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The Council Study

Study on the sustainable management and development of the Mekong River, including impacts of mainstream hydropower projects

Thematic Report on the Positive and Negative Impacts of Irrigation on the Social, Environmental, and Economic Conditions of the Lower Mekong River Basin and Policy Recommendations

(Interim Report)

November 2016

Content

1 Background

Overview of the Irrigation Sector in the LMB

Irrigation is the largest water user in the Lower Mekong Basin (LMB) using 12% of the average annual flow. All the countries of the Basin have policies and plans to expand irrigation areas to increase rice production and exports, diversify food production, respond to food security needs and address rural poverty. Various scenarios of current and planned developments suggest that future flows in the mainstream will accommodate the expansions of irrigation areas planned by all countries.

Differences are characterizing this expansion among the regions of the basin. First, some countries have seen a low development of the irrigation sector in the past 30 years with respect to others that have developed rapidly their irrigation infrastructures up to the 2000's: this is the case for Laos and Cambodia that have had a limited development compared to Thailand and Viet Nam. The total developed irrigated area within the LMB is estimated between 4.0 and 5.0 million hectares in the present state[1] . The share of each country is presented in the figure below:

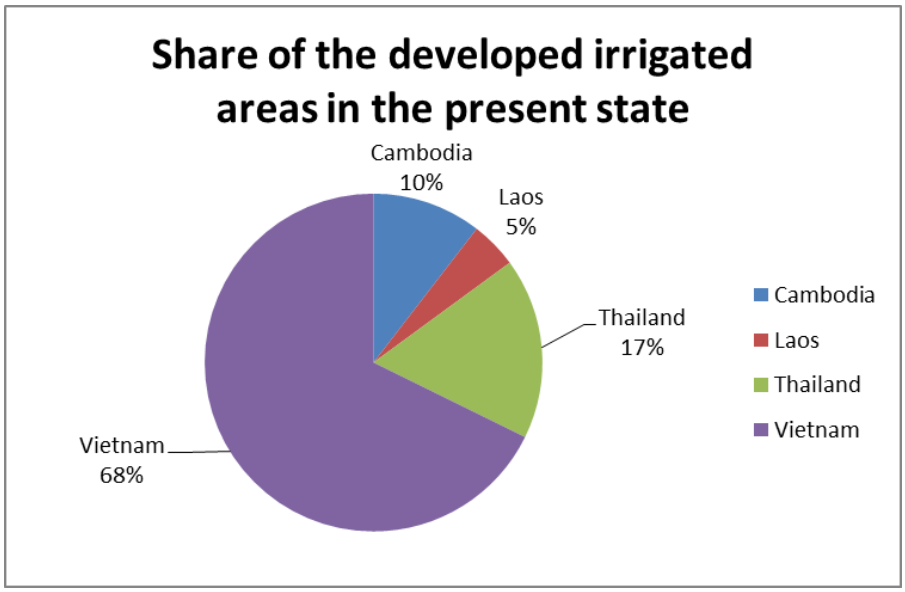


Figure 1: Share of the developed irrigation areas in the present state

According to the information collected, the total irrigation area could nearly double in the far future, reaching up to 7 million hectares. In these hypothetical plans, Laos, Cambodia and Thailand would increase dramatically their area development, whereas Viet Nam would only see a very limited one. These plans will need to be analyzed in space and time.

The central role of the irrigated agriculture in the future of the LMB, being a major water consumer and generating numerous impacts, is a key sector to be analyzed within the Council Study.

[1] Figures compiled from the data collected within the council study, updated in March 2016

The council study will prepare a report that will analyze the positive and negative impacts of the planned irrigation development in the LMB in order to provide recommendations for impacts avoidance and mitigation measures.

Among the objectives of the study for this theme, it is proposed to analyze the rate of irrigation expansion and the induced changes in flow parameters. The assessment of the Irrigation thematic area will provide key information on the resulting changes in environmental, social and economic parameters including issues of food security, employment and transboundary benefits and costs. Out of the analysis on this triple bottom-line, the study will also cover the impacts of irrigation on fisheries and of other developments on irrigation including dry season irrigation.

