Mekong River Commission
Basin Development Plan Programme, Phase 2

Assessment of basin-wide development scenarios

List of Technical Notes

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Note: Technical note on Fisheries Assessment is being prepared. Only power point presentation is available

Part 2: Impacts on water quality

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1 Introduction

Water quality is a key factor affecting the health of the Mekong River system and associated wetlands. Presently, at the local level, along the mainstream, pollution levels can rise above the standards during the dry season, particularly downstream of inflowing tributaries that drain sub-basins with larger or expanded irrigated areas e.g. NE Thailand and the Mekong Delta. Many wetlands contribute significantly to wastewater treatment.

In 2005 there were 87 water quality sampling stations in the Mekong basin, 55 primary stations with a basin wide or transboundary significance and 32 secondary stations. Twenty-three of the primary stations are located along the main stream, 23 on tributaries and 9 in the Delta. Data are available for a period of about 20 years.

Three water quality indices (WQI) are used: (i) for the protection of aquatic life (WQIal), (ii) for human impact (WQIhi) and (iii) for agricultural use (WQIag). Each WQI is composed of a number of water quality parameters. For WQIal these are DO, pH, NH_3, Conductivity, NO_{3-2} and total-P. The human impact WQI is considers DO, COD_{mn} and NH_4. The agricultural water quality index is based on salinity.

In the mainstream and tributaries the water quality for aquatic life is generally high, in the Delta conditions are less favorable. Signs of human impact on water quality are observed in most of the tributaries, and in the mainstream, downstream of Phnom Penh. Water quality does not restrict agricultural use, except in the Delta where high levels of salinity hinder agriculture.

Pollution with pesticides or industrial contaminants has not been detected.

Under the development scenarios pollutant loads to the rivers will increase due to increased return flows from irrigated agriculture (containing pesticides and nutrients) and increased discharges of (untreated) domestic and industrial waste water (having high levels of BOD, COD, nutrients and pollutants). At the same time flows in the receiving rivers change.

The final effect of these pollutant loads on the water quality of the main river depends on the discharge of the river. Impacts will be highest during low flows. The assessment therefore concentrated on dry season conditions. In the wet season discharges in the main river are so high that increased loads will be diluted very much.

Sediment concentrations may be affected by changes in sediment supply to the system (entrapment of sediments in hydropower reservoirs) and by changes in the flow characteristics of the river, effecting the sediment transport capacity.

1.1 Pollutants in agricultural return flows

The main areas of irrigation development have been mapped in the GIS and estimates on present and future agro-chemical (fertilizers, herbicides and insecticides and fungicides) use in ton/ha per crop and crop season have been made (MRC, 2009). By combining this information the total present and future agro-chemical use has been calculated for 21 major river basins in the Lower Mekong Basin and summarized for each of the four LMB countries and the basin as a whole.

Agro-chemical use in the LMB countries will increase under the scenarios for 2 reasons: firstly the area under irrigated agriculture will increase and secondly agriculture in the irrigated areas will intensify leading to higher rates of agro-chemical application.

1.1.1 Projected changes in irrigated areas

Irrigated agricultural areas in the four LMB countries are expected to increase in the four countries as given in the following tables.

Table 1: Irrigated crop areas under the Definite Future (2015) scenario, in ha

	Rice				
	1st Season	2nd Season	3rd Season	Non-rice Crop	Total
Lao PDR	166,476	97,224	0	6,977	270,677
Thailand	1,354,804	148,255	0	252,704	1,755,763
Cambodia	273,337	260,815	16,713	12,172	563,037
Viet Nam - Highland	141,684	76,184	0	34,841	252,709
Viet Nam Delta	1,528,225	663,410	1,478,740	294,899	3,965,274
Total LMB	3,464,526	1,245,888	1,495,453	601,593	6,807,460

Table 2: Irrigated crop areas under the 20 Year Plan scenario, in ha

	Rice				
	1st Season	2nd Season	3rd Season	Non-rice Crop	Total
Lao PDR	449,595	329,952	0	40,046	819,593
Thailand	2,635,477	427,741	0	560,784	3,624,002
Cambodia	456,828	378,917	21,594	19,879	877,218
Viet Nam - Highland	266,576	76,184	0	96,413	439,171
Viet Nam - Delta	1,528,225	663,410	1,478,740	294,899	3,965,274
Total LMB	5,336,701	1,876,204	1,500,334	1,012,021	9,725,258

Table 3: Increment in irrigated crop areas, 20 Year Plan vs Definite Future, in ha and %

	Rice									
	1st Season		2nd Season		3th Season		Non-rice crop		Total	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Lao PDR	283,119	170.1	232,728	239.4	0	0.0	33,069	474.0	548,916	202.8
Thailand	1,280,673	94.5	279,486	188.5	0	0.0	308,080	121.9	1,868,239	106.4
Cambodia	183,491	67.1	118,102	45.3	4,881	29.2	7,707	63.3	314,181	55.8
Viet Nam - Highland	124,892	88.1	0	0.0	0	0.0	61,572	176.7	186,462	73.8
Viet Nam Delta	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	1,872,175	54.0	630,316	50.6	4,881	0.3	410,428	68.2	2,917,798	42.9

1.1.2 Projected changes in fertilizer use and loss

Fertilizer application was very low in rainfed areas of Cambodia, Lao PDR and NE Thailand in 2007. This is a reflection of high risk of rice farming under rainfed conditions. Irrigated rice yields are significantly higher than the rainfed yields and require more fertilizer to fulfill the crops potential. These irrigated crops are the main dry season crops in the LMB. Current application rates in the Mekong Delta are significantly higher than in other parts of the basin.

The major elements required for plant growth are Nitrogen (N), Phosphorus (P) and Potassium (K). In addition, small amounts of Sulfur (S) and other elements may be required to achieve higher yields.

Nitrogen limits the yields of most rice crops. The efficiency of applying nitrogen fertilizer decreases with increasing rate of N fertilizer. Rather than increasing the fertilizer rate to an unreasonable level it is preferred to improve the efficiency of the applied fertilizer. This saves money and reduces elemental losses into the environment.

