Draft

Mekong River Commission
Basin Development Plan Programme, Phase 2

Assessment of basin-wide development scenarios

Technical Note 8

Agricultural impacts assessments

(Work in Progress)

February 2010

Note to the reader
This series of technical notes is prepared to serve facilitation and discussion on the assessment of basin-wide development scenarios of the Mekong Basin by stakeholders in the basin countries. The assessment process is continuing and feedback on the initial findings is requested.

Mekong River Commission
Basin Development Plan Programme, Phase 2

Assessment of basin-wide development scenarios

List of Technical Notes

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

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Summary

This short report provides support information required by the economists, social scientists and environmentalists in the Basin Development Plan-Phase 2 of MRC (BDP2) for the preparation of an economic assessment of the basin-wide development scenarios. Projections were made from the current situation based on the Definite Future Scenario through to the LMB 20-Year Plan Scenario. The irrigation areas used for these assumptions were provided by the BDP and IKMP. Areas were estimated in collaboration with riparian country partners to be 4,002,151 ha in the Definite Future Scenario and 5,993,044 ha in the LMB 20-Year Scenario. Water use was based on four irrigated cropping patterns involving rice and non-rice crops.

Data for the report was compiled through literature research, web based information, personal contacts and surveys. A number of assumptions were made to project future agricultural practices, crop yields, farm mechanization, farm employment, fertilizer rates and pesticide use. Assumptions remain the responsibility of the author.

Crop budgets were determined for the current situation and the LMB 20-Year scenario for each country and each crop. 42 of these budgets were developed. Farming systems vary widely in the current situation. For example, NE Thailand is more mechanized than Cambodia and Lao PDR, and fertilizer use is higher in Vietnam than in other countries. Taking these factors into account, the net incomes from these budgets range from US$27 per hectare in Thailand to US$304 per hectare in Vietnam from dry season crops. Return on labor ranged from US$4.70 per day in Lao PDR to US$6.6 per day in Vietnam delta for the dry season. The return per day of labor ranged from $3.4 to $8.9 across all crops. Hybrid maize was used as a standard for the non-rice crop.

A number of assumptions based on historical trends were used to project yields and input costs for the year 2030 under the LMB 20-Year Plan Scenario. Gross margins increased dramatically as did net incomes under this scenario. Net incomes were projected to range from a low of US$199 per hectare (for maize) to US$707 per hectare for dry season rice. Return on daily labor also increased, ranging from a low of US$6.5 to US$14.5.

Despite the high degree of farm mechanization expected by 2030, it will take an approximate 412,000 extra farm workers to crop the expanded 3 million ha of irrigated (as opposed to irrigable) land.

Higher yields projected for 2030 will require higher material inputs, including fertilizer and pesticide. Based on earlier assumptions, an extra 265,500 ton of N and 68,400 ton of P will be lost from the LMB, some of which will enter the Mekong river. Herbicide use will also increase in all countries as will insecticide and fungicide consumption in all countries except Vietnam.

A salt tolerance graph for rice was developed for the Mekong Delta, based on a literature review. There is no evidence to suggest that crop yields will deteriorate significantly within a 20 year period due to climate change.

The importance for farmers to retain healthy paddy environments is emphasized by the estimated value of aquatic food harvested from paddy fields in different environments.

1.0 Introduction

1.1 Basin development planning

The second phase of MRC's Basin Development Plan Programme (BDP2) is designed to provide an integrated basin perspective through the participatory development of a rolling Integrated Water Resources Management (IWRM) based Basin Development Plan. The plan will comprise the following elements:

- ***Basin-wide Development Scenarios***, which will provide the information that Governments and other stakeholders need to develop a common understanding of the most acceptable balance between resource development and resource protection in the Lower Mekong Basin, taking into account developments in the upper Mekong Basin. The results will guide the formulation of the IWRM-based Basin Development Strategy.

- ***An IWRM-based Basin Development Strategy***, which provides a shared vision and strategy of how the water and related resources in the LMB could be developed in a sustainable manner for economic growth and poverty reduction, and an IWRM planning framework that brings this strategy into the various transboundary and national planning, decision-making and governance processes.

- ***A Project Portfolio*** of significant water resources development projects and supporting non-structural projects that would require either promotion or strengthened governance, as envisioned in the 1995 Mekong Agreement.

The preparation of the Plan will bring all existing, planned and potential water and related resources development projects in a joint basin planning process, through a combination of sub-basin and sector activities, and a basin-wide integrated assessment framework.

1.2 Formulation and assessment of scenarios

The formulated basin-wide development scenarios represent different levels and combinations of sectoral development and consider the many development synergies and trade-offs among the different water-related sectors, such as irrigation and hydropower synergies and hydropower and fisheries tradeoffs. Table 1 below summarizes the scenarios agreed by the countries.

First the development scenarios are assessed on a range of hydrological indicators to evaluate future water availability and use, and the flow changes caused by different levels of water use, including the existing and planned developments in the Upper Mekong Basin. The scenarios for the foreseeable and the long term future will be assessed with and without consideration of climate change impacts. The results are then fed into the ‘assessment of the transboundary economic, social and environmental impacts and IWRM requirements’.

In these assessments, the development scenarios are evaluated against 13 main indicators that can measure how well each scenario achieves the countries’ objectives of economic development, social development and environmental protection. As well, a basin wide ‘equity’ indicator is included that measures the degree of ‘equitable development’ between each country that each scenario produces, taking into account benefits from existing water use and further planned investments in each country.

Table 1: Basin-wide development scenarios

No.	Short Title	Full Title	Development Period	Interventions/Projects
Baseline situation				
1	BS	Baseline scenario	-	Year 2000 infrastructure including existing HEP dams
Definite future situation				
2	2015-UMD	Upper Mekong dam scenario	2000 - 2015	Baseline extended to include the full HEP cascade on the Lancang
3	2015-DF	Definite future scenario	2000 - 2015	2015-UMD plus 25 additional HEP dams in LMB and 2008 irrigation and flood measures
Foreseeable future situation				
4	2030-20Y	LMB 20-year plan scenario	2010 - 2030	2015 DF plus 11 LMB mainstream dams and planned tributary dams, irrigation, and water supply
5	2030-20Y-w/o MD	LMB 20-year plan scenario without mainstream dams	2010 - 2030	As above, excluding 11 LMB mainstream dams
6.1	2030-20Y-w/o LMD	LMB 20-year plan with 6 mainstream dams in Northern Lao PDR	2010 - 2030	As above plus 6 LMB mainstream dams in upper LMB
6.2	2030-20Y-w/o TMD	LMB 20-year plan with 9 mainstream dams	2010 - 2030	2030-20Y, excluding the two Thai mainstream dams
7	2030 – 20Y Flood	Mekong delta flood management scenario	2010 - 2030	Baseline plus 3 options for flood control in Cambodia and Vietnam Delta
Long term future situation				
8	2060-LTD	LMB long-term development scenario	2030-2060	2030-20Y plus all feasible infrastructure developments in LMB
9	2060–VHD	LMB very high development scenario	2030-2060	As above, extended to full potential infrastructure developments

After basin-wide consultations on the assessment results, the countries will determine which development scenario would provide the most acceptable balance between economic, environmental, and social outcomes in the LMB, and would bring mutual benefits to the LMB countries. It is noted that in choosing a development scenario, the LMB countries are not committing to a particular set of projects (which are in any case subject to feasibility studies, EIAs etc.), but are identifying a development space within which they can plan and work. Conflicts and trade-offs may occur, but within the agreed vision and outcome of the IWRM-based Basin Development Strategy.

1.3 This study in relation to the basin-wide development scenarios

This short report supports information required by the economists, social scientists and environmentalists in the Basin Development Plan-Phase 2 of MRC (BDP2) to prepare an economic assessment of the basin-wide development scenarios described above.

The work described in this report refers to costs and practices currently used in agriculture in the Lower Mekong Basin (LMB) on the estimated rice and non rice irrigation areas. Projections are also made for the agricultural conditions which are likely to exist in the foreseeable future (LMB 20 Year Plan Scenario).

Data required for this assessment was collected from a number of sources and summarized as farm budgets for Gross Margin Analyses in the four irrigation patterns identified by the simulation modelers. These are identified as being a) First Season area (mainly irrigation in the wet season), b) Second Season Area (Mainly Dry Season rice, c) Third Season Area (supplementary irrigation) and d) Non rice crop area (some of this area may be under perennials). In addition the value of production off the cropping area not converted to irrigation was also developed. The estimated rice and non rice areas in for each season are presented in Table 2. The cropping patterns for these are presented in Appendix 1. In the LMB 20 Year Plan Scenario the area of irrigated land in the LMB will increase by approximately 2 million hectares. The distribution of these areas by different scenarios is presented in Table 3.

Table 2: Estimated rice and non-rice irrigation areas for scenarios

Country	Irrigable area	1st Season area	2nd Season area	3rd Season area	Non-rice crop area	Annual irrigated area
Definite Future scenario						
Lao PDR	166,476	166,476	97,224	-	6,977	270,677
Thailand i	1,411,807	1,354,804	148,255	-	252,704	1,755,763
Cambodia	504,245	273,337	260,815	16,713	12,172	563,037
Viet Nam	1,919,623	1,669,909	739,594	1,478,740	329,740	4,217,983
Total LMB	4,002,151	3,464,526	1,245,888	1,495,453	601,593	6,807,460
LMB 20-Year plan scenario						
Lao PDR	451,296	449,595	329,952	-	40,046	819,593
Thailand i	2,718,480	2,635,477	427,741	-	560,784	3,624,002
Cambodia	778,488	456,828	378,917	21,594	19,879	877,218
Viet Nam	2,044,780	1,794,801	739,594	1,478,740	391,311	4,404,445
Total LMB	5,993,044	5,336,701	1,876,204	1,500,334	1,012,020	9,725,258

Table 3: Incremental cropping areas by development scenario

Country	Increment irrigation area	1st season area	2nd season area	3rd season area	Non-rice area	Annual cropped area
LMB 20-Year plan scenario						
Lao PDR	284,820	283,119	232,728	0	33,069	548,916
Thailand	1,306,673	1,280,673	279,486	0	308,080	1,868,239
Cambodia	274,243	183,491	118,102	4,881	7,707	314,181
Viet Nam	125,157	124,892	0	0	61,571	186,463
Total LMB	1,990,893	1,872,175	630,316	4,881	410,427	2,917,799

1.4 Assumptions

A number of assumptions were used to describe the current situation of irrigated agriculture in the LMB and what may exist in 20 years time. The first assumption is that the area under irrigation will match those presented in Table 1. The second is that there will be considerable change in the farming practices in irrigated agriculture over a 20 year period. Also:

- An average is used for some practices. For example that 30% of the rice area in Laos and Cambodia is currently direct seeded (broadcast) and 70% transplanted and that in the 20 year scenario 70% will be broadcast and 30% transplanted.
- Crop yields will benefit from technological developments.
- All of the fertilizer currently used in Lao PDR and Cambodia is applied to irrigation (or potentially irrigable) areas. Input levels used in the GM analyses are for higher input systems achieving average to above average yields.
- Irrigated crop yields are somewhat related to fertilizer rates to a maximum level.
- Farmers currently using low levels of pesticides will increase their application to a maximum level already experienced in the dry season and on most crops in Vietnam.
- The pace of change in mechanization and reduction in labor used per unit of land in the LMB will be rapid

All assumptions are personal views of the author.

