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GREENHOUSE GAS EMISSION ASSESSMENT FROM FEW STORAGE BASED HYDROPOWER SCHEMES IN INDIA

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ABSTRACT

The occurrence of extreme weather conditions is the major phenomena which is linked to global warming. Main GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).There are a large number of water resources projects in the form of dams constructed across the world for various uses of water like irrigation, hydropower, flood control, drinking purposes, etc. So far hydro power was considered as the clean source of energy but recent studies have proven that the creation of dam along a water body results in the greenhouse gas (GHG) emission which is responsible for global warming. In this study, impact of storage based hydropower scheme on GHG emission is discussed. Eleven hydropower schemes in various hydro climatic zones of India are studied. The mean annual rainfall and temperature for the past 16 years (1997-2012) are considered as input variables for estimating the GHG emission at a particular age from a reservoir. The predicted diffusive flux in terms of CO_2 equivalents has been estimated for a particular year and over 100 years by using UNESCO/IHA GHG Risk Assessment Tool (Beta Version).

Keywords: *CO_2 equivalent, Diffusive Fluxes, Global Warming Potential (GWP), Storage Based Hydropower Schemes (SBHS), GHG Risk Assessment Tool.*

INTRODUCTION

The increasing anthropogenic activities have resulted in increasing concentration of natural gases, CO_2 and CH_4, in the atmosphere resulting in GHG effect (Houghton, 1996). According to the European Environment Agency (EEA), CO_2 emissions account for the largest share of GHGs equivalent to 80–85% of the emissions. Fossil fuel combustion for transportation and electricity generation are the main sources of CO_2 contributing to more than 50% of the emissions (Goldenfum, 2009). In India, generation of electricity with coal based thermal power plant is more than 65%, and hydropower and natural gases represent about 16% and 5% respectively. Till recently, hydropower was considered as the clean source of energy, however, during the last few years GHG emissions from storage reservoirs and their contribution has raised a question mark on the issue (Tremblay, 2005). Recent studies showed that the carbon which is transferred to water body will undergo decomposition under oxic and anoxic conditions and produce CO_2 and CH_4 (Farrèr and Senn, 2007). Once CO_2 and CH_4 are produced, they are not immediately released into the atmosphere; these gases remain dissolved in the water until any chemical event occurs that causes the gases to be released (Kansal, 2013). Hydropower plants are being considered more reliable and efficient as compared to the fossil fuel based plants. Small and medium-sized hydropower stations are preferred and are being installed in situations where there is an adequate supply of moving water with adequate head and there is need for electricity (Tortajada, 2012). Hydropower projects with a reservoir are also called storage based hydropower scheme (SBHS). Water released from the reservoir flows through a turbine, spins it, which in turn activates a generator to produce electricity. The water may be released either to meet changing electricity needs, irrigation requirements or to maintain a constant reservoir level. The design of the SBHS and type of reservoir that can be built is very much dependent on opportunities offered by the topography. The reservoir increases the dependable flow for the project. The generating stations are located at the dam toe or further downstream which are connected to the reservoir through tunnels or pipelines. In India, the majority of hydropower is generated by storage based schemes. By the year 2013, there were 183 Hydropower stations with installed capacity of 39,788 MW from 627 units. Such storage based schemes create large water bodies on upstream which results in the GHGs like CO_2, CH_4 and N_2O emission from water bodies. Considering a flowing water body without any reservoir, only natural emission like conduction, deposition and emission will take place. On creation of a reservoir, emissions from different parts of the reservoir in different pathways take place over the upstream and downstream of the reservoir (Goldenfum, 2009). It is known that water bodies play a significant role as the source of GHG emission, particularly in tropical climatic zones (Tremblay, 2005). One possible reason for this is that the annual water temperature is much higher in tropical climates (Guérin, 2006). This means that the rate of decomposition is faster leading to higher CO_2 and CH_4 flux in the water. Since very little GHG emission data is available in India, an attempt has been made in this paper to estimate the diffusive fluxes which is one of the pathway of GHGs from the hydropower by using UNESCO/IHA GHG Risk Assessment Tool (Beta Version). Finally, predicted values of diffusive fluxes has been shown depending upon the surface area and over a particular age and life time of the reservoir.

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GHGs EMISSION FROM A RESERVOIR

According to the European Environmental Agency (EEA), emissions of CO_2 accounts largest share of GHGs (equivalent to 80-85% of the emissions). Fig 1 shows detailed sources of GHGs emission from the reservoir. In addition to CO_2, CH_4 also gets emitted from the reservoir due to anaerobic decomposition of organic matter (OM) which is present in the bottom layer of the reservoir and macrophytes which are present on the surface of water. At air-water interface, both CO_2 and CH_4 get transferred by diffusion from the aquatic

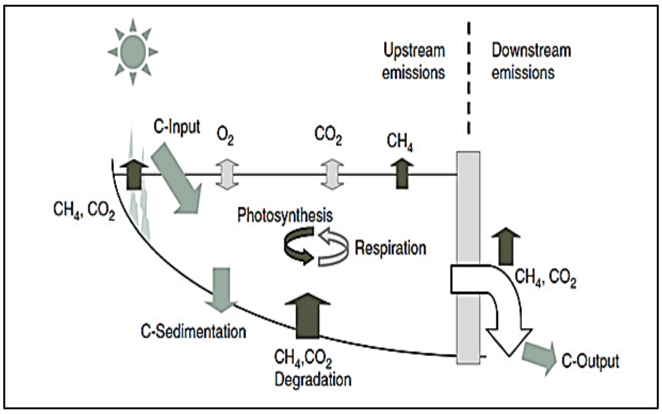


Fig. 1: Major GHG Fluxes in a Reservoir.

ecosystems in the form of fluxes. These fluxes are known as Diffusive Flux. Flux can be observed at both upstream and downstream of reservoir and it is based on the Henry's law of partial pressure difference of gases viz. air (Pa) and the water (Pw) (Fearnside, 2006). If Pw is higher than Pa the gas diffuses from the water to the atmosphere because a chemical compound always diffuses from the most concentrated layer to the less concentrated and vice versa. Diffusive flux emissions can be estimated using the UNESCO/IHA (United Nations Educational, Scientific and Cultural Organization / International Hydropower Association) Risk Assessment Tool (2012).