Phosphorus and potassium application rates are generally lower than for nitrogen. Higher applications of phosphorus are necessary in rainfed conditions to attain higher yields as it may become fixed in the soil if the soil is subjected to alternating wetting and drying. Potassium is taken from the field in straw and other organic matter. The higher the biomass taken from the field the higher the rate of required applied K.

It is presumed that N (active ingredient) applications will not significantly exceed 100 kg/ha. This application rate is found to be the most profitable level to apply in Vietnam. The ratio of fertilizers will also vary by soil type and stage of the crop. Fertilizers use for the third crop is estimated to lie between dry season and rainfed application respectively.

Assumed fertilizer application rates under the Definite Future and 20 Year Plan scenario in irrigated areas are given in the tables below. It has to be remarked that amounts given here for the Definite Future scenario actually refer to the present (2007-2008) situation.

Table 4: Fertilizer use in the LMB countries, under Definite Future scenario

Urea Fertilizer use Definite Future (kg/ha)				
	Rice			Non-rice Crop
	1st Season	2nd Season	3rd Season	
Lao PDR	40	80	0	150
Thailand	40	80	0	150
Cambodia	40	80	70	150
Viet Nam - Highland	40	80	70	150
Viet Nam –Delta	140	180	160	150
DAP Fertilizer use Definite Future (kg/ha)				
	Rice			Non-rice Crop
	1st Season	2nd Season	3rd Season	
Lao PDR	10	50	0	100
Thailand	20	60	0	100
Cambodia	20	60	30	100
Viet Nam - Highland	20	60	30	100
Viet Nam –Delta	120	120	120	100
NPK Fertilizer use Definite Future (kg/ha)				
	Rice			Non-rice Crop
	1st Season	2nd Season	3rd Season	
Lao PDR	0	0	0	0
Thailand	0	0	0	0
Cambodia	0	0	0	0
Viet Nam - Highland	0	0	0	0
Viet Nam –Delta	0	0	0	0

Table 5: Fertilizer use in the LMB countries, under the 20 Year Plan scenario

Urea Fertiliser use 20 Year Plan (kg/ha)				
	Rice			Non-rice Crop
	1st Season	2nd Season	3rd Season	
Lao PDR	120	160	0	200
Thailand	100	140	0	200
Cambodia	100	160	150	200
Viet Nam - Highland	100	160	150	200
Viet Nam –Delta	150	180	160	200
DAP Fertiliser use 20 Year Plan (kg/ha)				
	Rice			Non-rice Crop
	1st Season	2nd Season	3rd Season	
Lao PDR	50	120	0	150
Thailand	70	100	0	150
Cambodia	70	120	120	150
Viet Nam - Highland	70	120	120	150
Viet Nam –Delta	110	120	120	150
NPK use 20 Year Plan (kg/ha)				
	Rice			Non-rice Crop
	1st Season	2nd Season	3rd Season	
Lao PDR	0	10	0	0
Thailand	0	10	0	0
Cambodia	0	10	10	0
Viet Nam - Highland	0	10	10	0
Viet Nam –Delta	0	80	80	0

MRC (2008, MRC Technical Paper No. 19, An assessment of water quality in the Lower Mekong Basin) assumes that 20 percent of the applied N and 10% of the applied P will be lost by surface runoff and percolation and end up in the irrigation return flow. The percentages are confirmed by recent literature, e.g. Pathak et al., 2007 (B.K. Pathak, Iida, T. and F. Kazama, Denitrification as a component of N budget in a tropical paddy field, Global NEST Journal, Vol. 9, No 2, pp 159-165).

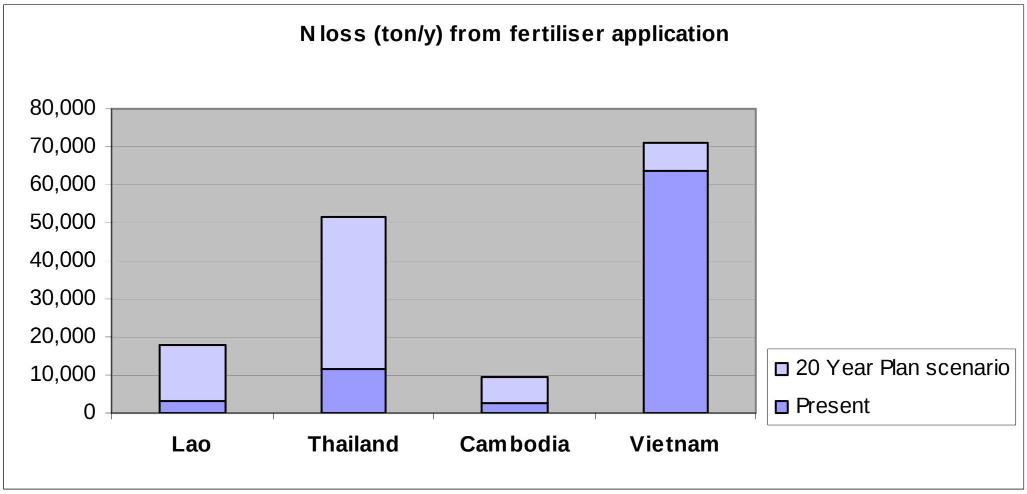
Incremental losses of N and P (as P_2O_5) have been calculated for the Definite Future scenario and the 20 Year plan scenario. The calculations are based on the following assumed active ingredient percentages of 46% N in UREA, 16% N in DAP, 15% N in NPK, 20% P (as P_2O_5) in DAP and 15% P (as P_2O_5) in NPK. Results of the calculations for the 4 LMB countries are given in Table 6 The table shows that N losses from irrigated agriculture to the river system in the basin will increase from 81,000 ton/y at present to 150,000 ton/y under the 20 year Plan scenario, an increase with 85%. P losses will double in this period, from roughly 10,000 to roughly 20,000 ton P_2O_5 per year. Increases are biggest in Lao PDR and Thailand, somewhat lower in Cambodia and limited in Vietnam. Of the incremental N load, 21% comes from Lao PDR, 58% from Thailand, 10% from Cambodia and 11% from Vietnam. Thailand also generates most of the incremental P load: 52%, followed by Vietnam (23%), Lao PDR (16%). Cambodia generated only 9 % of the incremental P load. See also Figure 1.