2.0 Information for gross margin (GM) analyses

There is considerable agricultural diversity within the LMB. Not all cropping systems in the basin fit exactly into the three simulation irrigation seasons. The crops and crop types are extremely variable. For example rice crops vary from the cultivation of photoperiod sensitive varieties which may take 5-6 months to mature through to photoperiod insensitive modern rice varieties maturing in less than 90 days. Non rice crops may also vary from perennial fruit trees through vegetables to maize. The following information is based on a typical irrigated area which uses high inputs to gain high returns.

A typical gross margin analysis contains elements of material costs, labor and machinery. Materials include seed, fertilizer and pesticides. Labor can be divided to compare changes over time due to an increasing degree of mechanization. Water services costs may or may not be included. In the cases presented below, water costs will be calculated on a 20 year development scenario and deleted from the net benefits of the scheme on a basin-wide basis.

An example of a gross margin analysis used in this assessment is presented in Table 4. Forty two (42) of these crop budgets were developed. Included were budgets for the rainfed situation (Current and 20 year plan) for the first, second and in the case of Cambodia and Vietnam, third irrigated rice crop. A similar set of data was also prepared for non rice crops. Hybrid maize was used as a standard for the upland crop.

The items, units, number of units and unit prices reflect the system in place in each country and the cost of those items in each country. The components of the farm budget are discussed individually. The costs of each item are presented in Table 5. The source of each cost base is also discussed below. The value of the crop outputs are presented in Table 6. The sources of valuing these outputs are also discussed individually.

Table 4: A typical gross margin analysis of rice crop (Lao PDR dry season)

No.	Item	Unit	# unit	Unit Price	Proportion	Total
	Inputs:					
1	**Materials**					
	Seed	kg	50	$0.30	0.70	$10.50
	Seed	kg	180	$0.30	0.30	$16.20
	Urea fertilizer	kg	80	$0.65	1.00	$15.60
	DAP	kg	50	$0.82	1.00	$41.00
	Herbicides	l	8	$4.20	0.30	$10.08
	Cow manure	cart	5	$3.50	1.00	$17.50
	Insecticide	kg	7	$4.20	1.00	$29.40
	Sub-Total					**$140.28**
2	**Labor**					
	Land preparation (animal)	Person	15	$3.10	0.85	$39.53
	Nursery broadcasting	Person	2	$3.10	0.70	$4.34
	Nursery pulling	Person	5	$3.10	0.70	$10.85
	Transplanting	Person	30	$3.10	0.70	$65.10
	Fertilizing organic	Person	5	$3.10	1.00	$15.50
	Fertilizing inorganic	Person	2	$3.10	1.00	$6.20
	Weeding	Person	25	$3.10	0.70	$54.25
	Pesticide application	Person	3	$3.10	0.30	$2.79
	Irrigation and field maint.	Person	20	$3.10	1.00	$62.00
	Harvesting	Person	25	$3.10	0.95	$73.63
	Hand threshing	Person	13	$3.10	0.50	$20.15
	Crop Transportation	ton	3.6	$4.20	1.00	$15.12
	Sub-Total		**145**		**114**	**$369.45**
3	**Machinery**					
	Land preparation	ha	1	$50.00	0.15	$7.50
	Harvesting	ha	1	$90.00	0.05	$4.50
	Threshing	kg	3,800	$0.02	0.50	$30.40
						$42.40
	Total Expenses					**$552.13**
	Revenue					
4	Yield	kg	3,800	$0.19		$722.00
	Sub-Total					**$722.00**
	Net - Income					**$169.87**
	Gross margin %					**30.77**

Table 5: Current price of agricultural inputs ($US)

Items	per unit	$US			
		Lao PDR	Thailand	Cambodia	Vietnam
UREA	kg	0.65	0.36	0.65	0.35
NPK (16:20:0)	kg	0.82	0.40	0.85	0.52
NPK (15:15:15)	kg	0.82	0.55	0.82	0.65
KCl	kg	0.50	0.42	0.50	0.54
Cow manure	cart	3.50	-	3.75	-
Farm labor	day	3.1	3.75	2.5	2.80
Land preparation (machine)	ha	50	55	60	54
Land preparation (cow)	ha	15 md	15 md	15md	15md
Harvesting by machine	ha	90	180	90	90
Threshing cost (by machine)	kg	0.012	0.012	0.012	0.012
Transport price farm to home	t	4.2	4.2	4.2	2.81
Pesticide	kg	4.5	4.20	3.75	4.80
High quality seed	kg	0.50	0.25	0.50	0.50
Ordinary seed	kg	0.30	0.20	0.30	0.30
Hybrid maize	kg	2.0	2.0	2.0	2.0

Source: FMMP_C2, April 2009; Web based national statistics; personal communication

Table 6: Current value of agricultural outputs ($US)

Item	per unit	$US			
		Lao PDR	Thailand	Cambodia	Vietnam
Rice (high quality)	kg	0.25	0.25	0.25	0.22
Rice (normal)	kg	0.19	0.19	0.19	0.19
Maize	kg	0.18	0.19	0.19	0.19

Source: FMMP_C2, April 2009; Web based national statistics; personal communication

2.1 Item quantities and costs in crop Gross Margin (GM) analyses

A typical crop will require inputs consisting of land, water, labor, seed, fertilizer, pesticide, and machinery to plant, manage and harvest the crop.

2.2 Labor quantity for GM analyses

Farming in the LMB is traditionally based on subsistence practices. Subsistence agriculture farms produce sufficient grain for the families with a little remaining to feed farm animals. Any cash income is derived from the sale of small animals or in extreme cases, the sale of grain or other farm produce. Net income is traditionally small. Improvements in productivity are a result of farm intensification and improvements in water (irrigation) control. As Lao PDR, Thailand, Cambodia and Vietnam become industrialized, farm household members travel to these centres to seek work. As a result, the number of household members available for farming is on the decline.

The total labor requirement per hectare depends upon the level of mechanization, paddy size and distance from labor source. Rice fields prepared by animal traction, transplanted, harvested and threshed by hand require 110-140 man days of labor (Table 7).

Table 7: Labor requirements for traditional farm operation

Operation	Manual labor days/ha
Tillage by animal	
1st plowing	6
2nd plowing	6
Harrowing	3
Sowing	
Broadcasting	2
Seeding/transplanting	35
Fertilizing	
Manure	5
Inorganic fertilizer	1
Weeding	25
Harvesting	
Cutting	26
Threshing	13
Transporting	6
TOTAL	118

Labor shortages are particularly prevalent in NE Thailand where farmers and farm workers travel to Bangkok and other centres for cash income derived from working on construction sites, driving taxis or working in factories. Some work is seasonal, allowing the farmers to return to their properties for planting and harvest. Their land may also be leased out to neighbours and companies, providing improved economy of scale. Farming practices have been adapted to cater for water shortages at critical times. This includes increased land preparation by tractor, broadcasting crops as opposed to transplanting, the use of herbicides rather than hand weeding, harvest by combine harvesters to replace harvesting by hand, carting and threshing. Animal numbers diminish as a result of increased mechanization and organic fertilizers (cow manure and green manures) are replaced by the application of inorganic fertilizers.

On-farm labor constraints are less obvious in Lao PDR, Cambodia and Vietnam but this situation will change over time. Farm budgets for all countries reflect changes in labor availability over a 20 year period as they become more mechanized.

2.3 Labor costs for GM analyses

Labor costs were measured by direct and indirect methods. In Lao PDR, the cost of labor for on-farm research trials was used as a median. In 2009, farm labor costs varied around $3.10 per day (Table 5). Lower rates apply in isolated areas and higher labor costs occur closer to city centres.

For Thailand, the minimum wage was used as the farm labor indicator. As mentioned above, laborers are able to earn well in excess of the minimum wage in the cities and there is often a shortage of labor in the NE of Thailand during critical periods of the year.

Labor costs in Cambodia were taken directly from those paid by development project personnel in the east and north of the country. Data from the MRC Flood Mitigation Management Program (FMMP) survey results was used for Vietnam.

2.4 Seed costs for GM analyses

Certified seed of government released varieties multiplied by seed companies is generally costed at approximately three times the value of the farmer harvest grain. At a paddy price of 25cents per kg for rice the price of certified seed would be approximately 75cents per kg. The extra costs is related to the production of high quality foundation seed, rogueing of the crop, cleaning of the seed and in most cases, treatment of the seed against insect pests. The surveyed cost of high quality seed was considered to be 66 cents in Lao PDR plus 60 cents in Cambodia and Vietnam. In Thailand, the Government subsidizes the cultivation of high quality seed by selling seed at 25cents per kg. High Yielding Variety (HYV) rice is generally sold at lower prices and seed is priced lower accordingly.

Farmers replace their seed once every four or five years. The cost of seed for the crop budgets was maintained at 50 cents per kg for high quality rice in Lao PDR, Cambodia and Vietnam and 25 cents in Thailand. HYV seed was valued at 30 cents per kg excepting for Thailand where the price was maintained at 20 cents (Table 5).

Farmers often grow maize on contract and cultivate hybrid varieties necessitating the purchase of seed each year. Otherwise open pollinated varieties are cultivated which deliver lower yields but at lower costs. Non rice crops are represented in the budgets as a typical hybrid maize crop with a seed cost of $2.00 per kg. Fresh seed must be purchased for each hybrid crop.