Several primary and secondary parameters are responsible for the emission of GHGs from the reservoir. These parameters are shown in Fig 2. Every parameter has to be taken into consideration while calculating GHGs from the reservoir. The emissions of CO_2 and CH_4 to the atmosphere takes place in the form of bubbling fluxes, diffusive fluxes from upstream and diffusion through macrophytes and degassing at downstream (Abril, 2005) (Fig 1).

GHG RISK ASSESSMENT TOOL

UNESCO/IHA (2012) has suggested the GHG Risk Assessment Tool. This tool can be used to predict the diffusive flux values at air-water interface with a 67% confidence interval. Several parameters control the intensity of the diffusive fluxes. For example, the gradient itself (the bigger is the gradient, the bigger is flux) and also some physical parameters like wind speed, water current velocity, rainfall, and temperature enhance the fluxes control the intensity.

Tool Development and Limitations

An empirical model was developed in the GHG Risk Assessment Tool to explain the variability of gross CO_2 and CH_4 diffusive fluxes. An intrinsically non-linear approach was adopted affording flexibility in the shapes of the curve describing the initial decline of GHG emissions following flooding in this model. The model for predicting CO_2 diffusive fluxes was able to explain about 45% of the variation observed in the data used for calibration, and had an uncertainty best described on a base-10 logarithmic scale (root mean square error = 0. 36). The model for predicting CH_4 diffusive fluxes was able to explain about 42% of the variation observed in the data used for calibration. Its uncertainty is best described on a base-10

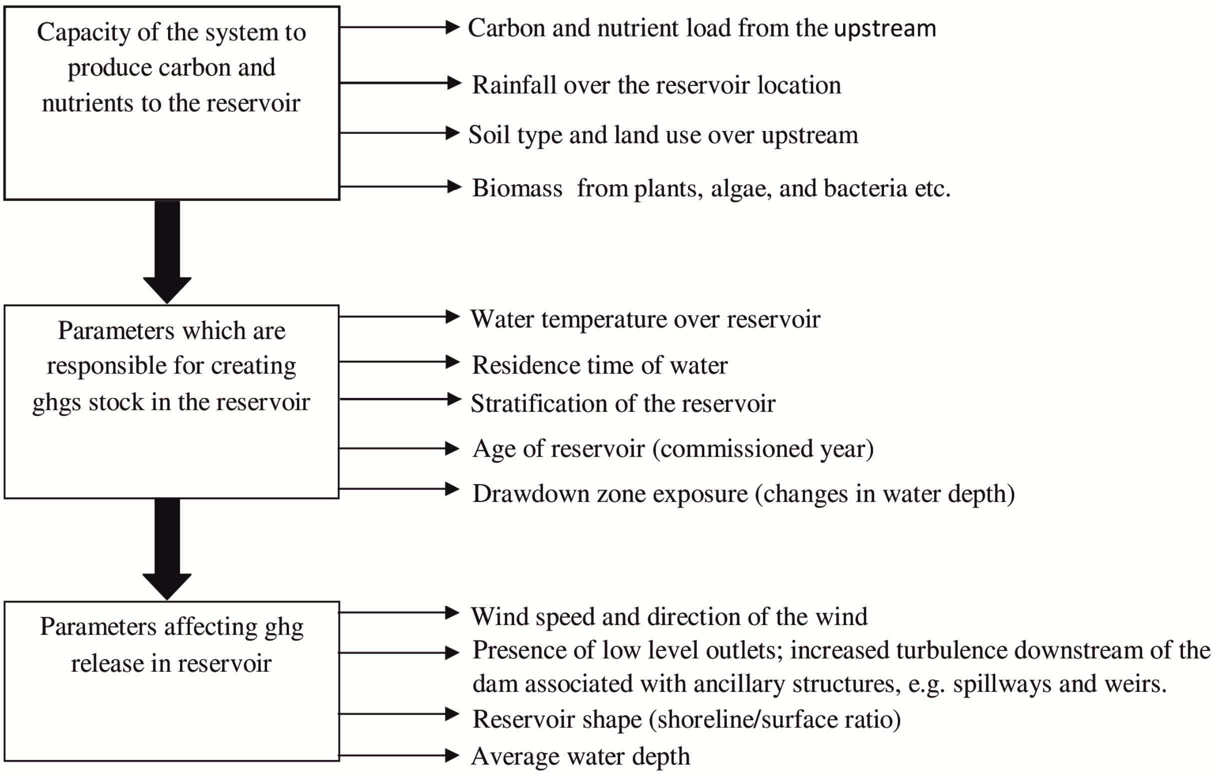


Fig. 2: Parameters responsible for GHG emissions

logarithmic scale with root mean square error of 0.55. The range of variability of the estimates can be expressed by the confidence interval of the predicted values shown in the eq (1). The confidence interval for the predictions is obtained as:

P [“lower limit” ≤ “GHG flux” ≤ “upper limit”] = α% (1)

meaning that there is α% of probability that the “GHG flux” will be in the interval between the “ lower limit” and the “upper limit”. The values for “lower limit” and “upper limit” of the 67% confidence interval for the predictions are taken from Table 1.

Table 1: Limits of predicted values of the 67% confidence interval

Predicted Value	Lower limit	Upper limits
Gross C-CO_2 Flux	$\frac{1}{2.3}$* “Predicted Gross C-CO_2 Flux”	2.3* “Predicted Gross C-CO_2 Flux”
Gross C-CH_4 Flux	$\frac{1}{3.55}$* * “Predicted Gross C-CH_4 Flux”	3.55* “Predicted Gross C-CH_4 Flux”

Both models have uncertainty best described on a base-10 logarithmic scale. Consequently, the factors 2.3 and 3.55 are derived from $10^{0.36}$ and $10^{0.55}$, respectively.