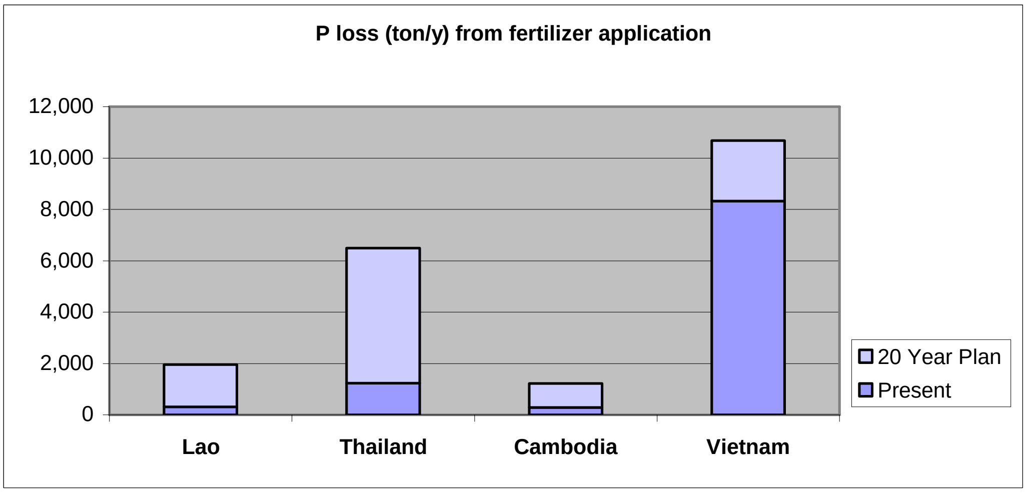
Table 6: Definite Future and 20 Year Plan scenario N and P (as P_2O_5) loss (ton/yr) per LMB country and for the basin as a whole

	N			P		
	Loss	Increase	% Change	Loss	Increase	% Change
Lao PDR						
Definite Future scenario	3,371	0	0	308	0	0
20 Year Plan scenario	18,039	14,668	435	1,954	1,647	535
Thailand						
Definite Future scenario	11,631	0	0	1,239	0	0
20 Year Plan scenario	51,700	40,070	345	6,487	5,248	424
Cambodia						
Definite Future scenario	2,455	0	0	281	0	0
20 Year Plan scenario	9,377	6,922	282	1,219	938	334
Vietnam						
Definite Future scenario	63,550	0	0	8,329	0	0
20 Year Plan scenario	71,019	7,469	12	10,683	2,354	28
Total basin						
Definite Future scenario	81,007	0	0	10,156	0	0
20 Year Plan scenario	150,135	69,128	85	20,344	10,187	100

To better understand which parts of the river system will be effected most by increased agro-chemical use, the calculations have also been made for 21 major sub-basins. Figure 1 shows the river basins distinguished. These sub-basins are sub-basins or combinations of the sub-basins as distinguished in the MRC Basin Development Plan. Table 7 gives the results of the calculations. The table shows that nearly half of the incremental N loss of nearly 70,000 ton/y will come from the Nam Chi/Nam Mun basin

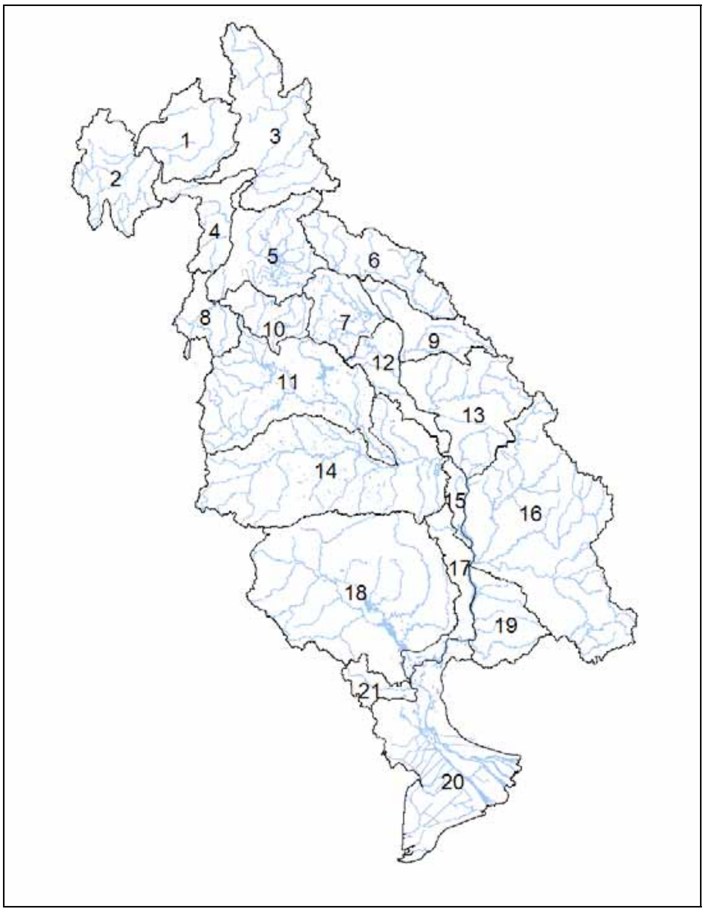
Figure 1 Present and projected N and P loss from fertilizer application in the LMB





(31,5000 ton/y). A considerable load is also coming from the 3 Ssbasins (7,100 ton/y), whereas the load on the Tonle Sap system will increase significantly as well (with 5,500 ton/y). Incremental P losses follow the same pattern: most of the additional load is coming from the same 4 basins mentioned above.