2 Current Status of the Irrigation Thematic area

Summary and discussion of "current" physical footprint of thematic infrastructure by selected geographic units

The vast majority of arable land in the Basin lies west of the Mekong mainstream. The Figure 2 below shows that most of the rice is cultivated around Chiang Rai in the north, northeast Thailand, Vientiane and the Seven Plains of Lao PDR, the Tonle Sap flood plains, south-eastern Cambodia and the Delta. Non-rice crops are grown in the same regions but also in the central highland of Viet Nam.

Rice dominates crop production in LMB countries, particularly in the lowland areas, with a total of over 23.1 million hectares (ha) being cultivated in 2010. Between 1990 and 2010, the overall area of rice increased by 33%. In the same period rice production has more than doubled from 40.4 million tons to 86.4 million tons.

With regard to rice yields, there was a very substantial increase in overall productivity from 2.33 tons/hectare in 1990 to 3.74 tons/hectare in 2010 (i.e. 60% increase). In 2010, rice yields ranged from 2.94 tons/hectare in Thailand to 5.34 tons/hectare in Viet Nam.

For the rice cultivation in the LMB, a variety of irrigation systems are employed and a number of variations exist within the region. **Gravity irrigation** with open channel networks is the typical irrigation system for most public schemes. Modernization has also transformed and upgraded some gravity schemes served by pressurized pipeline systems. Beside the large public schemes, the small scale irrigation is practiced all over the LMB. The combination of farm pond with mobile pump is widely used by those smallholders practicing subsistence agriculture.

Besides these rather formal systems, there are many variations of irrigation or partial irrigation systems that have been developed in specific natural conditions. Two examples can be reported: the "Colmatage or Prek" and "Tnup" They can be described as partial irrigation or a variation of irrigation because water supply cannot be planned or necessarily managed to meet crop water demand.