2.5 Fertilizer costs for GM analyses

Fertilizer costs presented in Table 5 represent surveyed costs in each country. The most common fertilizer applied to rice is Nitrogen in the form of UREA (46 %N) and Di-ammonium phosphate (16-20-0) or 16% nitrogen, 20 % phosphorous and 0%

potassium. A complete NPK fertilizer is often applied to upland crops in the form of 15:15:15 and on high yielding crops. Potassium is required to produce consistently high yielding rice crops on most soils. Fertilizer is generally cheaper in Thailand and Vietnam compared with Lao PDR and Cambodia. This may be related to the volume imported into the higher consuming countries. A cart if cow manure is valued at $3.50 - $3.75 per cart. Applications of organic fertilizer onto the poorer soils in Lao PDR and Cambodia are synergistic to the application of chemical fertilizer. This is also the case in NE Thailand and some farmers may continue to apply it.

2.6 Pesticide costs for GM analyses

Pesticides commonly used on rice and other crops include herbicides, insecticides and fungicides. Herbicides are commonly used in broadcast crops in Thailand and parts of Cambodia and Vietnam. The most common herbicide is 2,4-D which is cheap to purchase and easy to apply. Insecticides are more expensive and farmers tend to adopt integrated pest management (IPM) techniques to reduce their use. Fungicides are also expensive and rarely applied except in Vietnam. The average cost of the pesticides in each country is presented in Table 5 and fall in a similar cost range.

2.7 Land preparation costs for GM analyses

Rice land is traditionally cultivated with animal power using either cattle or water buffalo. Animal power is much slower than using tractors (Table 8) and with the high cost of labor is approximately the same cost. It takes five to six days to plow one hectare of land with animal power and approximately one day with a walking tractor. A 4WD tractor prepares 5-8 hectares per day. Time is of essence with farming and farmers prefer to prepare their fields by tractor if funds are available to pay contractors. Paddies are generally prepared twice to three times prior to sowing.

Table 8: Land preparation by different sources

Power source	Unit	Work rate (ha/day)	Contract rate $/ha
Animal power	pair	0.1 - 0.2	20-25
Walking tractor	7-11 kW	0.8 - 1.2	25-30
4WD tractor	60kW	5.0 - 8.0	25-30

2.8 Production output value for GM analyses

The gate price of rice in each country was determined by survey in August-October, 2009. At this time the price of high quality rice was US$0.25 per kg in Lao PDR, Thailand and Cambodia. Paddy prices tend to be lower in the Mekong Delta where the predominant varieties are HYVs. At this location the price for high quality rice was set at US$0.22 per kg. The price of HYVs grown in the dry season was priced at US$0.19 per kg for all countries (Table 6).

Maize, the predominant non rice crop across the delta was set as the example crop for the Gross Margin analyses. It was priced at 18-19 cents per kg.

3.0 Projected changes in agriculture in the LMB over 20 years

Projections for the increased areas under irrigation are presented in Table 2. These areas have been estimated by the irrigation specialists and water modelers in consultation with riparian country partners. Simulation models project that there will be sufficient water in the system to cater for the increased agricultural area if all the planned dams are constructed. The cropping patterns used for estimating water use are presented in Appendix 1.

3.1 Projected changes in rice yields

National rice yields in the LMB have been increasing at a rate of approximately 3% (non accumulative) annually since 1990. This figure was used to estimate the yield of rice in 2030 on a national basis (with simulated yields from 2008). A graphical representation of the projected national rice yields using a linear relationship is presented in Figure 1. The relationship should be asymptotic not linear with the maximum yields being reached before a 20 year period. It is unlikely that a 3% increase in yields will be achieved leading up to 2030 nor after it.

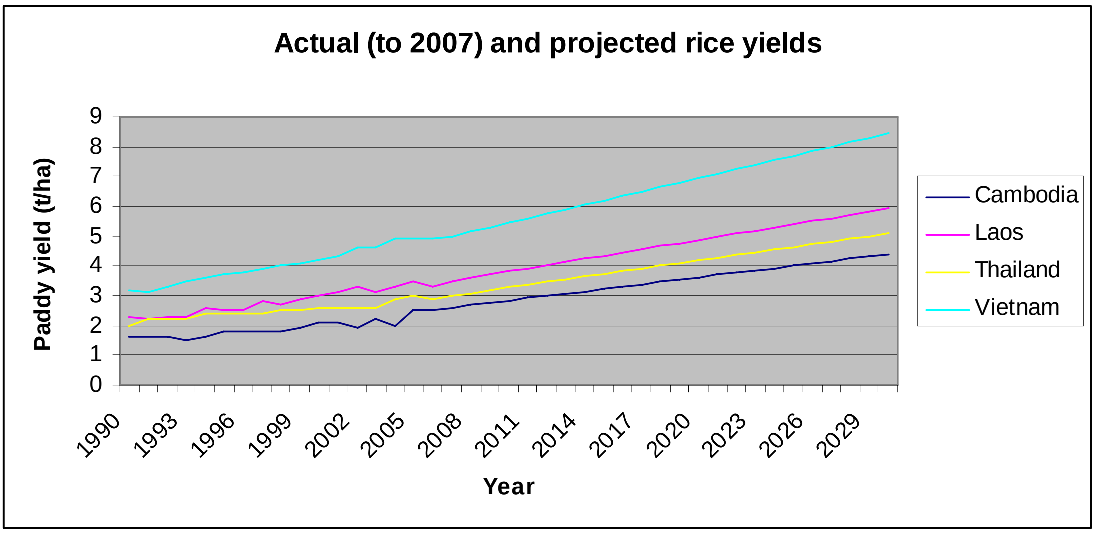

Figure 1: Actual national rice yields to 2007 and projected yields to 2030

A three percent yield increase over time is not high compared with other countries and is due in part, to improvements in technology. Some increase can also be attributed to a larger proportion of the land under irrigation. It is feasible for national yields to reach 4.4, 5.9 and 5.1 t/ha in 2030 for Cambodia, Lao PDR and Thailand respectively if the proportion of the land under irrigation increases significantly and there are yield increasing technological improvements. Vietnam has a larger percentage of its land under irrigation than the other three nations and has a well developed farming systems in the Mekong Delta. A national yield of 8.5t/ha for Vietnam is extremely high and breakthrough in new plant type will be necessary for national yields to be this high within 20 years. For simulation purposes, the rate of yield increase of 3% per annum over the 20 period was retained for calculating the yields for the predicted areas of rainfed and irrigated land in Laos, Cambodia and

Thailand. The Ministry of Agriculture and Rural Development (MARD) in Vietnam does not consider that rice yields will increase significantly above present levels (5.2t/ha) in the Mekong Delta unless there are big breakthroughs in technology (Nguyen Tri Ngoc, 2009). A 2% increase in yields was used in the model for the Mekong Delta.

Records for rainfed rice crop yields in Cambodia, Lao PDR, North East Thailand and wet season yields in the Mekong Delta kept during the period from 1980-1990 were used to predict the yields for the period from 1990 to 2030. These are graphed in Figure 2. In 1990, the average rainfed yields in Cambodia, Lao PDR and North East Thailand were 1.9, 1,9 and 1.8 t/ha respectively. Wet season (rainfed with some irrigation) crops in the Mekong Delta were 3.1t/ha. At an annual increment of 3% (and 2% for Vietnam) per annum, the projected yields for 2007 were 2.3, 2,3, 2.3 and 3.8 respectively. These are reasonably accurate figures for this ecosystem in that year. Based on these assumptions, a summary of current and predicted rice yields for 2030 are presented in Table 9.

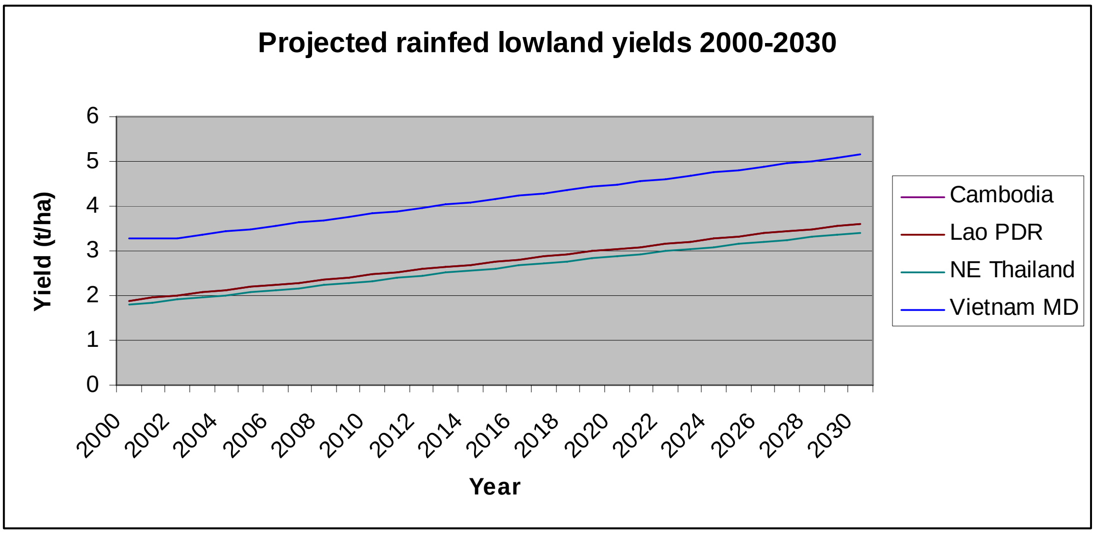

Figure 2: Projected rainfed lowland yields from 2000-2030, LMB

Table 9: Rice crop tolerance and yield potential as influenced by salinity

Country	*Current yields (t/ha)*		**Simulated yields for 2030 (t/ha)**	
	Rainfed	Rainfed with irrigation (1st crop)	Rainfed	Rainfed with irrigation (1st crop)
Lao PDR	2.3	2.8	3.6	4.4
Cambodia	2.3	2.8	3.6	4.4
Thailand	2.3	2.7	3.4	4.2
Vietnam		3.8		5.3
	Dry season (2nd crop)	3rd Season	Dry season (2nd crop)	3rd Season
Lao PDR	3.8		5.9	
Cambodia	3.9	3.6	6.1	5.4
Thailand	3.1		4.9	
Vietnam	5.3	5.2	7.5	7.0

Wet season crops irrigated crops were low during 2000 at 2.3, 2.3, 2.2 and 3.4 respectively for Cambodia, Lao PDR, NE Thailand and Mekong Delta. The simulated yields for the period up to 2030 are presented in Figure 3, and a summary presented in Table 9.