Figure 2: Location of the river basins used in the analysis. For names of the basins see Table 7



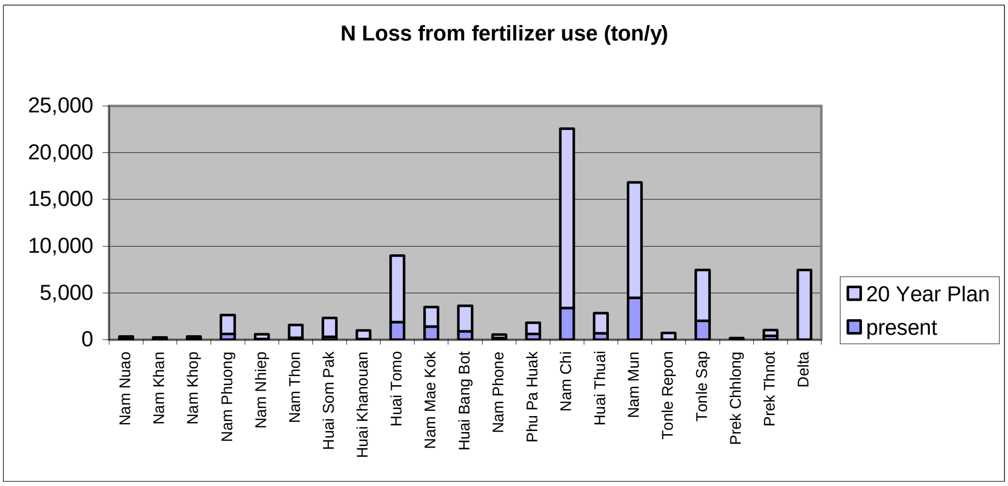
The consequences of these higher loads for water quality and ecology are discussed in Chapter 3.

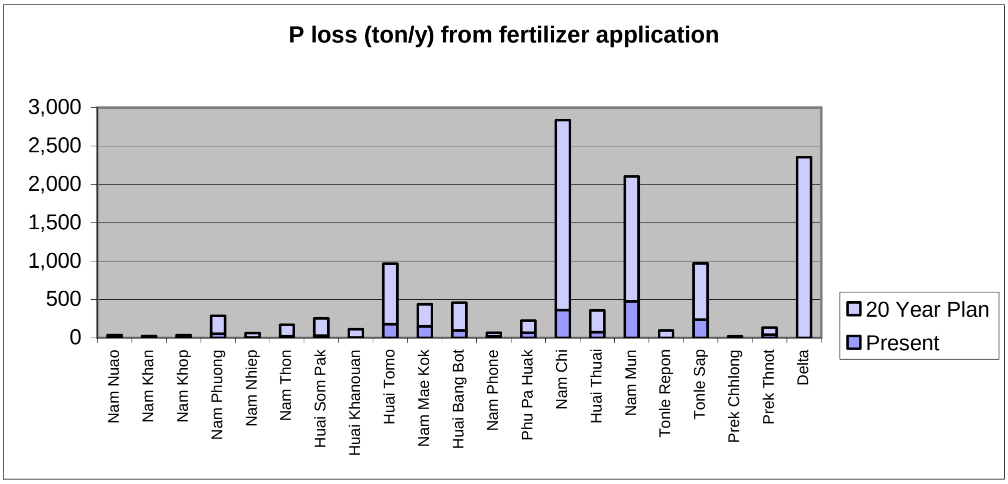
Table 7: Definite Future and 20 Year Plan scenario N and P (as P_2O_5) loss (ton/y) per catchment and country

Catchment		N Loss (ton/y)				P Loss (ton/y)			
		DF	20YP	Change		DF	20YP	Change	
Lao PDR				(ton/y)	%			(ton/y)	%
1	Nam Nuao	76	333	257	337	6	36	30	455
3	Nam Khan	69	239	170	248	6	26	20	333
4	Nam Khop	69	351	282	412	6	37	32	543
5	Nam Phuong	627	2,642	2,016	322	55	288	234	427
6	Nam Nhiep	65	576	511	789	5	65	59	1,085
9	Nam Theun	218	1,560	1,342	616	19	169	151	802
13	Huai Som Pak	305	2,334	2,029	665	27	256	229	838
15	Huai Khanouan	64	1,003	939	1,472	6	111	105	1,849
16	Huai Tomo (3Ss)	1,880	9,001	7,121	379	178	966	788	444
	Total	3,371	18,039	14,668	435	308	1,954	1,647	535
Thailand									
2	Nam Mae Kok	1,405	3,481	2,076	148	150	437	287	191
7	Huai Bang Bot	878	3,638	2,760	314	94	458	364	387
8	Nam Phone	184	538	354	192	19	67	48	250
10	Phu Pa Huak	604	1,802	1,198	198	65	227	162	250
11	Nam Chi	3,373	22,578	19,204	569	362	2,837	2,475	683

12	Huai Thuai	699	2,852	2,153	308	75	359	284	380
14	Nam Mun	4,487	16,811	12,325	275	474	2,102	1,629	344
	Total	11,631	51,700	40,070	345	1,239	6,487	5,248	424
Cambodia									
17	Tonle Repon	1	702	701	-	0	95	95	-
18	Tonle Sap	2,024	7,468	5,444	269	236	970	734	312
19	Prek Chhlong	21	164	143	686	2	21	19	910
21	Prek Thnot	410	1,043	633	155	43	133	90	210
	Total	2,455	9,377	6,922	282	281	1,219	938	334
Vietnam									
20	Delta	63,550	71,019	7,469	12	8,329	10,683	2,354	28
	Total	63,550	71,019	7,469	12	8,329	10,683	2,354	28
Total		81,007	150,135	69,128	85	10,156	20,344	10,187	100

Figure 3: Present and projected N and P loss from fertilizer application in the LMB sub-catchments





1.1.3 Projected changes in herbicide and pesticide and fungicide use

Use of pesticides has been on the increase in all riparian countries. However, there is no sign of any basin wide significant trend in any water chemistry parameter. Pesticide levels were below detection limits in river water studies conducted between 2003 and 2004 (MRC, 2007). Pesticide applications are low in Cambodia, Lao PDR and NE Thailand because of the low degree of intensive agriculture in these watersheds. In Lao PDR, the Ministry of Agriculture, Forestry and Fisheries is promoting the export of large quantities of 'organic rice' at premium prices indicating the governments will discourage the heavy use of pesticides in that country but it will be difficult to prevent farmers from protecting their higher yielding crops.

In Vietnam, insecticides account for 54% by weight of all pesticides sold. Of pesticides used on rice, 85% are insecticides. Fungicides are less common on rice. The use of herbicides will increase as direct broadcasting of rice becomes more popular to maintain the crop reasonably weed free.