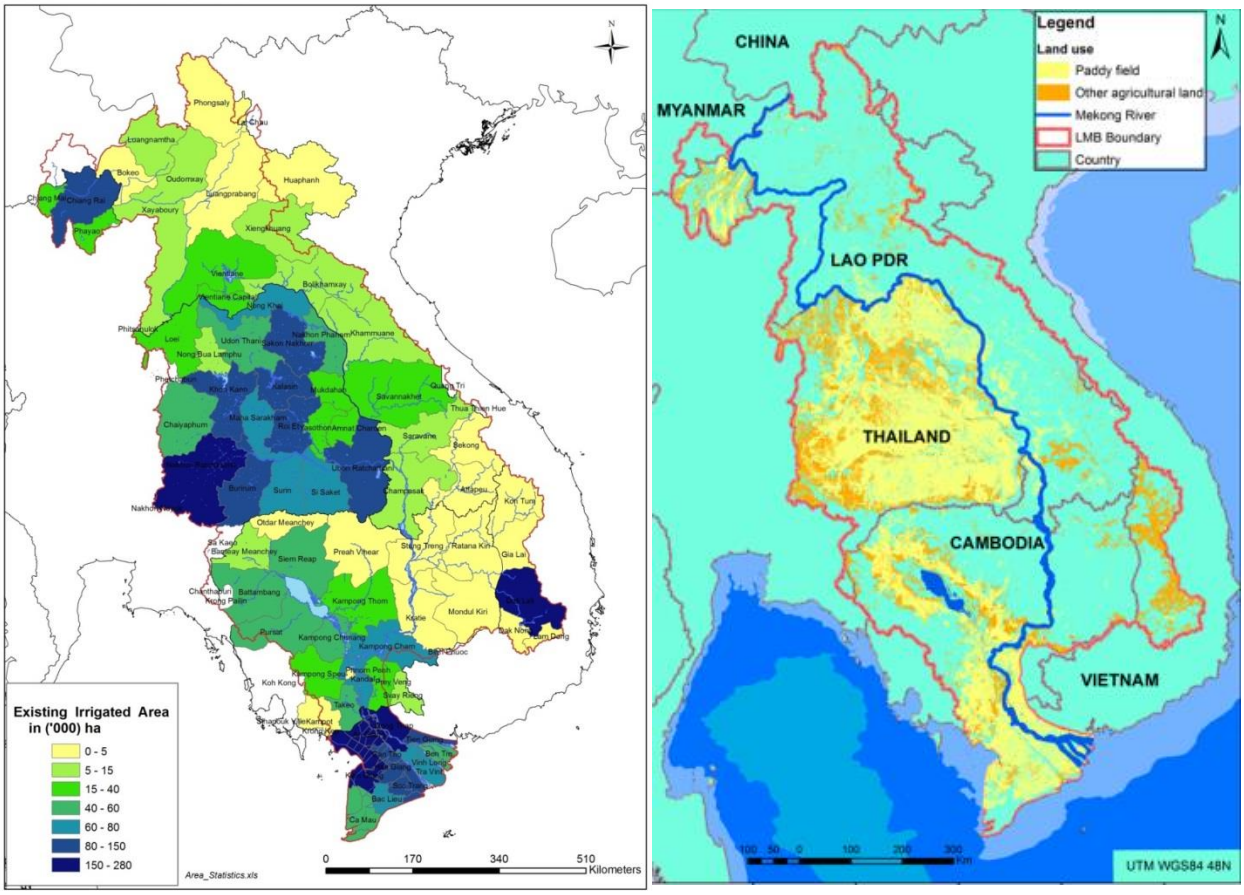


Figure 2: Percentage of Cultivable Land that is Irrigated in the Wet Season (Right) and Current situation of the Irrigation sector in 2007 (Left)

Cambodia

In Cambodia, water policy as a whole and irrigation in particular are seen as crucial elements of the development of agriculture, leading to food security and poverty alleviation, the main objectives pursued by the state in a country where agriculture amounts to half of the gross domestic product (GDP) and 90 percent of employment.

The total cultivated area of Cambodia is about 4.37million ha (24% of the land), while forests cover is about 56%. Rice is the dominant crop, which covers approximately 3.57million ha, (80% of agricultural land) including the area of receding, floating rice and paddy rice interspersed within villages. Field crops comprise of 6%, rubber 2%, garden crops 7%, orchard < 1% and others as being slash and burn 8%. Rice crop is dominating the sector mainly grown during the wet season in rain-fed lowland conditions. Wet season rain-fed lowland rice crop occupies about 84% of the total cultivated areas whereas the dry season rice crops with full and/or supplementary irrigation occupy about 11%.

Cambodia has to face the heritage the land transformation that occurred during the Khmer regime; Engineering irrigation and drainage works modelled the plains with poor planning and design criteria, affecting the development of the irrigation practice. The MOWRAM is programming since several years the development of the sector mainly through requalification and rehabilitation of those systems.

