IMPACT OF CLIMATE CHANGE ON WATER RESOURCES AND AGRICULTURE IN SRI LANKA

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ABSTRACT

This study focuses on the climate change effects on water resources and agriculture in Sri Lanka. For this study, climate projections from the Hadley Centre for Climate Prediction and Research, UK developed Hadley General Circulation Model HadCM3 were used. Projections are based on the most recent Inter-governmental Panel of Climate Change emission scenarios A2 and B2 for 2050s and compared with the rainfall data of baseline (1961-1990). Simple water balance CROPWAT model were used to estimate potential soil moisture deficit and irrigation water requirement. According to the results, the impact of climate change on the South-West monsoon (May to September) rainfall across the country is predicted to increase by 38% (A2) and 16% (B2). Further, higher volume of rainfall will cause runoff during South-West monsoon season and will cause severe floods and landslides in South-Western regions of the country. The North-East monsoon (December to February) is predicted to decrease by 34% (A2) and 26% (B2) in 2050s. Temperature is predicted to increase by about 1.5°C to 2°C. The maximum potential soil moisture deficit is predicted to increase by 11% (A2) and 4% (B2) in 2050s across the country compared to the base line and subsequently the annual runoff is predicted to decrease in certain dry zone locations. Therefore, the adaptation measures should focus on storage of excess runoff water during South-West monsoon for dry months and if possible divert it to the dry zone areas for agricultural activities. In addition the land filling in wet zone areas should be banned and allowed the free drainage of run off water. This could also encourage farmers in wet zone to cultivate paddy in low lying areas. Rainwater harvesting should be introduced in all areas to collect the excess water during monsoon seasons and use water saving methods.

INTRODUCTION

Paddy cultivation in the Dry Zone, accounts for 96% of the water withdrawals. The demand for water resources will increase due to the expansion of area under irrigated agriculture, increasing population, urbanization and industrialization. But due to climate change per capita annual water availability in the dry zone of Sri Lanka is projected to decline (IPCC, 2007). The problem of water scarcity would be exacerbated in the Dry Zone if the declining trends in the watershed areas continue which would in turn have serious implications on agriculture, food security, health, industries and energy. The predominant crops grown are paddy, coconut and other field crops for local consumption and tea, rubber, coconut and minor crops for export. Majority of the farm families in Dry zone of Sri Lanka depend directly on paddy cultivation. Paddy production is closely linked both, directly and indirectly, to rainfall and surface water resources. The acreage under irrigation and the cropping intensity of paddy has increased in the Dry Zone owing to the establishment of colonization schemes and the multipurpose *Mahaweli* Development Project.

Agriculture in Sri Lanka is highly susceptible to variations in temperature, rainfall, soil moisture deficits and increases in the intensity and frequency of extreme events. Delayed monsoon rains and an increase in the frequency of droughts and floods generally affect the extent of paddy sown and harvested and yields obtained. Temperature increase in Sri Lanka would affect the high value vegetable and potato cultivation in the central hill country. In addition the cool season potato cultivation in the *Jaffna* peninsula will get affected, if night time minimum temperatures continue to increase.

An enormous amount of water is required to produce food. Irrigation needs vary according to the balance between the precipitation and evapotranspiration and the resultant fluctuations in soil moisture status (McKenney and Rosenberg, 1993). Anthropogenically induced climate change is expected to influence rainfall and temperature patterns. Because the climate change will influence temperature and rainfall patterns, there are likely to be direct impacts on soil moisture. Changes in soil moisture due to global warming will have other hydrological effects. Some researchers work on past data to predict the impacts of climate change in future which is impossible due to drastic changes takes place in the hydrological cycle due to climate change. Findings based on past data only underestimate the impacts of climate change. Therefore, there is an urgent need to study the impacts of climate change for future using global circulation model or similar models which are capable to estimate the changes in climate on spatial and temporal basis. The aim of the paper is to predict the impact of climate change on water resources and agriculture using such models so that possible adaptation measures could be proposed to ensure the water and food security in the dry zone where the food production is predominant.