Tool Model Formulas

Several alternative formulations were attempted by the Goldenfum (2009) for GHG emissions from freshwater reservoirs during the UNESCO/IHA research project. The following general expression has been given as the best fitting expression which considers the parameters responsible for the emission of CO_2 from the reservoir by considering the age of reservoir as shown in the Eq. (2). The predicted values of diffusive flux as flux C-CO_2 and flux C-CH_4 has been estimated by using the equations given below

$$Flux\ C - CO_2 = 186.0 + 0.148 \times R + \left(944.485 + 1.91 \times T + 0.09727 \times T^2\right) \times e^{-0.044 \times \left[52.339 - 0.7033 \times T - 0.0358 \times T^2\right] \times Age} \quad (2)$$

where T is temperature (in degrees Celsius), R is mean annual runoff (in mm) over the reservoir location and Age is the age of the reservoir from the commissioned year.

The gross CH_4 emissions from the reservoir aged ≤ 32 is shown in the eq (3) and reservoirs with age 32 ≤ Age ≤ 100 years is shown in the eq (4).

$$\mathrm{Flux\ C - CH_4} = 101.46 + 0.056 * T - 0.00053 * P - 0.0186 * Age + 0.000288 * Age2 \quad (3)$$

$$\mathrm{Flux\ C - CH_4} = 10^{(1.16 + 0.056 * T - 0.00053 * P)} \quad (4)$$

where T is temperature (in degrees Celsius), P is mean annual precipitation (in mm) over the reservoir location and Age is the age of the reservoir from the commissioned year.

The above equations are the best suited equations and the above formulas depend on four main parameters like runoff (R), precipitation (P), temperature (T), and Age (age of the reservoir). However, depending on the location of the reservoir and the data availability one can incorporate more than of parameters.

CASE STUDY OF INDIAN STORAGE BASED HYDROPOWER SCHEMES

Indian reservoirs indicate complete spectra of different types of reservoirs found in the world. Some are located in tropic climate regions which can release a significant amount of GHGs while others in arid environments, where sequestration probably dominates over release of carbon. Between these extremes are reservoirs located in wet, humid or dry tropical environments. Their performance in terms of emission of GHGs is more difficult to trace out. In this paper, a case study of eleven reservoirs which are located in different parts of the country have been chosen and the respective diffusive flux has been calculated using GHG Risk Assessment Tool. Moreover, the total predicted diffusive flux which is emitted to the atmosphere has been found out and finally the predicted emissions are expressed as tons of CO_2 equivalent (CO_2eq). In Fig 3, red dots show the hydroelectric projects locations and the black dots show the eleven hydroelectric reservoirs which were considered for the study as shown in Table 2. The selection of these reservoirs has been made according to their location to represent the variation of emissions that can happen with respect to the climate change.

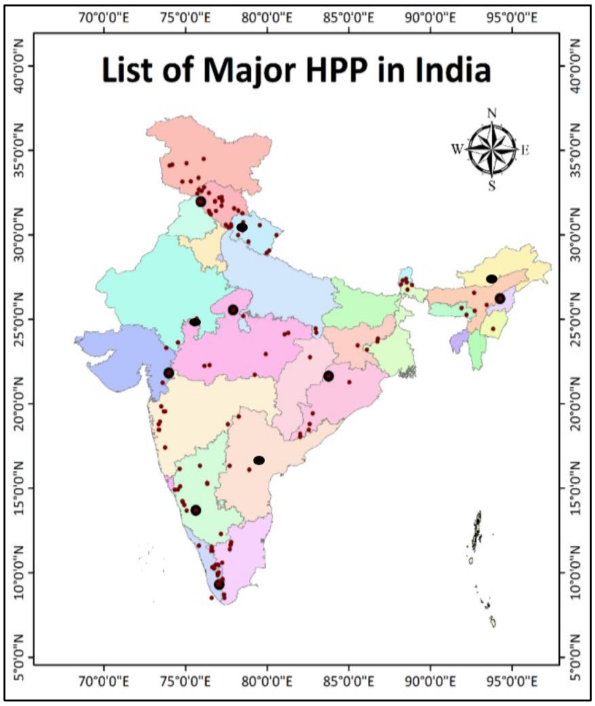


Fig. 3: Location of reservoirs under study.

Table 2: Details of reservoirs under study

S. No	State	Name of Station	Name of River	IC (MW)	Lat.	Long.	Year Commissioned
1	Gujarat	Sardar-Sarovar	Narmada	1450	21.82	73.98	2007
2	H P	Pong	Beas	396	31.96	75.94	1983
3	Karnataka	bhadra	bhadra	39.2	13.7	75.64	1965
4	Kerala	Sabarigiri	Pamba & Kakki	300	9.307	77.07	1967
5	M P	Madhikhera	Sone	60	25.55	77.91	2008
6	Nagaland	Doyang	Doyang	75	26.23	94.26	2001
7	Orissa	Hirakud	Mahanadi	275.5	21.64	83.75	1990
8	A P	Srisailam	Krishna	1670	16.09	78.90	1981
9	Uttarakhand	Tehri	Bhagirathi	1000	30.38	78.48	2006
10	Rajasthan	R P Sagar	Chambal	172	24.92	75.58	1970
11	Assam	Subansiri	Subansiri	2000	27.55	94.26	2014

Lat. - Latitude, Long. – Longitude

DATA ANALYSIS AND CALCULATIONS

The GHG assessment tool is used in this study. The reservoir data like its location, year of commissioning, and area etc. are collected from various sources and is used as the input to the model. The mean annual daily air temperature was obtained from 2 meters height for the located surface for the years 1997-2012. Run-off data is obtained from UNH/GRDC Composite Run-Off Fields V1.0. Mean annual precipitation has been calculated from NASA Prediction of Worldwide Energy Resource (POWER). The input values are shown in Table 3.

Predicted value for 100 years are the annual predicted values averaged over a period of 100 years and the predicted values of eleven reservoirs have been shown in the Table 4. The prediction of upper limits, lower limits and predicted values over 100 years are shown in following figures 4-14. In Table 5, the total emission from surface area of these projects at their particular ages has been estimated and represented in terms of tons of CO_2eq per year. For carbon dioxide, the ratio of the atomic mass of a CO_2 molecule to the mass of a carbon atom is 44:12. For converting to "tonnes of CO_2", multiply "tonnes of C" by 3.667 (i.e. 44/12). And then multiply it by the respective Global warming potential (GWP) in order to obtain the "g of CO_2eq". It can be denoted as gC-CO_2 or TC-CO_2.