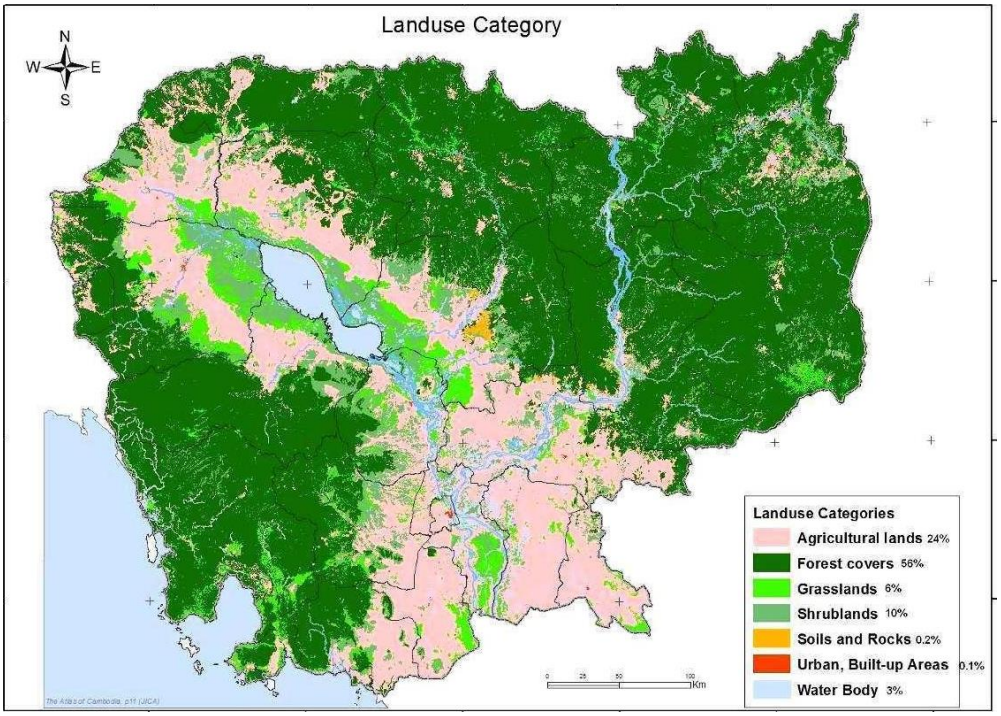


Figure 3: Land Use map of Cambodia

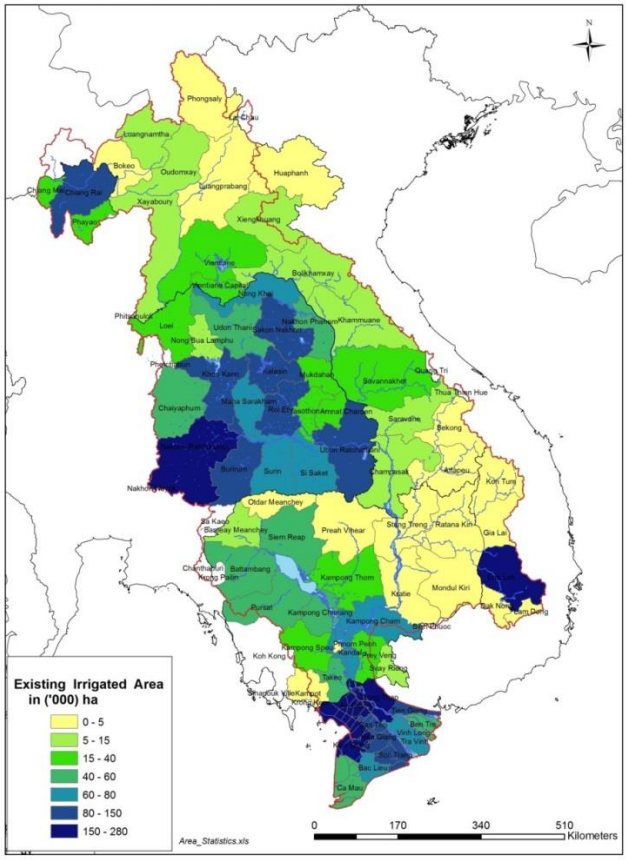


Figure 4: Current situation of the Irrigation sector (2007)

Laos

According to 2013 statistics, the Lao part of the Mekong basin (MBL) has a total area of about 264,233 km^2 and a population of about 6.3 million people. The study area has resources fertile land, water from Mekong River and rainwater can provide for agricultural production with an important contribution to the socio-economic development of a stable and sustainable MBL area.

The topography of the area is mountainous within the North and West regions and low land with flat in the Western and Southern regions. The average ground elevation range between 1000 m to 100 m above mean sea level. Flat plain is favorable for the development of irrigation systems and water control for agricultural production development. The country is located in the tropical monsoon area, with high temperatures and relatively stable with an average rainfall of about 1600mm. The rainfall regime is unevenly distributed over space about (1600-2400 mm / year), and time (the amount of rain in the rainy season, from May to October about 90%, in the dry season from November to April about 10% of the annual rainfall).

Agriculture is central to the Lao economy. It contributes 42 percent of GDP (2005/06); accounts for at least 15 percent of recorded exports; and accounts for 67 percent of the employed adult workforce.

The **Laos** irrigation sector was for a long time characterized by small scale irrigation systems, directly managed by farmers withdrawing water directly from the nearby river by gravity (wet season) or through the use of small diesel pumps (dry season). The development of the large scale hydropower sector has offered the possibility to use the stored water in the reservoirs and to feed large scale irrigation schemes connected with long engineered canal systems. This is the way the irrigation sector is being transformed in the future.