METHODOLOGY

There are seven Global Circulation Models (GCMs) developed by various countries and these models predict the future climate change in climatic variables such as rainfall, temperature, wind speed, relative humidity based on the green house gases, sea level rise and other related parameters for whole world except Antarctic regions for 2020s, 2050s and 2080s. Therefore the results are in larger pixel points such as 300km x 300km to cover the whole world. It creates problem for small countries like Sri Lanka which could use only two or three pixels points to extract the results of the global circulation models. It doesn't mean that the Global Circulation model results cannot be used to Sri Lanka or not reliable for Sri Lanka. There are scientifically and internationally accepted downscaling procedures available to down scale the 300km x 300km pixel results of climate change predicted by global circulation models to the 10km x 10km pixel used by Sri Lanka for base line data from 1961-1990 (New *et al.,* 2002). Therefore global Circulation model results on climate change could be scientifically used to predict the rainfall, temperature changes in Sri Lanka in 2020's, 2050's and 2080s.

This study was conducted in collaboration with Cranfield University, UK. Climate projections from the UK Hadley Centre for Climate Prediction and Research model (HadCM3) were used to assess the climate impacts (Hulme *et al.,* 1998) for IPCC developed Special Report on Emission Scenarios (SRES), A2 (Worst case) and B2 (second worst case) scenarios in 2050. Geographical Information Systems base maps were produced showing the change in rainfall, temperature, soil moisture deficit and irrigation requirement for paddy and other field crops for Sri Lanka. Latest version of the CROPWAT was used to estimate the evapotranspiration and water requirement for paddy and other field crops. Simple water balance was used to estimate the soil moisture deficit and runoff based on runoff coefficients.

RESULTS AND DISCUSSION

Impact of climate change on water resources

The North-East monsoon (December to February) is the major monsoon brings rainfall to dry zone areas. According to the results the north east monsoon is predicted to decrease by 34% (A2) and 26 % (B2). The North-East monsoon rainfall in dry zone areas such as *Jaffna, Mannar, Vavuniya, Anuradhapura, Batticaloa, Trincomalee* and *Hambantota* is predicted to decrease (Fig. 1). The highest decrease is predicted in *Trincomalee* and *Batticaloa* as 27% (A2) 29 %(B2). According to the predictions there is significant decrease in rainfall during the period from December to February mainly due to the significant decrease in rainfall during January and February months (Fig. 2) according to the A2 and B2 scenarios for 2050s compared to the baseline (1961-1990) scenario (De Silva *et al.,* 2006).