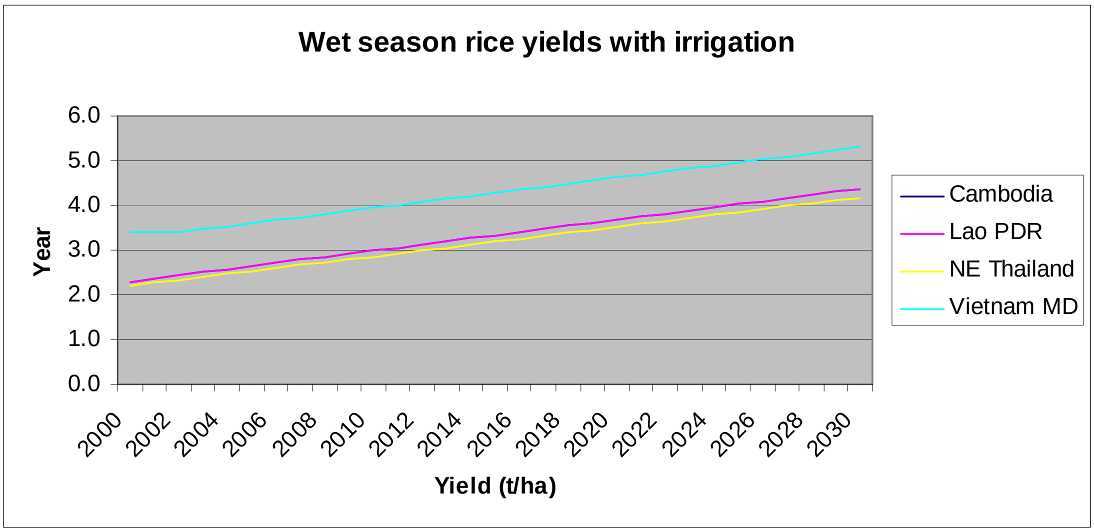

Figure 3: Projected irrigated wet season yields from 2000-2030, LMB

Maintaining a 2-3% per annum yield for 20years across the rainfed areas with or without irrigation will rely very heavily on dramatically improved water management, the introduction of higher yielding varieties and improved agronomic management to achieve 3.6, 3.6, 3.4 and 5.3t/ha for Cambodia, Lao PDR, NE Thailand and the Mekong Delta in Vietnam respectively. Yields of 3.5-3.6t/ha in 2008 were recorded in Cambodia, Lao PDR and North East Thailand and the 2030 target is feasible. In the Mekong Delta 6.0 t/ha crops are already harvested despite problems with floods and poor sunshine. A linear relationship does not reflect the direction of rice yields in the years immediately leading up to 2030.

Government records reported irrigated, dry season rice yields of 3.8, 3.9, 3.1 and 5.3t/ha in Cambodia, Lao PDR, Thailand and the Mekong Delta respectively during 2007 and projected yields of 5.9, 6.1, 4.9 and 7.5t/ha respectively for 2030 are feasible (Figure 4, Table 9). However, as described for the rainfed areas, in order to reach these yields, water management will need to be optimal as will the agronomic management practices. Input costs will be high and possibly above economic viability using current varieties.

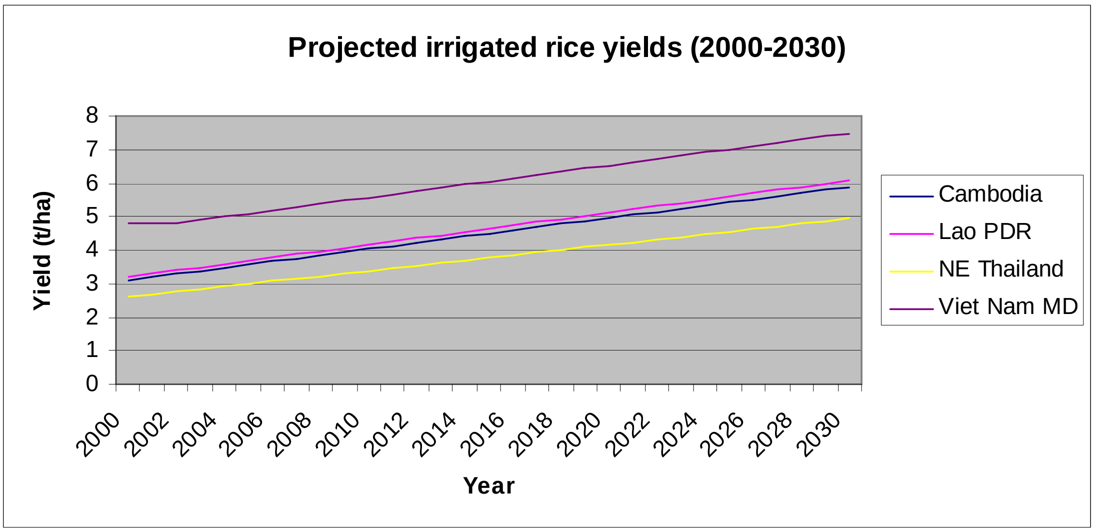

Figure 4: Projected irrigated lowland yields from 2000-2030, LMB

3.2 Projected changes in level of agricultural mechanization

Mechanizing farming activities has the potential of increasing farm productivity and improving production. For example, replacing animal traction with engine powered tractors will vastly speed up land preparation, thereby improving the timeliness of cropping patterns. A reduction in the time it takes to prepare the soil improves the chance of the plants taking advantage of higher solar energy months and avoiding droughts or floods. In some areas, it may also increase the number of crops that can be cultivated in one year. Additionally, unlike cattle or buffaloes, machines do not need to be grazed and cared for year round. Therefore, a higher % of the agricultural land can be cropped.

Agricultural equipment is expensive to purchase and operate (Rickman *et al*, 1997). Adoption of tractor powered land preparation, engine driven water pumps, combine harvesting and mechanical threshing are therefore also dependent on the cost of labor and opportunity cost of time lost through the employment of slower practices. Labor availability and cropping intensities are vastly different in the four LMB counties. Hence, farm mechanization varies dramatically across the region.

In Lao PDR, despite increasing costs, little of the land is prepared by tractor (although it is increasing rapidly). There is no combine harvesting of rice but mechanical threshing is increasing rapidly in the lowlands (Table 10). Tractors are almost exclusively used for land preparation in Thailand (because of the labor shortages) and the Mekong Delta of Vietnam (to enhance opportunities for extra cropping and because grazing areas are in short supply). Combine harvesters are used extensively in the flatter provinces in the east and with decreasing frequency towards the undulating topography in the west of NE Thailand. Some farmers are now increasing paddy sizes in the NE of Thailand by land leveling to improve the prospects of mechanized farming. Combine harvesting is either not economically feasible (Lao PDR and Cambodia) or impractical (small paddy size in the Mekong Delta) in the other LMB countries. Some sugar crops are mechanically harvested in Thailand and this practice will increase with improved farm gate prices. Other upland crops are all harvested by hand.

Table 10: Adoption of farm mechanization in the LMB 2009

Country	*Tractor land preparation (%)*	*Mechanically harvested (%)*	*Machine threshed (%)*	**Machine milled (%)**
Lao PDR	15	5	50	75
Cambodia	25	10	50	95
Thailand	95	60	100	100
Vietnam	90	80	100	95

Most lowland rice in the LMB countries is machine threshed and machine milled. Upland crops of sesame, soybeans and dry peas may also be threshed and cleaned by machine.

Pumping of irrigation water is predominately done by engine driven or electric pumps in all LMB countries. Hand or pedal driven water pumps are still active in the poorer areas of Lao PDR and Cambodia, especially when supplementary water is supplied to rice seedling nurseries. But this practice is in decline as the use of faster mechanical pumps spread across the countryside.

Mechanization in the Mekong Delta increased by 50% over the 11 year period from 1995 to 2006. The average rate of power input per 100 ha increased from 180 HP/100ha in 1995 to 243.4 HP/100ha reflecting the need to improve productivity (Ph m V'n Lang *et al*, 2008).

Mechanization in Thailand is reflected in the number of tractors operating in the agricultural sector. These increased seven fold between 1990 and 2006, many being used in the rice industry, which only increased in area by 15% (Table 11) over that period. The number of threshers also increased in number five fold. However, many of the 210,000 threshers known to have been in operation during 2006 were combine harvester threshers. These machines harvested the crops and threshed the rice thereby reducing transport costs and labor requirements.

Table 11: Rice areas, paddy yields, thresher and tractor numbers

	1980	1985	1990	1995	2000	2005	2006	2007
Thailand								
Rice area (million ha)	9.20	9.83	8.79	9.11	9.89	1.02	1.02	1.07
Paddy yield (t/ha)	1.9	2.1	2	2.4	2.6	3	2.9	3
Combine harvester threshers ('000)	18	30	42	69	122	198	210	
Agricultural tractors ('000)	18	31	58	149	305	371	379	
Vietnam								
Rice area (million ha)	5.60	5.72	6.04	6.77	7.67	7.33	7.32	7.20
Paddy yield (t/ha)	2.1	2.8	3.2	3.7	4.2	4.9	4.9	5
Threshers ('000)				150	232	232	232	232
Agricultural tractors ('000)	24	32	25	98	163	163	163	163
Cambodia								
Rice area ('000 ha)	1440	1450	1855	1924	1903	2415	2516	2566
Paddy yield (t/ha)	1.2	1.3	1.4	1.8	2.1	2.5	2.5	2.6
Threshers ('000)	na	na	na	na	na	na	na	
Agricultural tractors (no)	1233	1233	1200	1190	2160	3950	4000	
Lao PDR								
Rice area ('000 ha)	732	663	650	560	719	736	796	781
Paddy yield (t/ha)	1.4	2.1	2.3	2.5	3.1	3.5	3.3	3.5
Threshers ('000)	na	na	na	na	na	na	na	
Agricultural tractors (no)	464	780	890	1030	1080	1080	1080	

Source: http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567

Reliable figures (from FAOstat) of the thresher numbers are not available for Cambodia or Lao PDR but these are visibly increasing in density in the rural areas. The absolute numbers of tractors in both of these countries remain extremely small compared with Vietnam and Thailand.