Currently, 3,162 irrigation projects have been censed in Lao PDR within the lower Mekong basin region. They are classified as follows:

Table 1: Irrigation Existing Project Database_2014

Existing Irrigation Project in Lao PDR by Irrigation Database statistic_2014		
No	Irrigation Type	Amount of Project
1	Weir	2,218
2	Diversion gate	69
3	Pump Station	548
4	Reservoir	267
5	Other	60
Total		3,162
6	Existing irrigation area on wet season (Ha)	261,689.00
7	Existing irrigation area on dry season (Ha)	170,539.00

For the current situation, the total irrigated agriculture during the dry season 2014 reached 170,539 ha and 261,689 ha for the wet season.

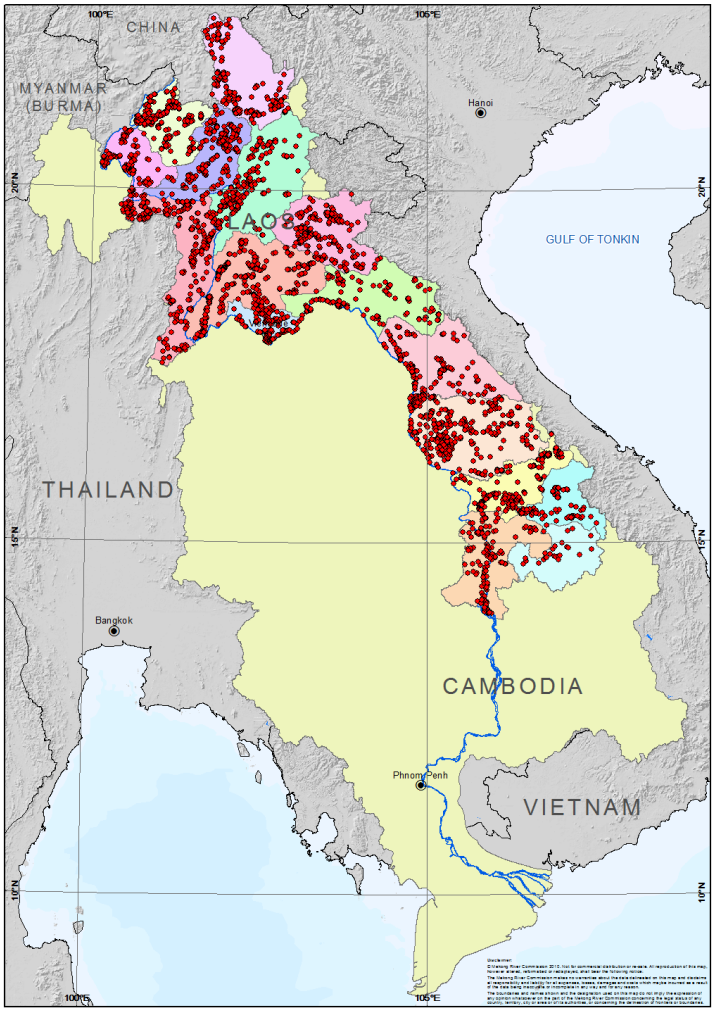


Figure 5: Location map of the irrigation projects – Lao PDR.

Thailand

Among 25 major river basins in Thailand, five river basins are flowing into Mekong River including Kok, Khong (North and Northeast), Chi, Mun, and Tonlesap River Basins. These basins covering the total area of 188,760 km^2 in 21 provinces which is 37% of the country's total area and serve 24.6 Million riparian people or approximately 38% of the country. The whole area of the Northeast of Thailand is in the Mekong River Basin in which the Chi and Mun river basins are the significant river basins having large catchment areas that constitute 23% of the total area of the country.

The potential area for irrigation development within the Thai share of the Mekong basin is up to 4.6 million hectares[2].

In North east **Thailand**, the irrigation sector is characterized by large scale gravity canal systems in that often draw water from a large scale dam and reservoir or barrage type structure: large scale weirs with control gates. These irrigation schemes are highly sophisticated engineering works but they change riverine aquatic ecosystems on a large scale, too.

In the current situation, 810 thousand hectares are irrigated.