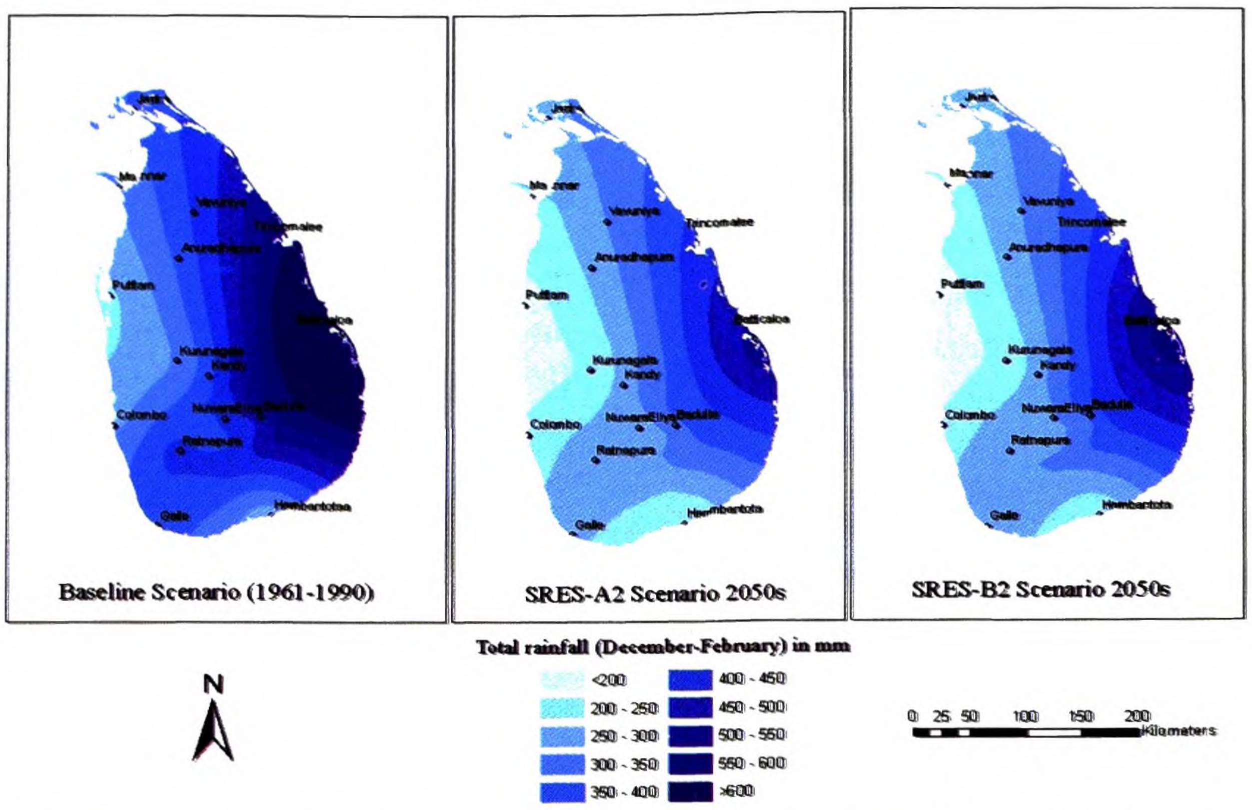

Fig. 1. Spatial variation in North-East monsoon rainfall for the baseline (1961-1990) and SRES A2 and B2 scenarios for 2050s.

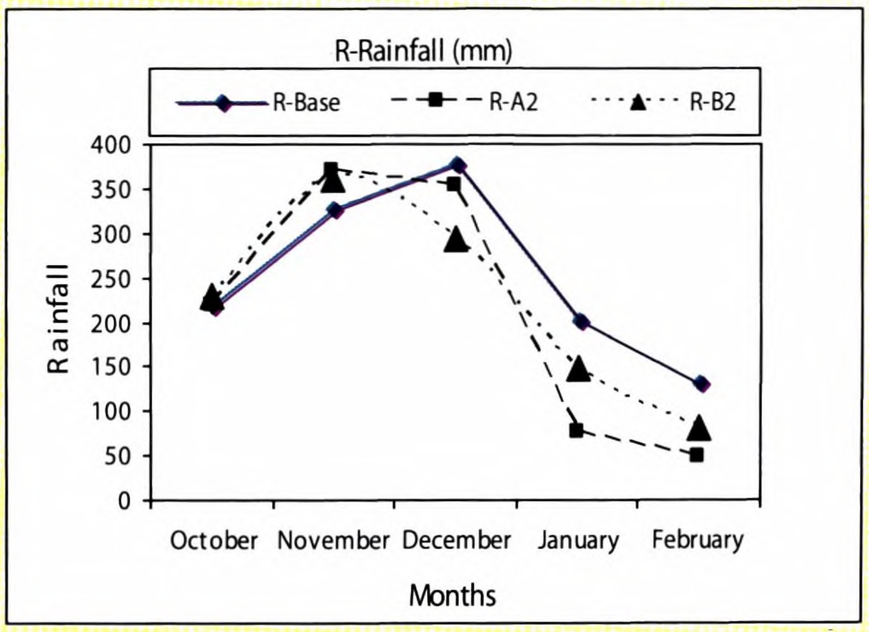

Fig. 2. Monthly rainfall from October to February

In contrast, the South-West monsoon rainfall is predicted to increase across the country by 38% (A2) and 16% (B2) in 2050s. The rainfall in *Colombo, Ratnapura, Galle* and *Nuwara Eliya* during May to September is predicted to increase by 43%-57% (A2) and 19%-27% (B2). (Fig.3).This increase in rainfall will cause floods and land slides in wet zone areas (De Silva *et al.*, 2007).