Land preparation by tractor in Thailand and Vietnam will most likely be completely by four and two wheel tractors by 2030 (Table 12). Lao PDR and Cambodia started from a lower base in 2008 and are estimated to be at 60% and 80% respectively in 2030 (Suchint *et al* 2003). Mechanical harvesting in Thailand is being increasingly done by combine harvester which reaps and threshes the rice in one operation. In Vietnam where the paddies tend to be smaller and less accessible to heavy combine harvesters, the crops are cut with cutters and panicles threshed in separate machines. Grain milling is becoming progressively cheaper to machine mill. This increased mechanization are reflected in the crop budgets.

Table 12: Adoption of farm mechanization in the LMB 2030

Country	*Tractor land preparation (%)*	*Mechanically harvested (%)*	*Machine threshed (%)*	**Machine milled (%)**
Lao PDR	60	50	80	90
Cambodia	80	50	90	95
Thailand	100	90	100	100
Vietnam	100	100	100	100

3.3 Projected changes in seeding rates

Rice is traditionally transplanted to maximize yields using manual labor. Transplanting requires the establishment of a nursery which receives close attention from the farmer. Seedlings will be transplanted into the main field when there is standing water in the field or immediately prior to this occurrence. Transplanting into free standing water reduces the weed density and therefore the amount of competition for the rice crop. Maintaining flooded conditions reduces the time necessary to keep the crop reasonably weed free. For transplanting, the seeding rate is approximately 50kg/ha.

Broadcasting seed directly into the main field requires less labor but application of herbicides is required for weed control. Broadcasting rates range across the districts of each country usually at about 180kg/ha of dry seed. This will be used as a standard rate for each country.

It is assumed that current rainfed and irrigated rice production in Lao PDR and Cambodia was 70% transplanted and 30% broadcast in 2007 (Azmi *et al* 2005) and that it will be 20% transplanted and 80% broadcast by 2030. In NE Thailand and the Mekong Delta it is assumed that 80% was broadcast in 2007 and will be 100% broadcast in 2030.

3.4 Projected changes in fertilizer rates

Fertilizer rates were 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. Approximate fertilizer rates for the different scenarios are presented in Table 13. Note that the fertilizer rates for the Mekong Delta are much higher than for the other three LMB countries.

Irrigated rice yields are significantly higher than the rainfed areas and require more fertilizer to fulfill the crops potential. These irrigated crops are the main dry season crops in the LMB. Again, the current application rates in the Mekong Delta are significantly higher than other countries.

Table 13: Current fertilizer rates per hectare on rice in the LMB

Country	*Nitrogen (kg UREA/ha)*	*Phosphorus (kg DAP/ha)*	*Potassium (kg KCl/ha)*	***Manure (cart/ha)***
	Wet season rice (irrigated and non irrigated) (1st season)			
Lao PDR	40	10		5
Cambodia	40	20		5
NE Thailand	40	20	20	
Vietnam	140	120	80	
	Dry season rice (2nd season)			
Lao PDR	80	50		
Cambodia	80	60		
Thailand	80	60		
Vietnam delta	180	120	80	
	Third season rice			
Lao PDR				
Cambodia	70	30		
Thailand				
Vietnam delta	160	120	80	

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 at higher fertilizer rates to achieve higher yields. This may be achieved by adding mixed chemical fertilizers.

Nitrogen limits the yields of most rice crops. The efficiency(AEN in Fig. 5) of applying nitrogen fertilizer decreases with increasing rate of fertilizer N. At the fertilizer N rate corresponding to maximum profit, the optimal range for AEN in farmers' fields is often in the range of 18 to 25 kg of grain per kg or applied N (Fig. 5). (http://www.irri.org/irrc/ssnm/SSNM/NBackground.asp) 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.

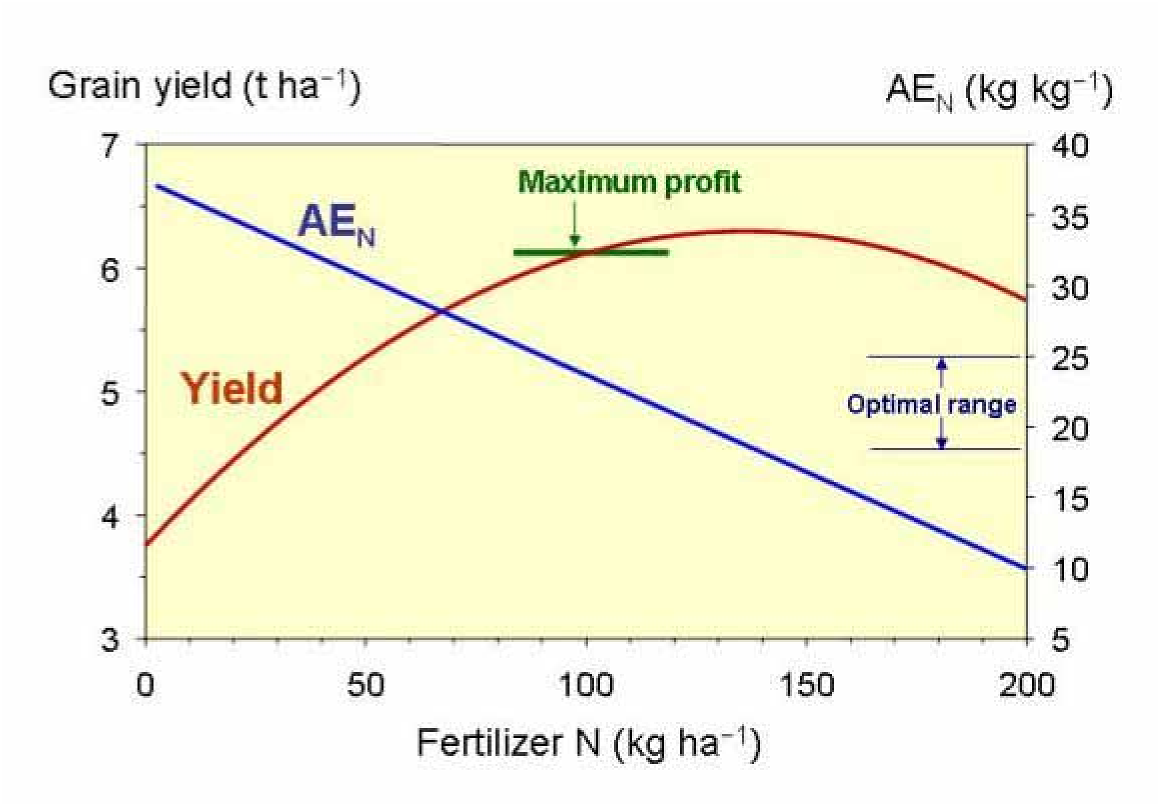

Figure 5: Relationship between grain yield and agronomic efficiency of fertilizer N (AEN)

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 wetting and drying conditions.

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.

Fertilizer applications will need to match projected yield increases in 2030. As mentioned above, fertilizer applications become less efficient at higher rates and need to be matched to improved water control and management. To achieve higher yields the fertilizer will need to be balanced (N,P, K) with minor elements. Fertilizers apart from those presented in Table 14 will need to be applied but in comparison with the major elements, the cost of these fertilizers will be minor.

It is presumed that N applications will not significantly exceed 100kg/ha (see Table 15). This application rate is often found to be the most profitable level to apply in Vietnam (Trinh *et al,* 2008). The ratio of fertilizers will also vary by soil type and stage of the crop. Extra manpower will also be required to apply the fertilizers at a critical times during the year.

Fertilizers for the third crop are estimated to be between the high and lower rates of dry season and rainfed respectively.

Fertilizer rates for hybrid maize are presented in Table 16.

Table 14: Fertilizer rates per hectare on rice in the LMB 2030

Country	*Nitrogen (kg UREA/ha)*	*Phosphorus (kg DAP/ha)*	*Potassium (kg KCl/ha)*	***15:15:15 (kg/ha)***
	Wet season rice (irrigated and non irrigated)			
Lao PDR	120	50	60	
Cambodia	100	70	60	
NE Thailand	100	70	60	
Vietnam	150	110	80	
	Dry season rice			
Lao PDR	160	120	60	10
Cambodia	160	120	60	10
Thailand	140	100	60	10
Vietnam delta	180	120	80	80
	Third season rice			
Lao PDR				
Cambodia	150	120	60	10
Thailand				
Vietnam delta	160	120	60	80

Table 15: Fertilizer rate per hectare by active ingredient 2030

Country	*Nitrogen (kg N/ha)*	*Phosphorus (kg P_2O_5/ha)*	*Potassium (kg KCl/ha)*
	Dry season rice		
Lao PDR	94	26	31
Cambodia	94	26	31
Thailand	82	22	31
Vietnam delta	113	35	50

Table 16: Fertilizer rates for hybrid maize

All counties	*Nitrogen (kg UREA/ha)*	*Phosphorus (kg DAP/ha)*	*Potassium (kg KCl/ha)*
	Wet season maize (irrigated)		
Present day	150	100	80
2030	200	150	100
	Wet season rainfed maize		
Present day	100	80	40
2030	130	100	60

3.5 Projected changes in pesticide usage

Rainfed rice crops in Lao PDR, Cambodia and NE Thailand were low yielding crops in 2007 and did not require high applications of pesticides for the control of insect pests and diseases. In the Mekong Delta the estimated cost of fungicides, herbicides, insecticides and slugicides was approximately $40-50 for each crop. Herbicide costs are $15-20 per hectare for broadcast crops. Pesticide costs are included in the cost tables for each crop (Table 5). As agriculture undergoes further intensification and mechanization, application rates of herbicides will increase from approximately 2.4 kg/ha to 5.6kg/ha in the Lao PDR and Cambodia and from 6.4 to 8.0 kg/ha in NE Thailand and Vietnam. Insecticide usage should not change dramatically in dry season but increase from a low 1kg/ha in Lao PDR and Cambodia to 3kg/ha in 20 years time. In the rainfed area of NE Thailand insecticide use may increase from 2kg/ha to 7 kg/ha. For hybrid maize which uses considerable pesticide, usage will increase from approximately 12 kg/ha to 17 kg/ha. These rates are discussed further in Section 5.3 below.

4.0 Crop gross margin analyses for current and with LMB 20 year plan scenario

With the above information, gross margins were calculated for each crop and predictions made for crops to be harvested in 2030 using predicted yields and predicted inputs.