For CH_4, the ratio of the atomic mass of a CH_4 molecule to the atomic mass of a carbon atom is 16:12. For converting to "tonnes of CH_4", multiply "tonnes of C" by 1.334 (i.e. 16/12). After that, adopting the IPCC GWP for a 100-yr time-horizon multiply by 25 in order to obtain the "T of CO_2eq". The total predicted emissions from surface area of these projects have been averaged over a century and represented in terms of tonnes of CO_2eq per year in Table 6. By applying above calculations and multiplying the predicted value obtained for a square meter for the whole reservoir surface area, finally a predicted value of T-CO_2eq is obtained for the eleven reservoirs.

RESULTS AND DISCUSSIONS

The results for CO_2 and CH_4 emissions obtained from the inputs of respective hydropower stations of a particular SBHS for the present age (2013) and over 100 years have been shown in Table 3 and Table 4 respectively. Predicted emissions over 100 years for every particular SBHS have been shown in figures 4 to 14. From Table 3 it is clear that maximum CO_2 emissions occur after flooding and then temperature plays the key role in deciding the flux of emissions. From the Equation (2), it is clear that the CO_2 emissions have a direct dependence on the runoff. Finally the predicted annual diffusive flux emissions from the SBHS over the complete reservoir have been assessed with surface area of the SBHS. In Table 5, the emissions of CO_2 and CH_4 have been converted into CO_2eq by multiplying with their GWP for the present age of the reservoir. In Table 6, the predicted average annual diffusive flux over 100 years has been assessed and converted into CO_2eq.

Table 3: Predicted values for CO_2 at particular year and over 100 years with lower and upper 67% confidence interval

INPUTS FOR RISK ASSESMENT TOOL						Emissions of CO_2 till 2013			Emissions of CO_2 Over 100years			REMARKS	
S. No	Name of station	Age	MAP mm/yr 1997-12	Runoff mm/yr	MATD (1997-12)	Predicted gross* annual CO_2 diffusive flux (mg C-CO_2 m^{-2} d^{-1})			Predicted gross* annual CO_2 diffusive flux (mg C-CO_2 m^{-2} d^{-1})			CO_2 Emission at that yr	CO_2 Emissions 100 yr
						67% confidence interval			67% confidence interval				
						Predicted value	Lower limit	Upper limit	Predicted value	Lower limit	Upper limit		
1	Sardar Sarovar	5	960.1	408	27	1156	503	2659	570	524	619	H	M
2	Pong	29	1129	751	21	361	157	831	408	376	444	M	M
3	Bhadra	47	1447	586	25	354	154	815	469	432	509	M	M
4	Sabarigiri	45	1547	501	25.2	361	157	830	464	427	505	M	M
5	Madhikhera	4	858	408	25.5	1115	485	2565	464	427	504	H	M
6	Doyang	11	2227	1407	20.8	744	324	1712	504	464	547	H	M
7	Hirakud	22	1457	561	26	679	295	1561	514	473	559	H	M
8	Srisailam	31	919	200	25	410	178	943	413	381	449	M	H
9	Tehri	7	980	405	14.57	589	256	1355	316	291	343	M	M
10	RanaPSagar	43	852	315	26	397	173	913	479	441	521	M	M
11	Subansiri Lower	1	1766.5	500	9	1062	462	2443	316	291	343	H	M

MAP – Mean Annual Precipitation, MADT – Mean Annual Daily Temperature, H- High, M-Medium.

Table 4: Predicted values for CH_4 at particular year and over 100 years with lower and upper 67% confidence interval

		INPUTS FOR RISK ASSESMENT TOOL				Emissions of CH_4 till 2013			Emissions of CH_4 Over 100years			REMARKS	
Sl. No	Name of station	Age	MAP mm/yr (1997-12)	Runoff mm/yr	MATD 1997-12	Predicted gross* annual CH_4 diffusive flux (mg C-CH_4 m^{-2} d^{-1})			Predicted gross* annual CH_4 diffusive flux (mg C-CH_4 m^{-2} d^{-1})			CH_4 Emissions at that	CH_4 Emissions over 100yr
						67% confidence interval			67% confidence interval				
						Predicted value	Lower limit	Upper limit	Predicted value	Lower limit	Upper limit		
1	Sardar Sarovar	6	960.1	408	27	238	67	846	160	141	181	H	H
2	Pong	29	1129	751	21	55	15	195	55	15	195	H	H
3	Bhadra	47	1447	586	25	62	17	220	68	60	77	H	H
4	Sabarigiri	45	1547	501	25.2	56	16	200	62	55	70	H	H
5	Madhikhera	4	858	408	25.5	231	65	820	149	131	169	H	H
6	Doyang	11	2227	1407	20.8	19	5	67	15	13	17	M	M
7	Hirakud	22	1457	561	26	75	21	266	77	67	87	H	H
8	Srisailam	31	919	200	25	118	33	420	130	114	147	H	H
9	Tehri	7	980	405	14.57	114	32	404	82	72	93	M	M
10	Rana P Sagar	43	852	315	26	146	41	518	160	141	182	H	H
11	Subansiri Lower	1	1766.5	500	9	55	15	194	31	28	36	M	M

MAP – Mean Annual Precipitation, MADT – Mean Annual Daily Temperature, H- High, M-Medium.

Table 5: Emissions calculated from total surface area and converting into T of CO_2 eq by 2013

State	Dam	Area (km^2)	IC (MW)	Predicted value (mg C - m^{-2} d^{-1})		[a]t of C-CO_2/yr	[b]t-CO_2eq/yr	[c]t of C-CH_4/yr	[d]t-CH_4/yr	[e]t of CO_2eq/yr	Total t-CO_{2eq}
				CO_2	CH_4						
Gujarat	Sardar Sarovar	375.3	1200	1156	238	158366.7	580678.0	32604.9	43473.2	1086830.6	1667508.6
H.P	Pong	260	396	361	55	34258.9	125616.0	5219.5	6959.3	173983.3	299599.3
Larnataka	Bhadra	112.5	39.2	354	62	14537.3	53303.3	2546.1	3394.8	84869.1	138172.4
Kerala	Sabarigiri	17.51	300	361	56	2307.2	8459.8	357.9	477.2	11930.1	20389.9
M .P	Madhikhera	56.73	60	1115	231	23087.3	84653.5	4783.1	6377.5	159437.1	244090.7
Nagaland	Doyang	26.06	75	744	19	7076.9	25948.5	180.7	241.0	6024.2	31972.7
Orissa	Hirakud PH	743	275.5	679	75	184141.4	675185.2	20339.6	27119.5	677987.5	1353172.7
AP	Srisailam	800	1670	410	118	119720.0	438973.3	34456.0	45941.3	1148533.3	1587506.7
Uttarakhand	Tehri	52	100	589	44	11179.2	40990.5	835.1	1113.5	27837.3	68827.8
Rajasthan	Rana P Sagar	198.2	172	397	146	28720.2	105307.3	10562.1	14082.8	352069.3	457376.6
Assam	Subansiri	33.5	2000	1062	10	12985.6	47613.9	122.3	163.0	4075.8	51689.7
					Total	**596380.7**	**2186729.2**	**112007.3**	**149343.1**	**3733577.8**	**5920307**