The annual runoff across the country is predicted to decrease by 10% (A2) and 8 % (B2) even though the annual average rainfall is predicted to increase (De Silva, 2007). However among the wet zone

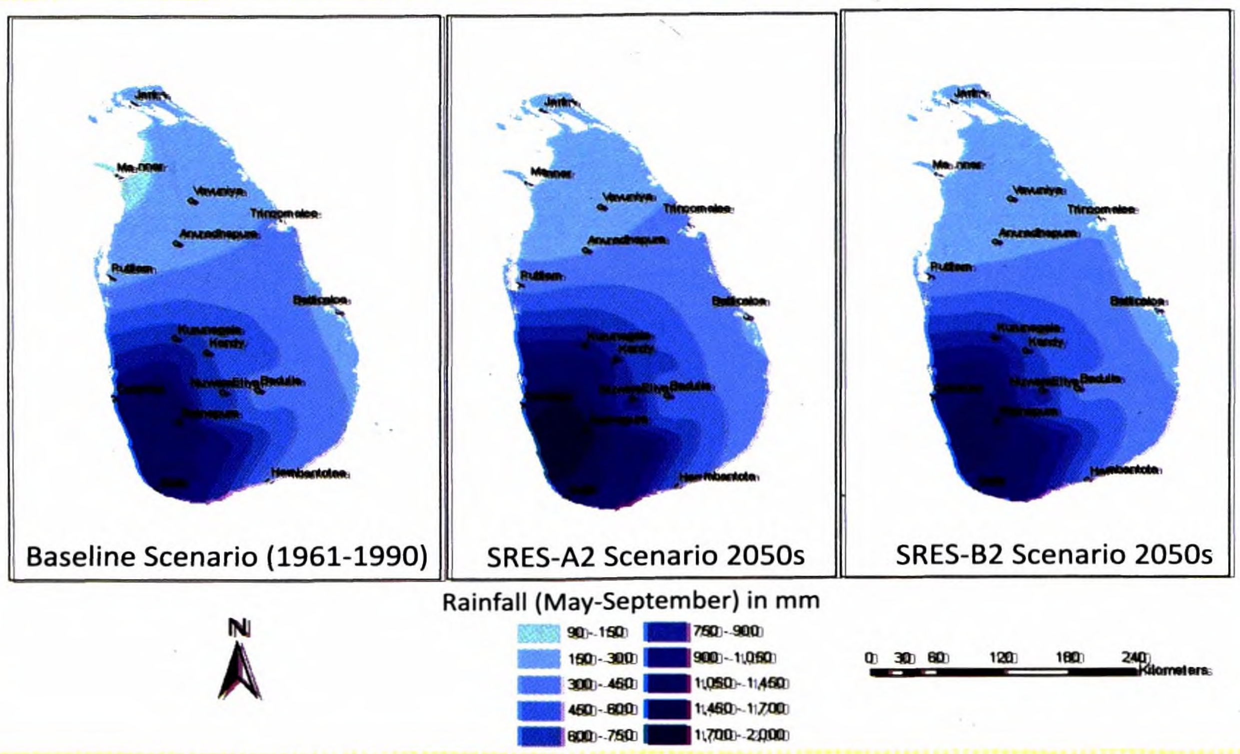

Fig. 3. Spatial variation in South-West monsoon rainfall for the baseline (1961-1990) and SRES A2 and B2 scenarios for 2050s.

areas the annual runoff in *Colombo* and *Kandy/Katugastota* is predicted to increase drastically. In *Colombo* the annual runoff is predicted to increase by 40% in A2 scenario for 2050s. In *Kandy/Katugastota* the predicted annual runoff for A2 scenario in 2050s is almost 100% increase compared to the baseline (1961-1990).

Impact of climate change on agriculture

Impact of climate change on annual average temperature predicted by HadCM3 model and Baseline is presented in Table 1. The average annual temperature is predicted to increase by 1.6°C (A2) and 1.2°C (B2). Highest increase in temperature is predicted in *Anuradhapura* by 2.1°C (A2) and 1.6°C (B2). The lowest annual average temperature increase is predicted in *Nuwara Eliya* by 1.1° C (A2) and 1° C (B2). Predicted temperature increases with decrease in rainfall in dry zone areas will create problems on the agricultural activities.

Decrease in rainfall and increase in temperature will create severe soil moisture deficit conditions. According to the results obtained, the areas with predicted highest potential soil moisture deficit ($PSMD_{max}$) are located in the Northern and Eastern parts notably in *Jaffna, Mannar, Vavuniya, Trincomalee, Anuradhapura* and *Batticaloa* (Table 2). In A2 2050s scenario, the northern part of the country becomes drier than at present due to the significantly higher $PSMD_{max}$.