Pesticide use across the Mekong basin is expected to increase over the 20 year period leading up to 2030. Herbicides will be extensively used in irrigation areas as farmers convert from transplanting to direct seeding in an effort to reduce labor costs. Minimum tillage methods may also become more common during this period, encouraging the basal application of glyphosate (Roundup) type herbicides. Glyphosate is relatively non toxic and is denatures as it hits the soil. Foliar application herbicides are slightly more toxic.

Fungicides are classified as being moderately toxic to toxic for humans, animals and fish. Systemic toxicity is generally low but some organic fungicides exhibit low acute oral and dermal toxicity in laboratory animals. Some breakdown components of fungicides may be more toxic to humans than the product itself.

Insecticides are generally toxic in nature to humans and are more strictly controlled by government agencies than other pesticides. Farmers are also aware of the adverse affect of pesticides on the balance of 'friendly' insects in the rice fields and there is a trend of reduced insecticide use after integrated pest management (IPM) training courses. The International Rice Research Institute is promoting the use of Integrated Pest Management concepts in rice to reduce these toxic effects and reduce the farmers' dependence on pesticides. Whether this has any effect on the overall consumption of pesticides over the next 20 years remains to be seen.

According to Nesbitt (2009) the use of insecticides and fungicides will increase significantly on rainfed and irrigated wet season crops for each country except Vietnam where usage may have already peaked. Dry season use should remain fairly stable across all countries for the same reasons. The use of herbicides will double in Lao PDR and Cambodia and increase by 25% in NE Thailand and Vietnam as broadcasting of rice seed becomes more popular.

Tables 8 and 9 show the expected changes in herbicide and insecticide and fungicide use for each of the countries. Note that the Definite Future figures actually represent the current situation.

Table 8: Herbicide and insecticide and fungicide use in the four LMB countries, kg/ha, Definite Future scenario (current situation)

Herbicide use Definite Future (kg/ha)				
	Rice			Non-rice Crop
	1st Season	2nd Season	3rd Season	
Lao PDR	2.4	2.4	0	8
Thailand	6.4	6.4	0	8
Cambodia	2.4	2.4	2.4	8
Viet Nam - Highland	2.4	2.4	2.4	8
Viet Nam -Delta	6.4	6.4	6.4	8
Insecticide and fungicide use Definite Future (kg/ha)				
	Rice			Non-rice Crop
	1st Season	2nd Season	3rd Season	
Lao PDR	1.0	7.0	0.0	12.0
Thailand	7.0	7.0	0.0	12.0
Cambodia	1.0	7.0	7.0	12.0
Viet Nam - Highland	1.0	7.0	7.0	12.0
Viet Nam -Delta	7.0	7.0	7.0	12.0

Table 9: Herbicide and insecticide and fungicide use in the four LMB countries, kg/ha, 20 Year Plan scenario

Herbicide use 20YP (kg/ha)				
	Rice			Non-rice Crop
	1st Season	2nd Season	3rd Season	
Lao PDR	5.6	5.6	0.0	8.0
Thailand i	8.0	8.0	0.0	8.0
Cambodia	5.6	5.6	2.4	8.0
Viet Nam - Highland	5.6	5.6	2.4	8.0
Viet Nam -Delta	8.0	8.0	6.4	8.0
Insecticide and fungicide use 20YP (kg/ha)				
	Rice			Non-rice Crop
	1st Season	2nd Season	3rd Season	
Lao PDR	3.0	7.0	0.0	17.0
Thailand i	7.0	7.0	0.0	17.0
Cambodia	3.0	7.0	7.0	17.0
Viet Nam - Highland	3.0	7.0	7.0	17.0
Viet Nam -Delta	7.0	7.0	7.0	17.0

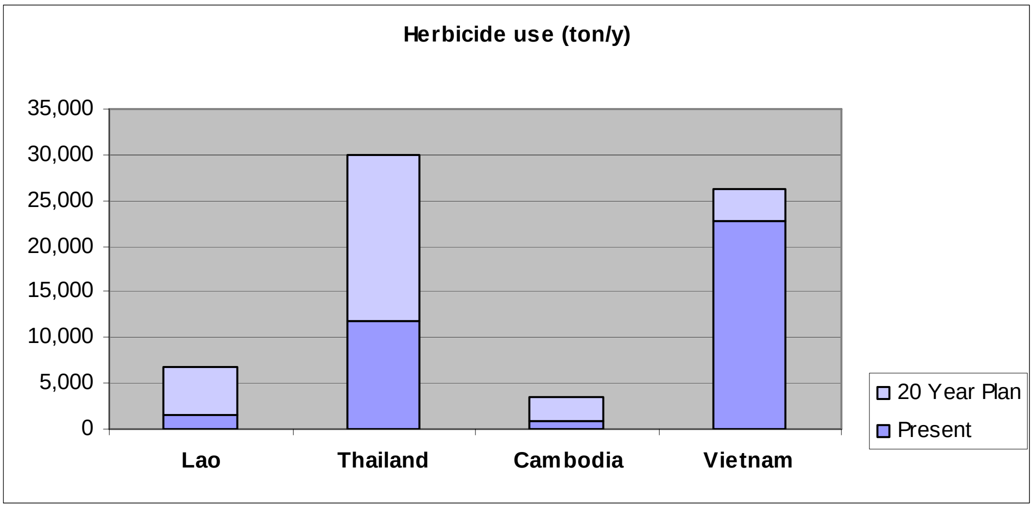
Present and 20 Year Plan scenario herbicide and insecticide and fungicide use have been calculated in the same way as fertilizer use has been calculated. The results for the 4 LMB countries and each of the 21 sub-basins are given in Table 10 and Figure .

Overall herbicide use in the basin will increase with 75% in the next 20 years, whereas the use of insecticides and fungicides is expected to increase with nearly 60%. Herbicide use increases most in Lao PDR and Cambodia (359 and 284%), more than doubles in Thailand (from about 12,000 ton/y to nearly 30,000 ton/y) and only increases with 15% in Vietnam. Insecticide and fungicide use increases with 250% in Lao PDR, with between 120 and 130% in Cambodia and Thailand and with only 5% in Vietnam.