Summaries of the gross margin analysis for each crop during 2007 and 2030 are presented in Table 17 and Table 18.

Table 17: Summary sheet for current farming systems

Country	Material costs	Labor costs	Mechanization costs	Net Income	Gross margin	Days of labor	Return on labor day
	($US)	($US)	($US)	($US)	(%)	no	($US)
	Rainfed rice						
Lao PDR	112	331	30	102	21	104	4.2
Cambodia	108	294	42	130	29	112	3.8
NE Thailand	140	196	202	37	7	49	4.8
Vietnam							
	Dry season rice (2nd crop)						
Lao PDR	140	369	42	170	31	114	4.7
Cambodia	147	294	55	245	49	112	4.8
Thailand	131	212	215	31	6	53	4.6
Vietnam delta	227	265	211	304	43	79	6.6
	Wet season rice (1st crop)						
Lao PDR	112	333	34	221	46	104	5.3
Cambodia	108	294	46	251	56	112	4.9
NE Thailand	140	196	208	130	24	49	6.7
Vietnam delta	214	222	209	344	53	76	7.5
	Third season rice						
Cambodia	118	294	53	435	94	112	6.5
Vietnam delta	255	242	187	38	6	83	3.4
	Hybrid maize						
Lao PDR	390	196	170	162	21	62	5.8
Cambodia	378	159	180	252	35	62	6.6
NE Thailand	292	237	175	266	38	62	8.1
Vietnam delta	324	190	174	396	58	66	8.9
	Rainfed hybrid maize						
Lao PDR	285	196	170	15	2	62	3.4
Cambodia	278	159	180	86	14	62	4.0
NE Thailand	215	237	175	76	12	62	5.0
Vietnam delta	236	178	174	172	29	62	5.6

Table 18: Summary sheet for farming systems in LMB 20 year plan scenario

Country	Material costs	Labor costs	Mechanization costs	Net Income	Gross margin	Days of labor	Return on labor day
	($US)	($US)	($US)	($US)	(%)	no	($US)
	Rainfed rice						
Lao PDR	256	216	116	212	36	66	6.5
Cambodia	258	177	104	261	48	64	6.8
NE Thailand	232	168	230	420	67	64	14.5
Vietnam							
	Dry season rice (2nd crop)						
Lao PDR	305	221	151	445	66	66	10.1
Cambodia	308	177	145	528	84	64	10.9
Thailand	206	168	230	347	60	41	12.7
Vietnam delta	247	211	260	707	98	73	12.5
	Wet season rice (1st crop)						
Lao PDR	256	222	131	492	81	66	10.9
Cambodia	258	177	121	543	98	64	11.2
NE Thailand	232	168	230	420	67	41	14.5
Vietnam delta	300	236	256	537	68	81	9.6
	Third season rice						
Cambodia	291	177	135	746	123	64	14.3
Vietnam	258	236	229	384	39	81	6.5
	Hybrid maize						
Lao PDR	496	196	170	488	57	62	11.0
Cambodia	481	159	180	654	74	62	12.3
NE Thailand	359	237	175	654	85	62	14.4
Vietnam delta	402	178	174	671	89	62	13.7
	Rainfed hybrid maize						
Lao PDR	335	196	170	199	42	62	6.4
Cambodia	328	159	180	283	42	62	7.1
NE Thailand	247	237	175	292	44	62	8.5
Vietnam delta	272	178	174	325	52	62	8.1

4.1 Cropping systems and income

It is noticeable that the net income for the rainfed crops is currently very low. This is a reflection of the low input, low yield farming system employed by farmers in Lao PDR, Cambodia and NE Thailand. In these countries the return on each day of labor is quite low. Material costs are often lower than presented in Table 17 in areas where subsistence farming is practiced. Material inputs are also low in NE Thailand but many of the practices are now mechanized. Fields are large enough in NE Thailand for 4WD tractors to prepare the land and harvest the crop using combine harvesters. Farmers can expect a return of approximately $6.20 per labor day. Farm size is also expanding to improve the economics of growing crops under low input systems.

Similar material inputs as the rainfed crop were used for the wet season crop with irrigation. The fertilizer rates were kept reasonably low because the limitation to crop growth in the wet season is often a lack of sun shine hours (energy) not fertilizer. Crops do not respond significantly to high rates of fertilizer. These crops are also often high value photoperiod sensitive varieties. With a guaranteed supply of water however, yields are higher and the gross margins improve as a consequence.

Dry season and third season crops are all planted to HYVs which respond well to fertilizer. Denser crops are more susceptible to insect, fungus and weed pests and material costs are higher. However, the yield potential is also higher and net income rises. The gross margins and return on each labor day are higher for dry season crops.

There are a wide range of non rice crops planted in the LMB. These include open pollinated maize, hybrid maize, field crops, vegetables and fruit trees. Not all the suitable non rice crop areas are close enough to markets to grow vegetables and fruit and often labor shortages may prevent their cultivation anyway.

Maize production is the most common crop grown in non rice areas and the most common method of farming is through contract with a buyer. The contractor will often provide or sell hybrid seed to the farmer because hybrids have the potential for higher yields. Material costs are very high for hybrid maize crops and the labor costs are reasonably high. Net incomes are close to growing a high input rice crop.

Hybrid maize production is representative of the non rice growing area in terms of gross margins and was used as a standard for these areas.

Crop yields in twenty years time are expected to be significantly higher than currently achieved if historical trends continue. Part of the improvement will be a result of newly released higher yielding varieties. Fertilizer rates will also be increased and crop protection (usually IPM measures) expanded. Much of these management practices will be contracted out by the farmers. Labor saving machinery will also become increasingly important in the farming systems, particularly in those of Lao PDR and Cambodia. Mechanization will reduce labor costs but it will also improve the timeliness resulting in higher efficiency. At current labor rates, the return on labor days is expected to much higher in 2030.

4.2 Future changes to cropping systems

The current cropping patterns employed in the Mekong Delta are unlikely to change over the next 20 years unless the economics of growing non rice crops change. The reasons for rice predominating in these areas are well described in Nesbitt (2003). These are listed as being (a) Tradition, (b) Subsistence, (c) Risk, (d) Storage, (e) Marketability and most importantly (f) Land suitability. As mentioned for (f) lowland soils are susceptible to waterlogging and inundation. Most upland plants (legumes and cereals) cannot tolerate these conditions. On the other hand rice is a semi-aquatic plant possessing aerenchyma cells that transport oxygen from the leaves to the roots allowing them to grow under waterlogged soil conditions.

Many of the soils of Lao PDR, Cambodia and NE Thailand are also acidic, have low levels of organic matter, low Cation Exchange Capacities (CEC's), fix phosphorus and can possess toxic levels of aluminium under aerobic conditions. These constraints to crop growth change within a few days of the soil flooding. Waterlogged soil quickly becomes anaerobic, inducing an increase in pH to a neutral level, toxic aluminium levels drop and phosphorus becomes available to the plant. Ekasingh *et al* (2004) described "the Northeast Region, with its poor soils, is not favored agriculturally for maize production".

In addition, many of the soils are sandy loams which form a hard plough pan or seal at the surface preventing water penetration. This results in temporary waterlogging after initial rainfall or irrigation. Upland crops do not grow well in these soils, but they are suited for rice production.

An expansion in the irrigation areas of Laos and NE Thailand will reduce the risk of rice production losses from drought and the gross margins are much higher (see Table 17 and Table 18 of this report). However, the soil type in these areas will prevent significant production of upland crops with high economic returns. For high value crops such as sugar cane, some contractors are slotting bentonite into the soils to improve CEC capacity and crop productivity. This expensive practice will not be widespread in the short term.

The area of land dedicated to growing upland crops (Tables 19a-19c) is much smaller in total than that planted to rice. Upland crops are generally grown in upland soil conditions during the wet season and little is cultivated with irrigation in the dry season.

Table 19a: Cropping areas in LMB (000' ha)

	Year	Rice	Maize	Cassava	Sugarcane	Other upland crops
Thailand	1999					
Wet season		4,647.4	383.2	619.5	480.0	119.7
Dry season		67.2				
Vietnam Delta	2000					
Wet season		2,425.0	19.0	153.0	76.0	9.0
Dry season		1,537.0				
Vietnam CH	2000					
Wet season		181.0	87.0	38.0	25.0	
Dry season		51.0				
Cambodia	2000					
Wet Season		1,647.0	54.1	13.5	5.2	79.1
Dry season		255.0	3.4	1.8	2.2	7.8
Laos	1999					
Wet season		631.0	41.0	13.0	5.0	22.0
Dry season		87.0				

Table 19b: Upland cropping areas in LMB (000' ha)

	Year	Soybean	Peanuts	Cotton	Kenaf
Thailand	1999				
Wet season		37.6	29.9	5.3	26.9
Dry season					
Vietnam					
Delta	2000				
Wet season			9.0		
Dry season					
Vietnam CH	2000	21.0	22.0	10.0	
Wet season					
Dry season					
Cambodia	2000				
Wet Season		33.0	7.5	0.0	20.8
Dry season			2.7	0.0	
Laos	1999				
Wet season		7.0	13.0		
Dry season					

Table 19c: Fruit tree and vegetable cropping areas in LMB (000' ha)

	Year	Fruit trees	Coffee	Vegetables
Thailand	1995	381	na	39.0
Vietnam				
Delta	2009	350	na	?
Vietnam CH	2000	?	300e	?
Cambodia	2000	164.0	little	32.0
Laos	1999	?	42.0	43.0

Source MAC, 2000, BSL, 2001, MAFF, 2000, VSY, 2002

Expansion in the area under fruit and industrial crop production has matched population growth. For example in 2000, the area under fruit trees in the Mekong Delta was 300,000 ha and was reported to be 350,000 ha in 2009 (VNBusinessNews.com - The Cuu Long (Mekong).

Lao PDR officials estimate that the area to be dedicated to the production of non rice crops in the LMB 20 Year Plan scenario (Table 2) will increase to 40,000 ha from a low base of 6,977 ha. Much of this increase area may be dedicated to vegetable production close to Vientiane and other city centres (Somsack et al, 2004) and the remainder for fruit trees. The expected expansion in the non rice area in Cambodia (12,172 ha to 19,879 ha) and Vietnam (329,740 ha to 391,311 ha) (Table 2) may also be utilized for similar purposes.