Table 1. Increase in mean annual air temperature (°C) predicted by HadCM3 model for A2 and B2 scenarios in 2050s compared to the baseline (1961-1990) at the main weather stations in the island.

Weather station	Latitude	Longitude	Baseline	HadCM3 model output for IPCC scenario	
				A2	B2
Anuradhapura	8.35°N	80.38°E	27.1	2.1	1.6
Batticaloa	7.71°N	81.70°E	28.0	1.3	1.2
Badulla	6.98°N	81.05°E	22.1	1.5	1.3
Colombo	6.90°N	79.86°E	27.5	1.5	1.1
Galle	6.03°N	80.22°E	26.5	1.7	1.4
Hambantota	6.12°N	81.13°E	27.1	1.5	1.3
Jaffna	9.65°N	80.02°E	28.0	1.9	1.5
Kandy	7.33°N	80.63°E	22.1	1.5	1.3
Kurunagala	7.46°N	80.37°E	26.9	1.7	1.0
Mannar	8.98°N	79.91°E	28.0	1.5	1.2
Nuwara Eliya	6.96°N	80.76°E	18.8	1.1	1.0
Puttlam	8.03°N	79.83°E	27.7	1.6	1.3
Ratnapura	6.68°N	80.40°E	25.7	1.7	1.4
Trincomalee	8.58°N	81.25°E	28.5	1.4	1.0
Vavuniya	8.75°N	80.50°E	27.7	1.6	1.5

Table 2. Maximum annual soil moisture deficit ($PSMD_{max}$) for baseline and A2 and B2 scenarios in 2050s at selected sites in the dry and intermediate zone areas.

Weather station	Latitude	Longitude	Baseline	$PSMD_{max}$ Percentage Change(A2)	Percentage Change(B2)
Jaffna	9.65°N	80.02°E	1162	+12	+5
Mannar	8.98°N	79.91°E	1162	+12	+5
Vavuniya	8.75°N	80.50°E	1032	+16	+8
Trincomalee	8.58°N	81.25°E	905	+21	+23
Anuradhapura	8.35°N	80.38°E	905	+8.4	+4
Batticaloa	7.71°N	81.70°E	782	+25	+13
Hambantota	6.12°N	81.13°E	663	-5.4	-2
Puttlam	8.03°N	79.83°E	782	+11	+13

For example at Jaffna, the baseline $PSMD_{max}$ is 1162 mm and the predicted $PSMD_{max}$ for the SRES A2, 2050s will be 1305 mm; 12% increase compared to the baseline (1961-1990).

Paddy irrigation requirements are predicted to increase on average across Sri Lanka by 23% and 13%, for the A2 and B2 scenarios respectively (De Silva *et al.,* 2007). The highest proportional increase is predicted to occur in *Batticaloa* (Fig. 4), by 45% (A2) and 15% (B2). This increase is mainly due to the decreased rainfall during January and February. Only around *Hambantota,* a comparatively dry area is the paddy irrigation requirement predicted to decrease, by 2% (A2) and 4% (B2). This result agrees with previous climate change impacts study by Droogers (2004) in the Southern part of Sri Lanka.