Table 10: Herbicide and Insecticide and fungicide use in the 4 LMB countries under the Definite Future (present) scenario and the 20 Year Plan scenario

	Herbicides			Insecticides and fungicides		
	Use	Increase	% Change	Use	Increase	% Change
Lao						
Definite Future scenario	1,463	0	0	1,939		
20 Year Plan scenario	6,721	5,258	359	6,723	4,783	247
Thailand						
Definite Future scenario	11,761			13,665		
20 Year Plan scenario	29,874	18,113	154	31,752	18,087	132
Cambodia						
Definite Future scenario	908	0	0	1,455	0	0
20 Year Plan scenario	3,483	2,575	284	3,192	1,737	119
Vietnam						
Definite Future scenario	22,828	0	0	25,720	0	0
20 Year Plan scenario	26,352	3,524	15	27,098	1,378	5
Total basin						
Definite Future scenario	36,235	0	0	41,519	0	0
20 Year Plan scenario	63,373	27,138	75	65,911	24,392	59

Figure 4: Present and projected herbicide use (ton/y) in the LMB countries

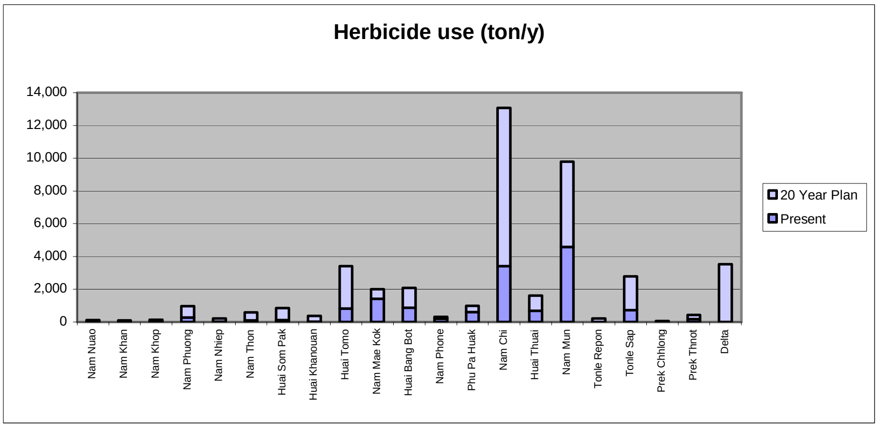


When considered on the level of sub-basins the trend in pesticide use are comparable with the trends in fertilizer use. The 3 Ss Basins and Nam Chi and Nam Mun are responsible for more than 50% of the total increase in pesticide use in the LMB. In Cambodia pesticide use in the Tonle Sap basin increases considerably. Table 11 gives the details.

Table 11: Definite Future and 20 Year Plan scenario herbicide and insecticide and fungicide use (ton/yr) per catchment and country

Catchment		Herbicide use (ton/y)				Insecticide and fungicide use (ton/y)			
		DF	20 YP	Change		DF	20YP	Change	
Lao				ton/y	%			ton/y	%
1	Nam Nuao	33	124	91	274	41	116	75	181
3	Nam Khan	29	89	60	207	38	84	47	123
4	Nam Khop	30	132	102	341	37	124	88	238
5	Nam Phuong	276	973	697	252	344	920	576	168
6	Nam Nhiep	29	207	178	622	34	199	164	479
9	Nam Thon	102	576	474	465	115	536	421	366
13	Huai Som Pak	121	854	732	603	178	792	613	344
15	Huai Khanouan	25	363	337	1,331	37	330	292	784
16	Huai Tomo	817	3,403	2,586	316	1,115	3,623	2,508	225
	Total	1,463	6,721	5,258	359	1,939	6,723	4,783	247
Thailand									
2	Nam Mae Kok	1,427	2,011	584	41	1,650	2,130	480	29
7	Huai Bang Bot	873	2,085	1,212	139	1,018	2,197	1,179	116
8	Nam Phone	190	311	120	63	222	331	109	49
10	Phu Pa Huak	602	1,000	398	66	699	1,128	429	61
11	Nam Chi	3,404	13,065	9,661	284	3,934	13,623	9,689	246
12	Huai Thuai	687	1,623	937	136	805	1,725	921	114
14	Nam Mun	4,577	9,780	5,202	114	5,338	10,618	5,280	99
	Total	11,761	29,874	18,113	154	13,665	31,752	18,087	132
Cambodia									
17	Tonle Repon	1	209	209	39,714	0	260	260	72,958
18	Tonle Sap	714	2,784	2,071	290	1,252	2,538	1,286	103
19	Prek Chhlong	11	64	53	499	7	55	47	634
21	Prek Thnot	183	426	243	133	194	338	144	74
	Total	908	3,483	2,575	284	1,455	3,192	1,737	119
Vietnam									
20	Delta	22,828	26,352	3,524	15	25,720	27,098	1,378	5
	Total	22,828	26,352	3,524	15	25,720	27,098	1,378	5
Total		36,235	63,373	27,138	75	41,519	65,911	24,392	59

Figure 5: Present and projected herbicide use (ton/y) in the LMB sub-catchments



1.2 Pollutants in waste water discharges

A rough estimate has been made of the increase in waste water pollutant loads produced from the major urban areas in the LMB. The calculations are based on expected population numbers under the various scenarios and an assumed person equivalent load of 30 g BOD, 2.4 g Total-P and 8 g Total-N per day (MRC, 2008, An Assessment of Water Quality in the Lower Mekong Basin, MRC Technical Paper No 19, Nov 2008). The estimations have been made for the major cities along the main river and the major tributaries as well as for all the urban areas in each of the 20 sub-basins. The results are given in the tables below.