Thailand expects to see an almost doubling in the area of non rice crops (252,704 ha to 560,784 ha). According to the cropping patterns presented in Appendix 1, most of these crops will be fully irrigated being planted during the dry season. Kenaf will remain a wet season crop.

As mentioned above, much of the area in the NE of Thailand is unsuitable for high yielding upland crops and their production will need to be concentrated on fertile soils.

4.3 Farm areas in the LMB can increase

The farm areas in each of the four riparian countries are approximately 1.6, 4.3, 1.7 and 1.1 ha in each of Lao PDR, NE Thailand, Cambodia and Vietnam respectively. Bestari *et al* (2006), Cai *et al* (2008), Suchint *et al* (2003), Sununtar et al (2008), Minot and Golotti (2000). Some authors (Huan *et al*, 1999) quote 2.3 million farmer being in the Mekong Delta of Vietnam which places the farm area in the Mekong Delta at approximately 1 ha per farm. One farmer (and his family) is able to efficiently manage approximately 1 ha of irrigated rice at one time. The manageable area will expand as paddy size increases and through further mechanization. One farmer in Australia can manage 100 ha or more of paddy rice, indicating there is considerable scope for labor efficiency improvement.

4.4 Future changes to mechanization and farm employment

Labor shortages have encouraged a high degree of mechanization in NE Thailand farming areas (Kalsirisilp and Singh 2001). There is little scope for extra mechanization in these areas and labor efficiencies in the future will most likely result from farm area consolidation. The Mekong Delta in Vietnam is also highly mechanized. The introduction of a stripper in Vietnam will improve efficiency further but the farm size needs to increase to over 1 ha before this machine will become economically viable (Anonymous 2007).

There is considerable scope for mechanization in Lao PDR and Cambodia. The number of days spent on a hectare of rice could reduce from 109 days to 66 days over the next 20 years. This is a reduction of 43 days the farmer is required to work one hectare of crop. In Cambodia, mechanization may save a similar amount of labor. If the area under irrigation does not change, there will be a significant labor savings over the 20 year period. However, it is planned for the area under irrigation to expand from 6.8 million hectares to over 9.7 million hectares. Although mechanization will take place, the rural sector will need to employ an extra 82 million man days to farm the expanded area (Table 20). At 200 work days per year, this equates to the employment of over 400,000 farm laborers. Most of this extra labor requirement will be in Lao PDR and NE Thailand.

Table 20: Agricultural mechanization and farm employment

	Annual irrigated area	Average farm size (ha)	Mean labor days/ha (wet and dry season crops)	No. man days	Change in man days	Extra no farmers at 200 work days per year
Definite present						
Lao PDR	270,677	1.6	109	29,503,793		
NE Thailand	1,755,765	4.3	112	196,645,680		
Cambodia	563,037	1.7	42	23,647,554		
Vietnam	4,217,983	1.1	78	329,002,674		
TOTAL	**6,807,462**			**578,799,701**		
20 year plan (2030)						
Lao PDR	819,593		66	54,093,138	24,589,345	163,929
NE Thailand	3,624,002		64	231,936,128	35,290,448	235,270
Cambodia	877,218		41	35,965,938	12,318,384	82,123
Vietnam	4,404,445		77	339,142,265	10,139,591	67,597
TOTAL	**9,725,258**			**661,137,469**	**82,337,768**	**411,689**

5.0 Water quality from irrigation areas

Current sources of water pollution in the Mekong River include silting, salt, fertilizers, pesticides, acid water, and contamination from industrialized sites and toxic discharge from fish ponds.

5.1 Sediment loads in water from agricultural areas

At the MRC regional workshop in October, 2008 on discharge and sediment monitoring and geomorphological tools for the LMB, Prof D Walling from the University of Exeter, UK, considered that there was relative stability of sediment loads throughout the LMB from 1960 through to 2000. This observation was supported in the MRC river quality report card (MRC, 2008). A reasonably stable trend in sediment loads is therefore predicted for the future unless there is widespread land clearing in the interim or large scale entrapment from new dams.

Sedimentation enhances the capacity of cropping soils. Higher grain yields can be expected after the areas are flooded with water possessing sediments. Sediment deposits also provide an important food source for aquatic fauna and flora (MRC, 2009). Cropping of upland areas can increase sedimentation runoff after high rainfall causes erosion from sloping land with bare soil. However, there is rarely erosion or sedimentation runoff from lowland areas, particularly from irrigation sites. Paddy soils are more likely to collect suspended sediments.

5.2 Nitrogen and phosphorus in water from agricultural areas

In NE Thailand, Laos and Cambodia, the use of agricultural chemicals remains very low. As a result natural and agricultural pollutants of the river system remain low in the upper river basin (MRC 2008). With the expected large increase in irrigation area and greater intensification, the level of N and P reaching the river could increase. The MRC Environment Programme Reviewer (MRC, 2008a) estimated that 225,138 t of N and 37,523 t of P is lost from LMB agriculture annually (Table 21 (adapted from Table 1.3 in MRC, 2008a)). If a small amount of this reaches the Mekong River then increases in fertilizer use across an expanded area of irrigation in the 20 year scenario will lead to a significant increase in the amount of N and P reaching the river by 2030.

N and P application rates are predicted to increase by between 225-250 and 350-500% respectively in Lao PDR, Cambodia and Thailand over the next 20 years using improved technology to take advantage of the extra applied fertilizer. In addition, the irrigated area will increase from 4-202% (Table 2). Using 20% loss from the irrigation system for N and 10% loss for P as suggested in MRC (2008a), there will be an extra loss from the agricultural areas in the LMB of 265,518 metric tons of N and 68,411 tons of P. Most of this loss will come from NE Thailand where the area under cultivation will increase by over 1.9 million ha. Nitrogen and Phosphorus applications to agricultural areas in the Mekong Delta of Vietnam are at their optimum levels and are unlikely to increase significantly over the next 20 years.

Increased nutrient losses from the agricultural area will place an extra burden on the already high levels in the Mekong Delta where nitrogen levels in river water have steadily increased over the past 20 years and are a cause for concern (MRC, 2003). With the current water nutrient levels, it is suspected that algal blooms could develop in the Mekong Delta if river flows are restricted. It is recognized that a considerable amount of these nutrients are from fish farms on the delta. Paddy fields have been demonstrated to clean some of these nutrients (MRC, 2009). Nitrogen and phosphorus concentrations in irrigation water will benefit crop production unless toxins develop during algal blooms.

Table 21: Estimates of losses of nutrients from agriculture within the LMB (adapted from Table 1.3 in MRC, 2008a)

Country	Loss of N t/year	Loss of P t/year)	Approx. increase in N use from 2007 – 2030 (%)	Approx. increase in P use from 2007 – 2030 (%)	Area increase (%)	Extra loss of N t/year in 2030	Extra loss of P t/year in 2030
Cambodia	474	79	225	500	56	597	221
Lao PDR	486	81	250	350	202	2,454	573
Thailand	108,102	18,017	225	350	106	257,823	66,843
Vietnam	116,076	19,346	0	0	4	4,643	774
TOTAL	**225,138**	**37,523**				**265,518**	**68,411**

Fertilizer use efficiency is improving in most parts of the developed world. This is a direct consequence of the higher cost of fertilizers leading to better management practices. These practices include the development of slow release fertilizers, judicious application rates, timing of application, improved plant spacing and deep placement. Such practices are being adapted for the tropics and adopted by farmers in the LMB.

5.3 Pesticides in water from agricultural areas

Until recently the use of pesticides has been on the increase in all riparian countries (Nesbitt, 2005). 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, Laos and NE Thailand because of the low degree of intensive agriculture in these watersheds. In Laos, the Ministry of Agriculture, Forestry and Fisheries is touting the export of large quantities of "organic rice" at premium prices indicating the government 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. http://www.pan-uk.org/pestnews/Issue/pn29/pn29p11.htm) according to the PAN international.

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 denatured as it hits the soil. Foliar application herbicides are slightly more toxic. For example, 2,4-D has been in use for over 60 years (first developed in 1946) and is the most common herbicide in use in Asia. The phenoxy form is considered to non toxic to humans. Other narrow leaf herbicides are in the low-medium toxicity level.

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 (Heong pers comm.). The International Rice Research Institute is promoting the use of Integrated Pest Management concepts in rice http://www.knowledgebank.irri.org/ipm/index.php/key-concept-or-tools-for-thinking-about-ipm-crop-health-2745 (Huan *et al* 2000) 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.

The Gross Margin analyses presented in this report suggest that 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 (Heong pers comm.). 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 (Table 22) as broadcasting of rice seed becomes more popular.

Table 22: Application rates of herbicides, fungicides and insecticides (kg/ha)

	Lao PDR	Cambodia	NE Thailand	Vietnam
Rainfed				
Current herbicide use	2.4	2.4	6.4	
Use in 2030	5.6	5.6	8.0	
% increase	133	133	25	
Current insecticide and fungicide use	1.0	1.0	2.0	
Use in 2030	3.0	3.0	7.0	
% increase	200	200	250	
Dry season (2nd)				
Current herbicide use	2.4	2.4	6.4	6.4
Use in 2030	5.6	5.6	8.0	8.0
% increase	133	133	25	25
Current insecticide and fungicide use	7.0	7.0	7.0	7.0
Use in 2030	7.0	7.0	7.0	7.0
% increase	0	0	0	0
Irrigated wet season (1st)				
Current herbicide use	2.4	2.4	6.4	6.4
Use in 2030	5.6	5.6	8.0	8.0
% increase	133	133	25	25
Current insecticide and fungicide use	1.0	1.0	7.0	7.0
Use in 2030	3.0	3.0	7.0	7.0
% increase	200	200	0	0
Third season				
Current herbicide use		2.4		6.4
Use in 2030		5.6		8.0
% increase		133		25
Current insecticide and fungicide use		7.0		7.0
Use in 2030		7.0		7.0
% increase		0		0
Non rice crop				
Current herbicide use	8.0	8.0	8.0	8.0
Use in 2030	8.0	8.0	8.0	8.0
% increase	0	0	0	0
Current insecticide and fungicide use	12.0	12.0	12.0	12.0
Use in 2030	17.0	17.0	17.0	17.0
% increase	42	42	42	42

5.4 Acid water in agricultural areas in LMB

Acid water and aluminium contamination are both problems in the Mekong Delta and will continue to be so on a localized basis for many years to come as acid sulphate soil areas are drained. These problems will remain localized if river flows are maintained. The most severely affected areas are the Plain of Reeds in Vietnam and some sites in the upper delta region of Cambodia. Construction of a network of drains and canals in the delta allows Mekong river water to flush these areas (MRC, 2008)

5.5 Salt water in agricultural areas in LMB

Much of NE Thailand is on the Korat Plateau, the geology of which is rich in salt. Concerns for saline runoff from salt affected soils in NE Thailand have not eventuated in recent years, with few monitoring sites in the Mekong river showing any increased salt concentration above natural levels. This potential source of contamination will require monitoring in the future. If the problem does escalate it may be necessary to take some land out of production or for the reforestation of hills and expansion of the irrigation areas to prevent the rise of the water table containing high salt content.