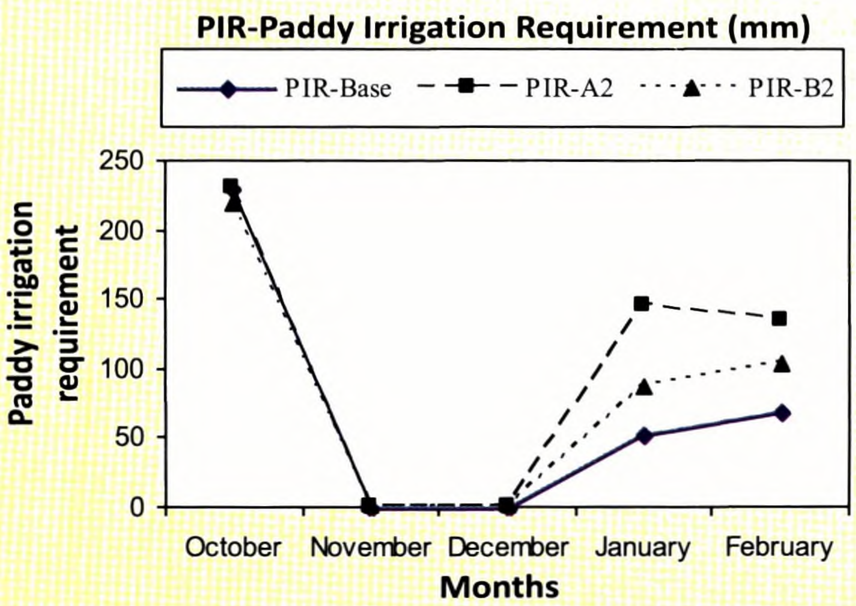

Fig. 4. Monthly paddy irrigation requirement in the (*Maha*) season for the baseline, A2 and B2 scenarios for 2050s in *Batticaloa.*

Irrigation water requirement for other field crops too increased drastically due to the predicted increase in temperature which contributes to the higher soil moisture deficit. Therefore, to compensate the soil moisture deficit additional irrigation water is needed. Accordingly study shows that the irrigation need for chilli is predicted to increase by 18% (A2) and 11 % (B2) compared to the baseline. Similarly the future irrigation need to cultivate tomato also estimated and accordingly the irrigation need for tomato will increase by 14 % (A2) and 8% (B2) compared to the baseline.

CONCLUSIONS

Annual average rainfall in across Sri Lanka is predicted to increase by 14 %(A2) and 5%(B2) in 2050s due to global warming. However, the annual average rainfall is predicted to decreases in dry zone areas whereas the increase is predicted in wet zone areas. Predicted decrease in rainfall in dry zone areas with the temperature increase has serious impacts in potential soil moisture deficits. Changes in rainfall are amplified in runoff, leading to significant decreases in annual runoff in the dry zone areas whereas the increase in annual runoff is predicted in wet zone areas. Predicted increase in potential soil moisture deficits will create higher irrigation demand and the predicted decrease in runoff will have serious impacts in the storage of runoff water in traditional village tanks for irrigation purposes. Therefore, the agricultural activities in the dry zone will be severally affected. However, the predicted increase in runoff in wet zone areas such as *Colombo* and *Kandy* may lead an opportunity to store the excess water in wet zone and then divert it to dry zone to face the water shortage conditions. Possibilities could be studied to improve and augment the *Mahaweli Gange* Project to the dry zone areas. The adaptation decisions are for policy makers but the results presented in this paper based on future predictions based on the climate change impacts on Sri Lanka related to water resources and will provide a guide for planning possible adaptation measures to ensure water and food security in Sri Lanka.

According to the results the annual average rainfall is predicted to increase due to increase in South-West monsoon in wet zone areas. Rainfall in wet zone areas such as *Colombo, Kandy, Galle, Ratnapura* and *Nuwara Eliya* are predicted to increase where the demand for water is low. During the South-West monsoon period the rainfall in *Colombo* is predicted to increase by 48% compared to the baseline (1961-1990) in 2050s. Therefore, the predicted incremental increase is 25%, 29%, 34%, 43% and 48% in 2010, 2020, 2030, 2040 and 2050 respectively. This agrees with the findings of Kayne *et al.,* (1995) as the rainfall in *Colombo* increased by 30% during the period of

1869 - 1993 due to increase in sea surface temperature. Similarly, the predicted runoff is about 40% in *Colombo* and almost 100% in *Kandy.*

Adaptation measures should be designed to store the excess water in wet zone areas during South-West monsoon for other months when there is no rainfall. Further the excess water can be stored by careful planning and then transfer the water to the dry zone areas where demand for water is high to ensure water security. The proposed *Yan Oya* Diversion project will get the advantage of climate change to store and divert the predicted increase in rainfall and runoff in wet zone areas surrounding *Kandy* and *Matale* to augment *Hululuwewa* to provide water for dry zone areas to increase paddy and other field crop cultivation. In addition adaptation measures such as improving the drainage facilities by enlarging the water ways to safely divert the predicted increase in rainfall and runoff in greater *Colombo* area is essential to face the trends in climate change. It is also important to ban the land filling the low-lying areas in wet zone and encourage people to cultivate these areas. In addition rainwater harvesting in all regions should be encouraged to store the excess water during rainy season. Water saving methods such as drip irrigation in dry zone areas and cultivation of low water requiring crops such as maize would be beneficial.

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