[a]Includes conversion of predicted value of CO_2 into Tons over the complete surface area per year
(Surface area x predicted value of CO_2 x 0.001 x 365)
[b]Converting C-CO_2 into CO_{2eq} by multiplying with GWP of CO_2(t C-CO_2 x 3.6 x 1)
[c]Includes conversion of predicted value of CH_4 into Tons over the complete surface area per year
(Area x predicted value of CH_4 x 0.001 x 365)
[d]Includes conversion of C-CH_4 into CH_4 (t C-CH_4 x 1.3 , [e]Converting C-CO_2 into CO_{2eq} by multiplying with GWP of CO_2(t-CH_4 x 25)

Table 6: Emissions calculated from total surface area and converting into T of CO_2 eq averaged over 100 years

State	Dam	Area (km^2)	IC (MW)	Predicted value (mg C - m^{-2} d^{-1})		[a]t of C-CO_2/yr	[b]t-CO_2eq/yr	[c]t of C-CH_4/yr	[d]t-CH_4/yr	[e]t of CO_2eq/yr	Total t-CO_{2eq}
				CO_2	CH_4						
Gujarat	Sardar Sarovar	375.3	1200	570	160	78087.4	286320.5	21919.3	29225.7	730642.4	1016962.9
H.P	Pong	260	396	409	60	38814.1	142318.4	5694.0	7592.0	189800.0	332118.4
karnataka	Bhadra	112.5	39.2	469	68	19259.8	70619.3	2792.5	3723.3	93082.3	163701.6
Kerala	Sabarigiri	17.51	300	464	62	2965.5	10873.5	396.3	528.3	13208.4	24081.9
M .P	Madhikhera	56.73	60	464	149	9607.6	35228.0	3085.2	4113.6	102840.4	138068.4
Nagaland	Doyang	26.06	75	504	15	4794.0	17578.0	142.7	190.2	4756.0	22333.9
Orissa	Hirakud PH	743	275.5	514	77	139394.2	511112.2	20882.0	27842.7	696067.2	1207179.3
AP	Srisailam	800	1670	413	130	120596.0	442185.3	37960.0	50613.3	1265333.3	1707518.7
Uttarakhand	Tehri	52	100	316	31	5997.7	21991.5	588.4	784.5	19612.7	41604.2
Rajasthan	Rana P Sagar	198.2	172	479	160	34652.3	127058.4	11574.9	15433.2	385829.3	512887.8
Assam	Subansiri	33.5	2000	316	6	3863.9	14167.6	73.4	97.8	2445.5	16613.1
						458032.6	1679452.7	105108.5	140144.7	3503617.4	5183070

[a]Includes conversion of predicted value of CO_2 into Tons over the complete surface area per year
(Surface area x predicted value of CO_2 x 0.001 x 365)
[b]Converting C-CO_2 into CO_{2eq} by multiplying with GWP of CO_2(t C-CO_2 x 3.6 x 1)
[c]Includes conversion of predicted value of CH_4 into Tons over the complete surface area per year
(Area x predicted value of CH_4 x 0.001 x 365)
[d]Includes conversion of C-CH_4 into CH_4 (t C-CH_4 x 1.3 , [e]Converting C-CO_2 into CO_{2eq} by multiplying with GWP of CO_2 (t-CH_4 x 25)

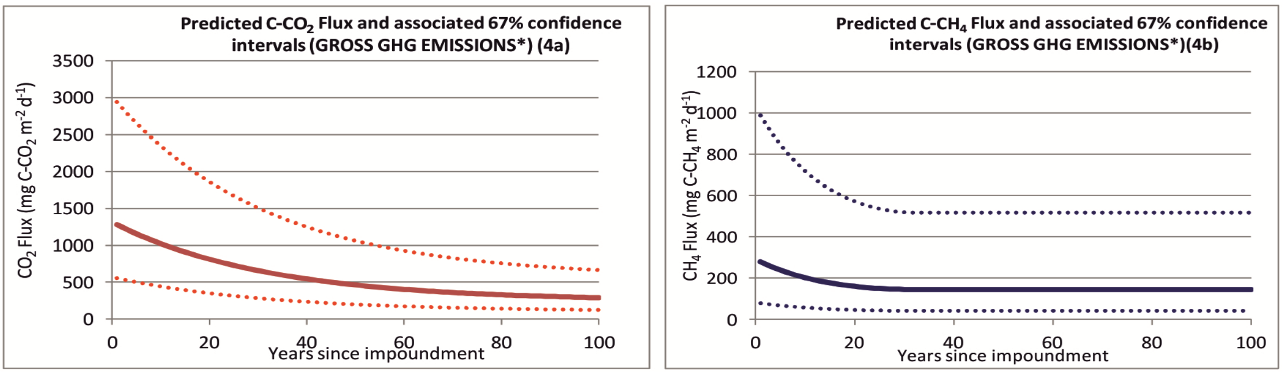


Fig 4: Sardar Sarovar predicted values over 100 years of (a) Gross GHG C- CO_2 diffusive fluxes (b) Gross GHG C- CH_4 diffusive fluxes