Table 12: Changes in waste water pollutant loads (ton/y and %)

	BOD (ton/y)			N (ton/y)			P (ton/y)		
	Discharge	Change		Discharge	Change		Discharge	Change	
Lao	ton/y	ton/y	%	ton/y	%	ton/y	%	ton/y	%
Present	32,358	0	0	8,629	0	0	2,589	0	0
20 Year Plan scenario	49,534	17,175	53.1	13,209	4,580	53.1	3,963	1,374	53.1
Thailand									
Present	52,414	0	0	13,977	0	0	4,193	0	0
20 Year Plan scenario	56,152	3,738	7.1	14,974	997	7.1	4,492	299	7.1
Cambodia									
Present	24,872	0	0	6,633	0	0	1,990	0	0
20 Year Plan scenario	35,234	10,362	41.7	9,396	2,763	41.7	2,819	829	41.7
Vietnam									
Present	37,110	0	0	9,896	0	0	2,969	0	0
20 Year Plan scenario	54,130	17,020	45.9	14,435	4,539	45.9	4,330	1,362	45.9
Total basin									
Present	146,755	0	0	39,135	0	0	11,740	0	0
20 Year Plan scenario	195,051	48,296	32.9	52,014	12,879	32.9	15,604	3,864	32.9

The figures in the table above pertain to changes in the amount of urban wasteload produced. On the basin level, an increase in produced urban waste load of 33% is expected. Increases of course reflect assumed population growth figures and are greatest in Lao PDR (over 50%) and somewhat lower in Cambodia and Vietnam (40 to 50%). Predicted increases in Thailand are limited, less than 10%.

However, most of these discharges will not reach the river systems, since sanitation facilities are in place in most municipalities. MRC (2003) gives figures on urban sanitation coverage in the LMB countries for the year 2000. For Lao PDR the cited coverage ranges between 46 and 67%, for Thailand a coverage of 96% is given, coverage in Cambodia is much lower (18 to 56%), whereas for Vietnam figures of 73 and 82% are given. Besides, in many urban areas 'black water' is disposed through domestic septic/leaching systems or collected by trucks from household holding tanks and deposited in municipal lagoons and leaching pits. For Lao PDR, Cambodia and Vietnam more recent figures are provided by the Water and Sanitation Program – East Asia and the Pacific (WSP-EAP) of the World Bank, in three Reports on Economic Impact of Sanitation in Lao PDR, Cambodia and Vietnam (WSP-EAP, WB, A five-country study conducted in Cambodia, Indonesia, Lao PDR, The Philippines and Vietnam, 2008, 2009). The reports indicate that 84% of the urban population in Lao PDR has improved sanitation facilities, for Cambodia a figure of 56% is given, whereas in Vietnam improved sanitation facilities take care of 92% of the load from urban areas.

When these reductions are taken into account, and assuming further improvement of sanitation, also in the rural areas, the increase in pollution load due to population growth is limited compared to the increased loading of the system by agro-chemicals.

1.3 Suspended sediments

Changes in expected suspended sediment loads are discussed in the report on geomorphological changes (Carling, 2010).

Within a timeframe of 20 years sediment delivery to Cambodian and Vietnamese floodplains (including Tonle Sap) will not diminish. Sediment concentrations and deposition in kg/ha will remain unchanged and changes in grain size distribution of the sediment will not be noticeable. The total sedimentation area will reduce as a result of lower flood levels. At a time horizon of 50 years concentrations and deposition rates will decrease somewhat, but changes will still be very limited. The same is valid for the grain size distribution. Probably the D_{max} value will remain as it is, D_{50} may increase a little.

2 Impacts on river water quality

2.1.1 Nutrients

Not all nutrients leached from agricultural land or discharged in waste water add to the final load at a river basin scale. While in transit in the basin concentrations of N, P and C will reduce: the so-called self-purifying capacity of the water system.

Water bodies purify themselves through a combination of several physical, biological and chemical processes. The most important ones are

- Dilution: when a polluted river is joined by less polluted tributaries or during the rainy season, volume of water in the polluted river is increased thus reducing the pollutants concentrations by dilution process;
- Sedimentation: nutrients are bound by fine sediment particles and when sediments deposit, e.g. in river stretches where flow velocities reduce or in floodplains during inundations, the pollutants settle as well;
- Aeration: turbulence mixes air into water increasing the dissolved oxygen (DO) content. The increased oxygen concentration facilitates many chemical and microbiological processes in water required to reduce the pollutants concentrations;
- Adsoprtion: pollutants are adsorbed onto rocks, pebbles, sand particles, logs and plant surfaces thereby reducing the concentration in the river water: and
- Phyto-remediation: aquatic plants and vegetation on the riverbanks absorb nutrients such as nitrate and phosphate from water. In addition, studies have shown that plants are also capable of removing pesticides and heavy metals from water. Especially, when a segment of a river turns into a marsh on its way, the river quality is largely improved by the vegetation grown there.

Liljestrom (Nitrogen and phosphorus dynamics in the Mekong Basin: Nutrient balance assessment on a catchment scale, Masters Thesis, Helsinki University of Technology, 2007) states that nutrient retention depends on the size of the basin, the sub-basins flow paths and a number of specific catchment factors and can range between 0 and 100%. Comparison with other basins in the region led to the assumption that the nutrient retention in a basin like the Mun – Chi basin (120,000 km^2) is about two thirds, both for N and P.

Applying this retention rate enables a further analysis of the nutrient discharges in the 3 basins that are the largest expected changes in fertilizer loss, the Mun – Chi Basin, the 3 Ss Basin and the Tonle Sap Basin. Impacts of increased nutrient loads will be biggest during the dry season, when flows in the main river are lowest.

Only nutrient discharges from agriculture are considered here, as stated already, nutrients discharged to the surface water with waste water are relatively small as compared to the discharges from agriculture. Although not on a transboundary basin level, high population concentration may locally result in water quality problems. Further improvement of sanitation is thought to limit these problems in future.

2.2 Mun – Chi Basin

For the analysis of the impacts of increased fertilizer use in the Mun – Chi Basin, fertilizer use for the dry season crop is used (February, March, April). Nitrogen loss from the dry season crop increases from 1,006 ton under the Definite Future scenario to 5,705 ton under the 20 Year Plan. Phosphorus loss increases from 130 to 748 ton.

Increase in concentration of N and P can be calculated by applying the nutrient retention rate of 67% as discussed in Chapter 2 and by dividing the resulting load by the total discharge of the main river at Pakse over the 3 month period, both for the Definite Future and the 20 Year Plan scenario, see Table 13.

Table 13: Amounts of N and P discharged from the Mun – Chi Basin into the main river near Pakse and resulting increase in concentrations.

