).The amount of methane emitted by livestock depends on the body size, metabolism, activity level of the animals, and their feed quality(Steinfeld*et al*., 2006). The author's perception is that the quantity of methane emitted by livestock under Sri Lankan condition has not been estimated scientifically,though few estimates have been already been published.

Lokupitiya (2016) estimated the enteric methane emission of Sri Lankan cattle and buffaloes using the tier 2 method proposed by the Intergovernmental Panel on Climate Change (IPCC) and concluded that the methane emission factor for dairy cows, buffaloes and sheep were lower than the respective IPCC default values (Table 1).As this is an estimate, Lokupitiya (2016) highlighted the need to validate the estimates through adequate measurements.

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Table 1. Methane emission factors estimated for enteric fermentation in Sri Lankan cattle and buffaloes estimated using IPCC (Tier 2) method.

Livestock category		Methane emission by Kg head^{-1}year^{-1}	
Dairy cattle		50	IPCC default - 58
	Local	52	
	Improved	42	
Buffaloes		49	IPCC default - 55
	Dairy	65	
	Other buffaloes	44	
Sheep		3	IPCC default - 5

Adopted from Lokupitiya(2016)

Recently, FAO and the New Zealand government funded a project on "Reducing enteric methane emissions for food security and livelihoods" and estimated the methane and nitrous oxide emissions by cattle in Sri Lanka considering the feeding type, feeds available, agro-ecological zones of the country and the production systems. Unlike previously, the study also considered the manure management and GHG inventory of roughage production. The results indicated that GHG emission is the highest in the Dry Zone whilst lowest in the Wet Zone. The mid country, which contributes to about 40% of the national milk production but had only less than 10% of the cattle population has showed the second lowest GHG emissions. Comparatively, production efficiency of cattle at Dry Zone is low, resulting in the highest contribution to the GHG emission. This has provided vital information for mitigation and adaptation activities for future (Figure 1).

RESEARCH AND DEVELOPMENT ACTIVITIES RELATED TO GHG EMISSION IN SRI LANKA

Mitigation

In addition to few estimations, the research in the livestock sector conducted directly on GHG emissions, mitigation and adaptation measures in Sri Lanka is in scarcity. This may be due to the non-availability of sufficient infrastructure in the country (e.g. respiration chambers to measure GHG, SF6 tracer technique, etc.) or lack of funds and expertise. However, there are several studies conducted to increase the production efficiency of the livestock, mainly through improving nutrition, housing, welfare and health. They do not directly address or report on reducing GHG emissions or mitigation and adaptation measures to climate change, but indirectly has related the issue up to some extent, for example, improving feeding efficiency has been found to reduce methane emission and increase milk production (Gill *et al*., 2010). Similarly, measures taken to reduce the effects of high temperature and humidity through improved housing designs would also pave the way for adaptation measures for climate change (Table 2).

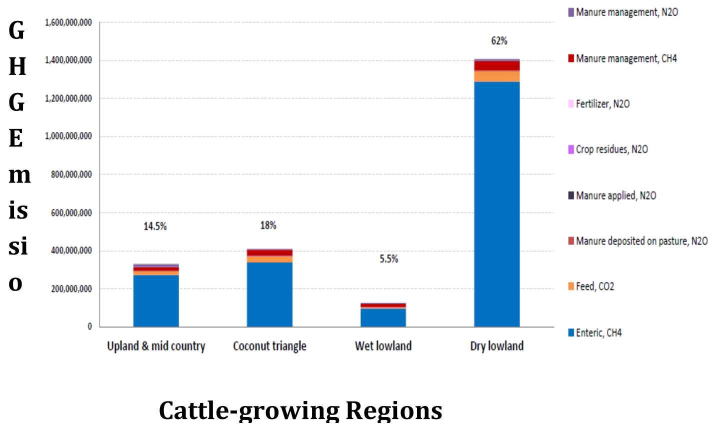

Figure 1. Contribution of dairy cattle production systems to GHG emission.Source: FAO, New Zealand government funded project on “Reducing enteric methane emissions for food security and livelihoods” (Unpublished data).

Table 2. Mitigation interventions and their impacts on some nutrition studies conducted in Sri Lanka.

	Impacts of intervention	**Reference**
Adaptation of Total mixed ration (TMR)	Milk production, milk fat and total solid contents increased	Bodahewa*et al.*(2014)
Supplementation of tree fodder and low cost concentrate to heifers grazed on natural vegetation.	Supplementation increased dry matter, total digestible nutrients, growth and milk production.	Seresinhe*et al.*(2012)
Supplementation of Urea molasses multinutrient block(UMMB) with low quality roughages.	UMMB supplementation increased milk yield and yields of milk fat, protein and the body weight.	Weerasinghe*et al.*(2011)
Supplementation of leaf meal block along with forage diet.	Supplementation increased dry matter intake, daily weight gain and milk production	Somasiri*et al.*(2010)
Exogenous fibrolytic enzymes cellulose and xylanase supplemented with Guinea grass (*Panicum maximum* ‘A’) and rice straw (*Oryzasativa*)	Weight gain, nutrient intake (DM, OM,NDF) and digestibility increased. Enteric methane production as a percentage for rumen gas production reduced numerically.	Sujani*et al.* (2015)

Adaptation

High ambient temperature in most parts the country is one of the major problems faced by the livestock farmers. Warm climate does not allow temperate breeds to perform well but the local breeds adapted to those conditions produce less milk. Mid and up country of Sri Lanka have favorable climatic conditions for high producing animals, but land availability is low for livestock farming. Therefore, the dairy farming had to be moved to Intermediate and Dry Zones of the country.Further, the temperature of cooler parts of the county is also likely to increase as a result of climate change. Considering this aspect and that more land is available for livestock farming in the Intermediate and Dry Zones, there is a trend to constructfarm houses to tackle high heat. Most farms consider well-ventilated, high roof sheds to accommodate more air movement and some have introduced cooling and fogging systems. These farms having temperate breeds are located in hot and humid places such as Hambantotain the southern province of the country and have proven to be successful, although no scientific study has been conducted to-date (Figure 2).

Figure 2. Fog ventilated dairy cattle housing at Ridiyagama national livestock development farm, which rare temperate breeds of dairy cattle.

GAPS AND FUTURE RESEARCH NEEDS

Accurate data is a prerequisite for modelling and suggesting mitigation and adaptation plans to overcome the adverse effects of climate change. WhenGHG emissionsare considered, Sri Lanka has only estimates, but emissions under local feeding and management conditions have not been scientifically measured and no facilities are available in the country to measurethese parameters at the ground level. Further, several studies that have been conducted to improve productivity of livestockhave not directly addressed climate change or GHG emissions. Therefore, the country is in urgent need of establishing a GHG emission measuring facility for livestock, which would help in determining the accurate adaptive and mitigating measures that can be implemented. Funding agencies should include climate change as a component in their priority list. All the stakeholders including government ministries and departments, research institutes, funding bodies and universities should be advised to address mitigation and adaptation measures to climate change in their research and development agenda on livestock, whenever possible.

CONCLUSION

Climate change has a negative effect on livestock industry in the country. The data available on GHG emissions is based mainly on estimates, therefore, the capacity building on this aspect should be given priority. Some studies and development projects have been implemented in the country without directly addressing the mitigation or adaptation measures against global warming, but has contributed towards that goal. Therefore, to better prepare for adverse effects of climate change, more research and development programs on this aspect should be implemented in the livestock sector.

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