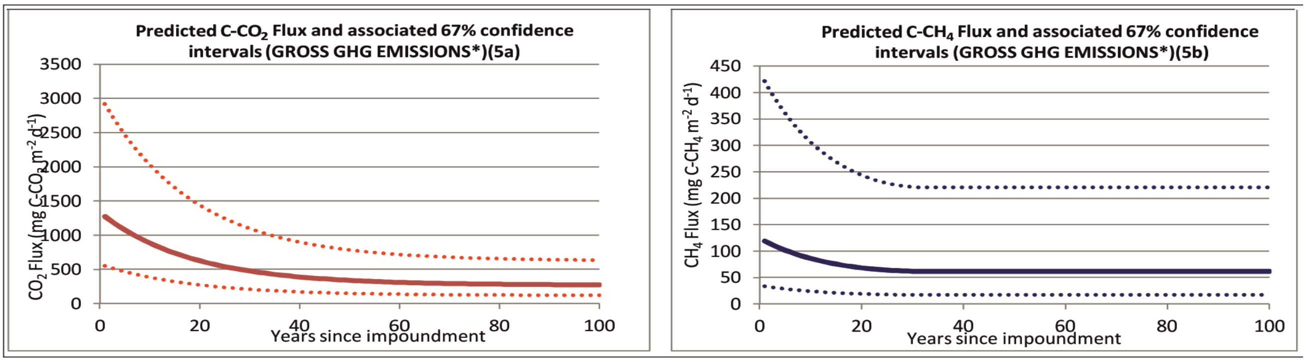


Fig 5: Pong Station predicted values over 100 years of (a) Gross GHG C- CO_2 diffusive fluxes (b) Gross GHG C- CH_4 diffusive fluxes

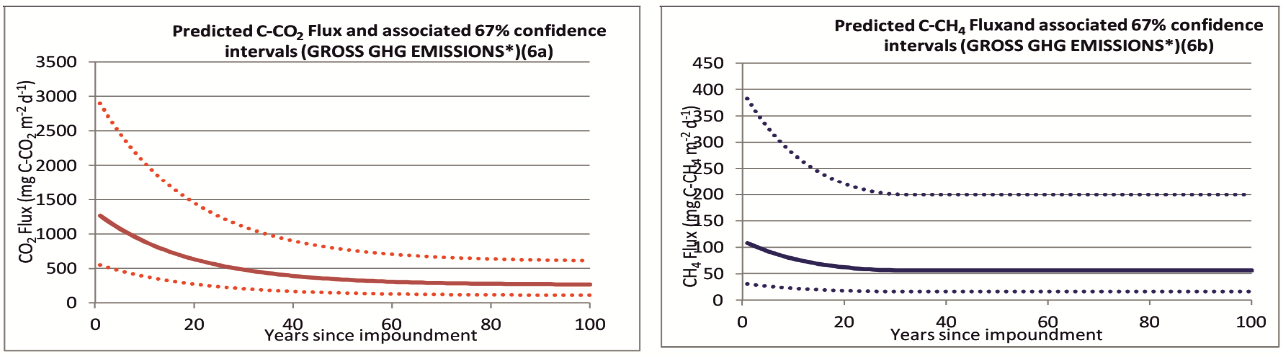


Fig 6: Bhadra Station predicted values over 100 years of (a) Gross GHG C- CO_2 diffusive fluxes (b) Gross GHG C- CH_4 diffusive fluxes

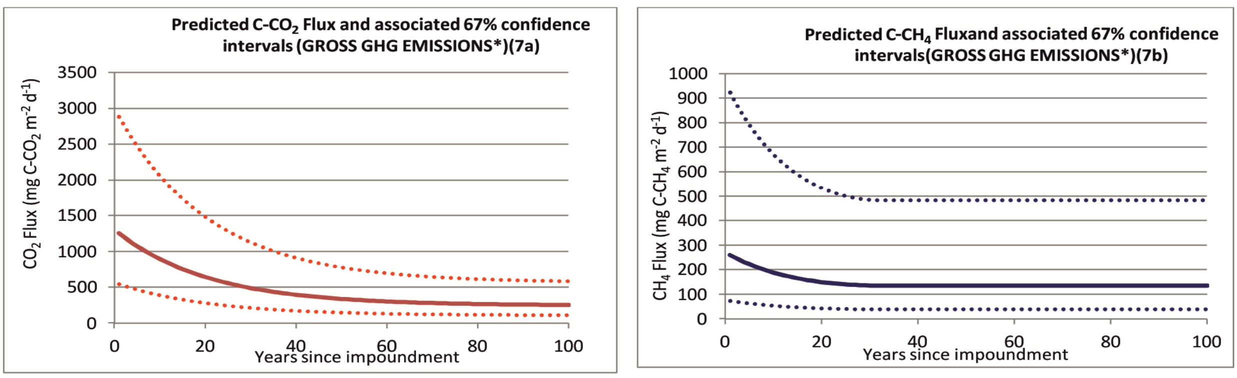


Fig 7: Sabarigiri Station predicted values over 100 years of (a) Gross GHG C- CO_2 diffusive fluxes (b) Gross GHG C- CH_4 diffusive fluxes

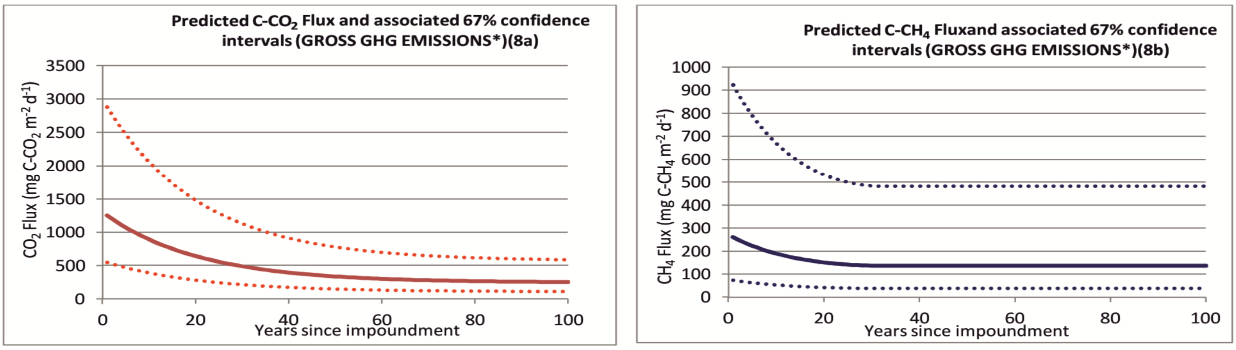


Fig 8: Madhikhera Station predicted values over 100 years of(a) Gross GHG C- CO_2 diffusive fluxes (b) Gross GHG C- CH_4 diffusive fluxes