	Load (ton)		Discharge	Concentration (mg/l)	
	N	P	(MCM)	N	P
Present	335	43	13,366	0.025	0.003
20 Year Plan	1,902	249	22,310	0.085	0.011
Increase	1,566	206	8,945	0.060	0.008

According to MRC Technical paper No. 19, An Assessment of the water quality in the Lower Mekong basin, 2008, present $N_{3\text{-}2}$ levels at Pakse are around 0.1 mg/l, well below the threshold value of 0.7 mg/l. The additional N inflow is therefore thought not to affect the water quality, levels will stay below the threshold value.

Total P concentrations at Pakse are around 0.05 mg/l, again well below the threshold value, which is 0.13 mg/l for Total-P. Increased P concentrations of 0.008 mg/l will not affect the water quality.

2.3 The Three Ss Basin

In the 3Ss basin nitrogen loss from the dry season crop increases from 704 ton under the Definite Future scenario to 2,427 ton under the 20 Year Plan. Phosphorus loss increases from 79 to 328 ton.

Increase in concentration of N and P are again calculated by applying the nutrient retention rate of 67% and by dividing the resulting load by the total discharge of the main river at Strung Treng over the 3 month period, both for the Definite Future and the 20 Year Plan scenario, see table 14.

Table 14: Amounts of N and P discharged from 3Ss Basin into the main river near Stung Treng and resulting increase in concentrations

	Load (ton)		Discharge	Concentration (mg/l)	
	N	P	(MCM)	N	P
Present	235	26	22,193	0.011	0.0012
20 Year Plan	809	109	31,339	0.026	0.0035
Increase	574	83	9,146	0.015	0.0023

According to MRC Technical paper No. 19 (2008), present $N_{3\text{-}2}$ levels at both Pakse and, Kratie, the stations upstream and downstream of Stung Treng, are well below the threshold values. The additional N inflow is therefore thought not to affect the water quality, levels will stay below the threshold value.

Total P concentrations at Pakse and Kratie are around 0.05 mg/l, again well below the threshold value of 0.13 mg/l for Total-P. Increased P concentrations of 0.002 mg/l will not affect the water quality.

2.4 Tonle Sap

2.4.1 Nutrients

Dry season rice cropping in the Tonle Sap Basin takes place in the months January, February and March. N losses under the Definite Future scenario are 1280 ton, as compared to 3,745 ton under the 20 Year Plan scenario. P losses are 166 ton (Definite Future) and 506 ton (20 Year Plan). Applying the nutrient retention rate of 67% and assuming an average discharge of the Tonle Sap River of 2,000 m^3

over the months of January, February and March results in changes in concentrations well comparable with those calculated for the main river near Pakse, see Table 15.

Table 15: Amounts of N and P discharged from the Tonle Sap Basin into the Tonle Sap Lake and discharged via the Tonle Sap River

	Load (ton)		Volume	Concentration (mg/l)	
	N	P	(MCM)	N	P
Present	427	55	15,552	0.027	0.0036
20 Year Plan	1248	169	15,552	0.080	0.0108
Increase	822	113	0	0.053	0.0073

Liljestrom (2007) calculated annual Nitrogen and Phosphorous fluxes at Prek Kdam. The results show that the annual net nitrogen flux (in a hydrological year) ranges between approximately 15,000 ton into the lake to 15,000 ton out of the lake. The annual net phosphorus flux ranges between approximately 1,200 ton into the lake to 1,700 ton out of the lake. The variation and ranges are large and the net fluxes are spread quite evenly over the entire range. The average values of the net fluxes indicate that the lake, on average, acts as a nitrogen sink and as a phosphorus deliverer. It has to be noted that these observations are based on a relatively short observation period: 7 years only.

However, the results on nutrient flux calculations for the Prek Kdam monitoring site suggest that there is great variation in nutrient transportation into and out of the Tonle Sap Lake via the Tonle Sap River. According to the results, the lake acts during some hydrological years as a nutrient sink, and during others as a nutrient source. Nitrogen and phosphorus fluxes vary independently from each other.

The large variation in the net nutrient fluxes between hydrological years indicates that the nutrient movement and transformation processes are complex. More research is needed on factors that influence and contribute to the lake’s nutrient dynamics.

The increase in loads of 800 ton (N) and 100 ton (P) in the dry season is small compared to the annual flux of 15,000 ton (N) and about 1,500 ton (P). Therefore, also given the very large variation of fluxes over the years, increased nutrient loads to the lake are thought not to have significant impacts.

2.4.2 Herbicides, pesticides and fungicides

There are no signs of any basin wide significant increase in herbicide, pesticide and fungicide levels in the Mekong River’s water and sediments: pesticide levels were below detection limits in river water studies conducted between 2003 and 2004 (MRC, 2007). As stated before, pesticide applications are is low in Cambodia, Lao PDR and NE Thailand because of the low degree of intensive agriculture.

Expected increases in use, going from the Definite Future to the 20 Year Plan scenario, are considerable. However, it is very hard to predict whether or not this will lead to detectable concentrations in the surface water and river sediments. Locally, intensive cultivation may result in concentrations that are above the thresholds values, as is already reported from certain parts of the basin.

3 Impacts on ecology

Overall, increases in concentrations of nutrients and agrochemicals seem such that only limited impacts on the basins ecology are to be expected. Locally situations may very well become less favourable.

Eutrophication may result in excessive plant growth and decay, as a consequence the composition of species may change: simple algae and plankton replace more complicated plants. As a result the composition of benthic species may deplete, the food base for fish may change and correspondingly so the species composition of the fish.

Enhanced growth of choking aquatic vegetation or phytoplankton (e.g. algal blooms) disrupts normal functioning of the ecosystem, causing a variety of problems such as a lack of oxygen in the water, needed for fish and shellfish to survive. Massive fish kills may result.

The resource value of the water system e.g. for recreation, fishing, hunting, and aesthetic enjoyment decreases substantially. Health-related problems can occur where surface water is used as drinking water.

These problems are most likely to occur in areas where loading of the water systems with nutrients is extremely high, e.g. in the vicinity of large population concentrations where large amounts of (untreated) wastewater are discharged. The problem is aggravated when flows are reduced or flowing water bodies are converted to semi stagnant waters.

4 References

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