Saline water intrusion in the lower Mekong delta is also a problem (White, 1996, Tuong *et al* 2003, Kotera *et al* 2008) with 2 million ha of land subject to dry season salinity. Saline water is known to extend 50km inland during the dry season. There are projects and planned projects to restrict the intrusion of salt water with positive and negative effects (White, 1996 and Tuong *et al* 2003) regarding water quality.

Saline water and soils are a serious constraint in agriculture. It causes a range of crop production problems in many parta of the world. In Thailand, saline soils prevent the cultivation on upland crops in small areas in Tung Kula Ronghai in Roi-et Province. Saline water intrusion from the ocean in the lower Mekong delta also reduces rice yields.

Crops are affected by saline conditions by varying degrees. Some crops can produce acceptable yields at greater soil salinity than others. Ayers and Westcot's summary of salinity work indicates that there is a 5-10 fold range in salt tolerance of agricultural crops. Four crops commonly grown in the LMB are presented in Table 22. Barley is 8 fold more tolerant of salt than beans. Rice is considered to be moderately sensitive. These guidelines indicate that rice will suffer yield reductions if the water contains salt levels above an Electrical Conductivity (EC) of 2 dS/m or the soil contains salt above an EC of 3dS/m. The EC is a measure of the ions which make up the salts. Conversions of this measurement into other units are as follows:

1dS/m = 1000 EC units (or mS/cm) = approximately 640 mg/l (or ppm)

Saline water affects the osmotic potential of the plant root, thereby affecting water and nutrient uptake. Thus, there are yield reductions as salinity increases. A number of studies have been conducted to overcome such a loss yield. Zeng and Shannon (2000), for example, tried to increase potential yield by increasing the seeding rate. In their study yield was halved at an ECe of 6.5. This level falls in the range in Table 22. Another method of reducing losses from salinity is the introduction of salt tolerant rice varieties. Singh (undated) reports the development of a rice variety which tolerates an ECe of 6-10. A breeding program is also underway in the Mekong delta to breed varieties which will tolerate salt levels in a similar range (Nguyen *et al*). Such varieties would mover the crop further up the salt tolerance scale.

In glasshouse pot trials, rice plants are more sensitive to salt than in the field. Motamed et al (2008) considered that the threshold level for grain yield maximization was 1.3 dS/m which is below that presented in Table 22. In another study, Folkard and Wopereis (2000) found that yields declined about 0.6-1 to/ha per unit of EC for EC levels above 2dS/m. Gratten *et al* and Scardaci *et al* (1995) also considered the threshold level to be at 2dS/m above which rice yields were reduced significantly. This relationship appears to be "on average" fair and the values in Table 23 for rice have been graphed in Figure 6 for convenience.

Table 23: Crop tolerance and yield potential of selected crops as influenced by irrigation water salinity (ECw) or soil salinity (ECe)

FIELD CROPS	100%		90%		75%		50%		0%	
	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w
Barley (*Hordeum vulgare)*	8	5.3	10	6.7	13	8.7	18	12	28	19
Rice (paddy) *(Oriza sativa)*	3	2	3.8	2.6	5.1	3.4	7.2	4.8	11	7.6
Corn (maize) *(Zea mays)*	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Bean *(Phaseolus vulgaris)*	1	0.7	1.5	1	2.3	1.5	3.6	2.4	6.3	4.2

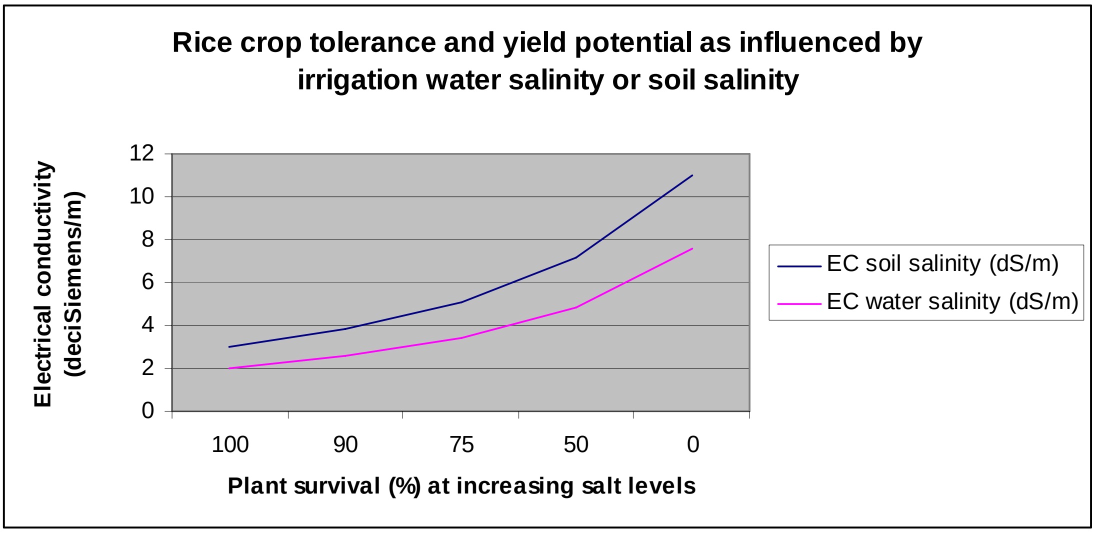

Figure 6: Rice crop tolerance and yield potential as influenced by salinity

5.6 Aquatic food from rice paddies in the LMB

Farmers in the LMB rely heavily on harvesting aquatic food from the paddies. A study on multi-functionality of rice paddies over the LMB (MRC, 2009) stated that "paddy fields, both rain-fed and irrigated, provide many valuable wild products that are of great economic value to the farm households. These wild species make important contributions to the food supply of rural households, especially as a source of nutritionally valuable vegetables and proteins. They are also an important source of cash income for rural households".

Studies by the AIT Aquaculture Outreach Programme in NE Thailand have estimated household fish collection from ricefields was in the order of 300-400 kg/household/year in a "good year" and 100 kg/household in a "bad year". Leenanond et al (1989) found an average family fish production from ricefields of 310 kg/family/year in the Tung Kula Ronghai area of NE Thailand. Gregory (1997) suggested that estimates of fish production per unit area of ricefield are notoriously difficult to estimate but his studies indicated a harvest in NE Thailand would be approximately 100 kg/ha/year. The MRC 2008b mean yield of fish plus other aquatic animals was 119 kg/ha/season (±25 as 95% confidence limits) with a mean value of US$102/ha (±$23/ha), based on market prices. This study considered that it "underestimated the yield and value of the fishery, because additional catches were made by fishers using unmonitored illegal gears, and unmonitored catches were also made during the dry season".

In NE Thailand the study reported in MRC, 2009 estimated that US$497 worth of wild food was collected from a hectare of rainfed paddy field and US$351 worth from irrigated paddies. Farmers have more time to collect from rainfed paddies and yields are subsequently higher. This income compares rather well with the 100-200kg/ha estimated production in paddies by Kent Hortle and Penroong Bamrungrach (MRC, 2009a) (see Table 24).

These studies illustrate an extra element to the economic benefits derived from paddy fields. An increased area of irrigation will expand this impact in relation to the area irrigated.

Table 24: from Hortle and Bamrungrach (MRC, 2009) Summary table of wetland areas, yield per unit area (high yield estimate) and maximum estimated total yield

Wetland class	Area (000 km2)	Yield (kg/ha/year)	Total yield (000 tonnes/year)
1 **Major flood zone:** permanent water-bodies and seasonally flooded land; includes some ricefields and aquaculture	58,017	200	1,160
2 **Rain-fed zone:** mainly ricefields and associated habitats not within the major flood zone	129,835	100	1,299
3 **Large water-bodies:** including reservoirs outside the flood zone	7,512	300	225
TOTAL	194,364		**2,684**

6.0 Climate change on agricultural production in the LMB

This section is purely a summary for completion on discussion on the changes which irrigated agriculture will go through over the next 20 years in the LMB. It is not a comprehensive review.

Agriculture in the LMB will be affected by rising atmospheric CO2 levels and rising temperatures apart from changes in overall rainfall and volatile weather patterns plus rising sea levels accepted to be part of climate change. Increases in atmospheric CO2 will be assist photosynthesis resulting in possible higher yields. Balanced against this will be the effects of increasing temperatures. Crop models developed for rice at IRRI (Matthews et al, 1995) predicted decreases in yield in countries surrounding the LMB with an increase in temperature alone, and increases in yield when only CO_2 level was raised. The exact effect on existing crop yields at a specific site depends on the combination of these two factors. Vietnam Government (MNRE) studies expect temperature increases in the South to range from 1.4-2.6 degrees over the 21st century depending on emission scenarios. Eastham, 2008 (in WWF, 2009) expects temperatures in the LMB over the next 20 years to increase by 0.79^o C. ADB (2009) figures concur with this estimate as did discussion in a MRC climate change workshop (MRC 2009b). In the latter discussion it was stated that annual precipitation is also projected to increase by ~ 0.2 m (13.5%), resulting mainly from an increase in the wet season (May to October). Increased rainfall will assist the cultivation of rained crops and potentially provide extra water for irrigation.

ADB (2009) simulations point to a leveling off of crop yields for the period from 2000-2010 and then a deterioration, leading to reductions in yield of approximately 50% in Vietnam and Thailand by the end of the century. These simulations do not take into consideration the positive effects of higher atmospheric CO_2 levels.

Given that, over the next 20 years, rainfall is expected to increase by 13.5%, CO_2 levels will increase and temperature based predictions suggest that yields will not deteriorate significantly until after 2030 it is tempting to suggest that crop yields, especially irrigated crops, may not suffer significant yield reductions over this period. The results of simulation models are not conclusive on this matter either.

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