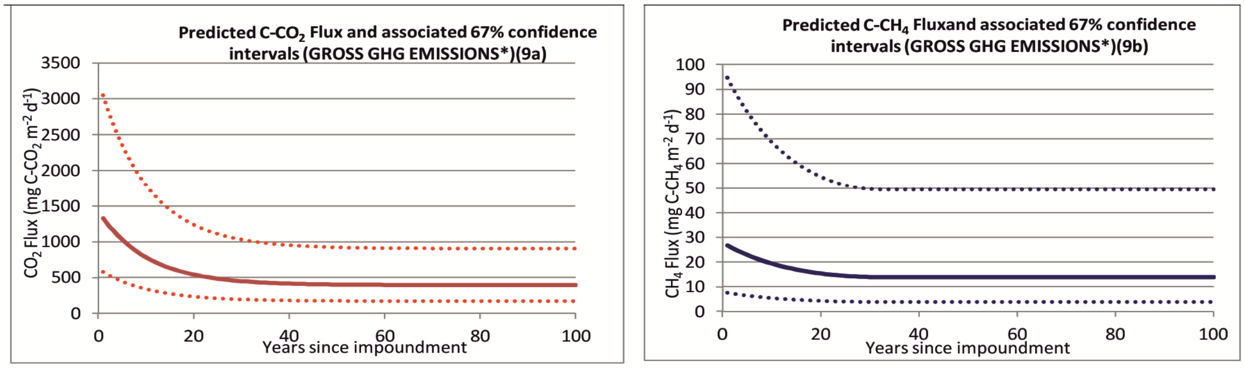


Fig 9: Nagaland Station predicted values over 100 years of (a) Gross GHG C- CO_2 diffusive fluxes (b) Gross GHG C- CH_4 diffusive fluxes

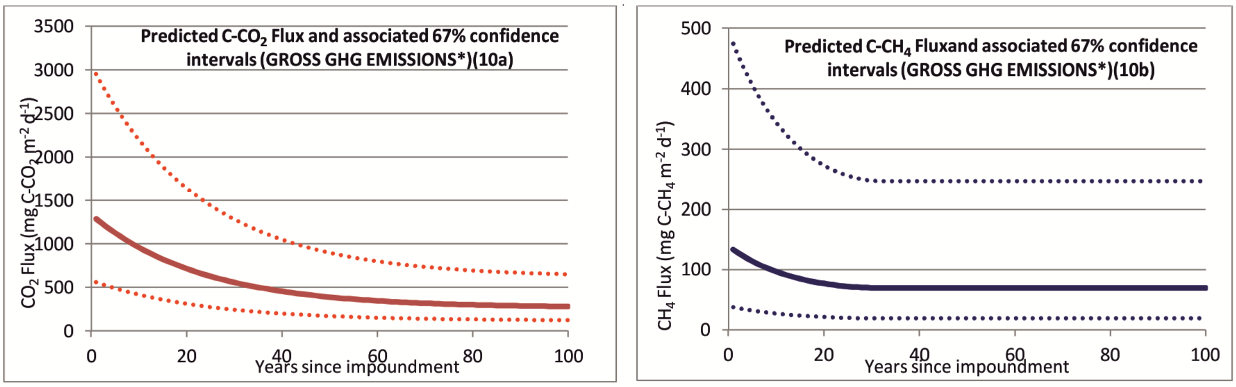


Fig 10: Hirakud Station predicted values over 100 years of (a) Gross GHG C- CO_2 diffusive fluxes (b) Gross GHG C- CH_4 diffusive fluxes

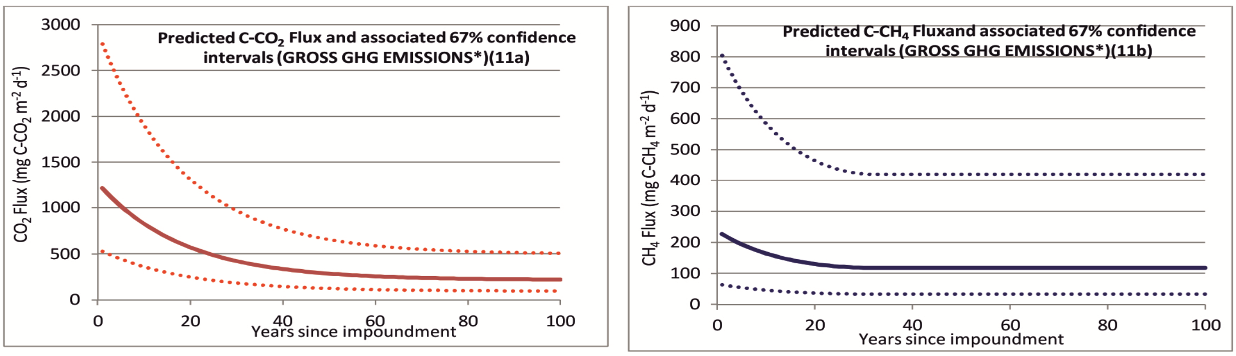
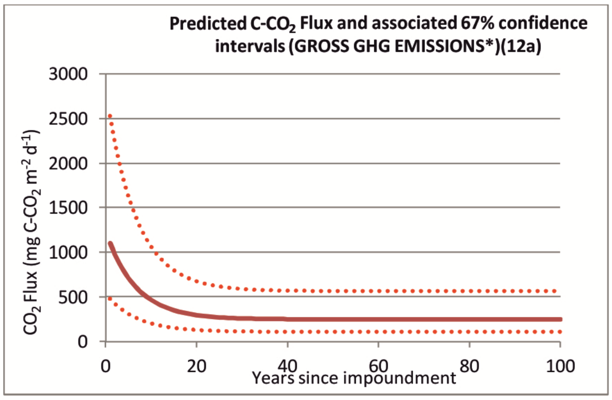


Fig 11: Srisailam Station predicted values over 100 years of (a) Gross GHG C- CO_2 diffusive fluxes (b) Gross GHG C- CH_4 diffusive fluxes



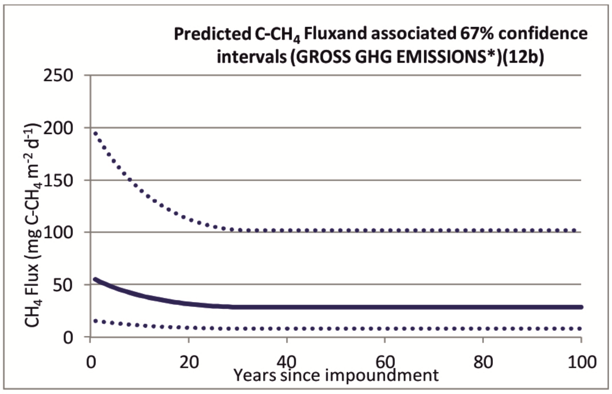
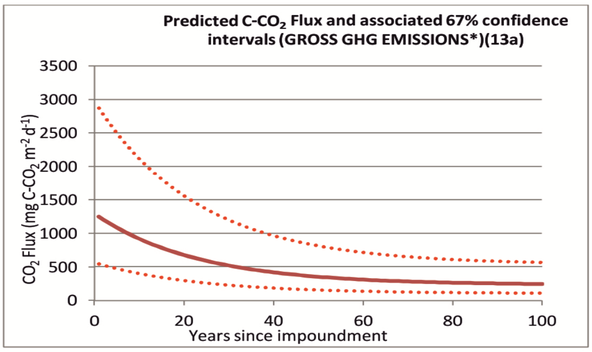


Fig 12: Tehri Station predicted values over 100 years of (a) Gross GHG C- CO_2 diffusive fluxes (b) Gross GHG C- CH_4 diffusive fluxes



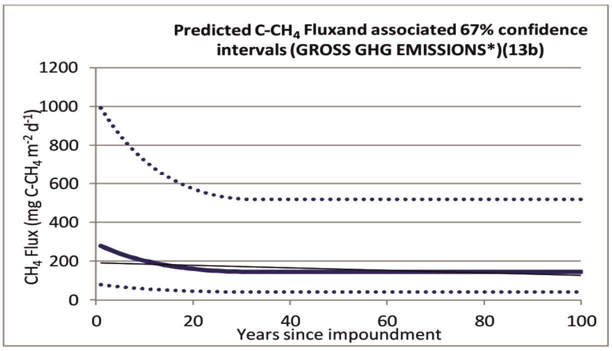
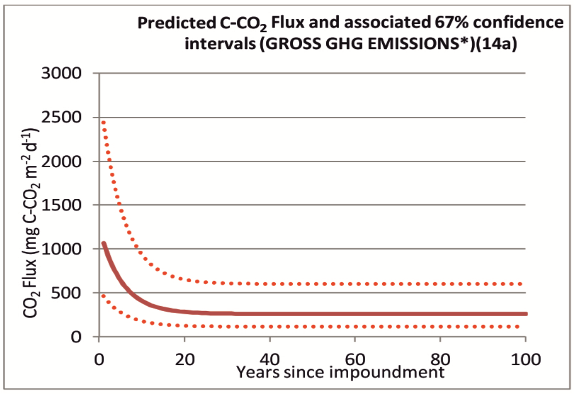


Fig 13: Rana p Sagar Station predicted values over 100 years of (a) Gross GHG C- CO_2 diffusive fluxes (b) Gross GHG C- CH_4 diffusive fluxes



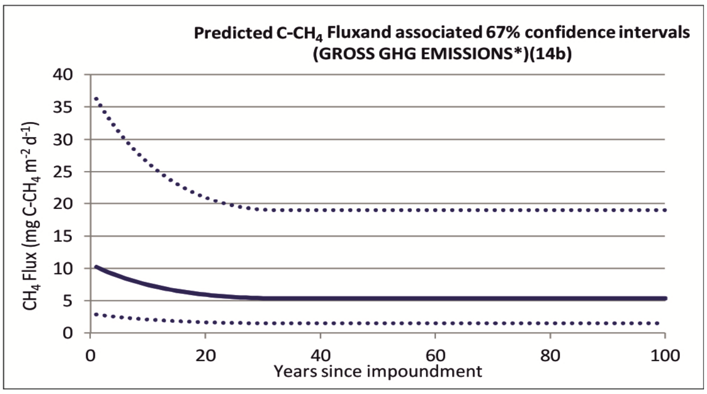


Fig. 14: Subansari Station predicted values over 100 years of (a) Gross GHG C- CO_2 diffusive fluxes(b) Gross GHG C- CH_4 diffusive fluxes

Source: Derived from UNESCO/IHA GHG Risk Assessment Tool (Beta Version)

CONCLUSIONS

Water bodies have the potential to emit large amounts of CO_2 and CH_4 and therefore contribute to global warming. The decomposition of organic matter is the main reason for the production of these GHGs. So we have to control the entrance of organic matter and nutrients into water bodies up to some extent. In the present case study of eleven major reservoir in India, the present (2013) predicted emission are about 6 million T-CO_2eq per year at their respective ages. At present CH_4 emissions are high for all the reservoirs as compared with the threshold limits of the model except Doyang and CO_2 emissions are high for reservoirs of Sardar sarovar, Madhikhera, Doyang and Hirakud dam. While considering life time assessment of the reservoir (100 years) the emissions of CH_4 is high for all reservoirs except Doyang. However, CO_2 emissions throughout the life time assessment (100 years) the emissions is within threshold limit. Even though these are predicted values, the CH_4 emissions is high for all the reservoirs, so mitigation measures must be taken to reduce the emission of CH_4 because GWP of CH_4 is 25 times higher than CO_2. For example, a possibility to minimize the CO_2 and CH_4 production in water bodies due to falling trees before flooding process should be explored so that less organic matter is available for decomposition. Due to the fact that the oxidation of CH_4 through methanotrophic bacteria seems to be a key factor to decrease the amount of CH_4 released into the atmosphere, this mechanism should be supported somehow to minimize the emissions from water bodies although there is still a need for a lot of research to understand all the important processes.

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