Table 2: Basic information of Kok, Khong, Chi, Mun, and Tonlesap Basins

Topic	Item	Unit	Khong (North)	Khong (Northeast)	Kok	Chi	Mun	Tonlesap	Total	Country	%
General	Catchment Area	rai	6,247,973	29,494,896	4,562,394	30,706,169	44,419,750	2,553,700	117,984,882	321,281,184	36.72
		ha	999,676	4,719,183	729,983	4,912,987	7,107,160	408,592	18,877,581	51,404,989	36.72
		km^2	9,996.8	47,191.8	7,299.8	49,129.9	71,071.6	4,085.9	188,775.8	514,049.89	36.72
	Average Annual Rainfall	mm	1,354.5	1,530.0	1,490.1	1,207.9	1,268.0	1,497.4	1,391.3	1,431.60	97.19
	Average Annual Runoff	MCM	3,480.2	20,763.0	3,192.7	11,159.4	17,117.7	1,605.9	57,318.9	199,277.40	28.76
Land Use	Agricultural Area	rai	3,037,004	17,807,421	1,823,416	20,339,177	32,403,266	1,627,796	77,038,080	169,255,098	45.52
		ha	485,921	2,849,187	291,747	3,254,268	5,184,523	260,447	12,326,093	27,080,816	45.52
		km^2	4,859.2	28,491.9	2,917.5	32,542.7	51,845.2	2,604.5	123,260.9	270,808.2	45.52
	Potential Area for Irrigation	rai	1,413,297	3,921,443	564,385	11,226,682	11,686,902	257,700	29,070,409	60,294,241	48.21
		ha	226,128	627,431	90,302	1,796,269	1,869,904	41,232	4,651,265	9,647,079	48.21
		km^2	2,261.3	6,274.3	903.0	17,962.7	18,699.0	412.3	46,512.7	96,470.8	48.21
Population, Economics	No. of Household	housing unit	343,925	1,373,961	829,855	1,616,636	1,197,024	106,213	5,467,614	20,597,664	26.54
	Population	population	962,398	5,099,756	2,201,296	6,164,100	9,853,398	323,553	24,604,501	64,397,764	38.21
	Population Density	population/km2	77	110	94	125	146	78	105	125	84.00
	GDP	Million Baht	180,020	327,722	192,173	533,059	646,049	73,559	1,952,582	20,077,300	9.73
	Net Household Income	Baht/Household/Month	2,866	2,312	2,424	15,170	3,464	2,641	4,813	6,499	74.05
Water Demand	Irrigated Agriculture	MCM/year	82.2	295.0	80.3	4,608.1	4,261.0	42.9	9,369.5	45,053.6	20.80
	Rainfed Agriculture	MCM/year	144.2	972.0	81.9	n/a	33,892.0	344.6	-	61,115.7	-
	Domestic	MCM/year	70.3	171.8	160.7	217.7	303.4	23.6	947.5	24,177.0	3.92
	Industrial	MCM/year	13.1	11.8	11.4	33.0	44.6	6.5	120.4	2,592.4	4.64
	Livestocks	MCM/year	5.2	48.9	10.2	62.4	135.8	3.6	266.1	679.5	39.16
	Ecology	MCM/year	378.3	3,174.6	698.4	157.1	1,383.0	262.2	6,053.6	28,532.6	21.22
	Total Demands	MCM/year	693.3	4,674.1	1,042.9	-	40,019.8	683.4	47,113.5	-	-
Present Water Resources Development Project	Number	no.	626	1,789	232	2,116	2,732	145	7,640	16,126	47.38
	Capacity	MCM	210.7	1,462.1	126.1	5,356.0	4,357.9	159.4	11,672	76,370.0	15.28
	Irrigation Area	rai	378,650	1,255,739	362,902	2,635,466	2,251,276	106,250	6,990,283	28,363,084	24.65
		ha	60,584	200,918	58,064	421,675	360,204	17,000	1,118,445	4,538,093	24.65
		km^2	605.8	2,009.2	580.6	4,216.7	3,602.0	170.0	11,184.5	45,380.9	24.65
	Beneficial Area[1/]	rai	603,930	902,147	290,647	878,749	1,606,309	68,460	4,350,242.0	12,198,326	35.66
		ha	96,629	144,344	46,504	140,600	257,009	10,954	696,039	1,951,732	35.66
		km^2	966.3	1,443.4	465.0	1,406.0	2,570.1	109.5	6,960.4	19,517.3	35.66
Planned Water Resources Development Project	Number	no.	180	701	89	1,277	1,168	84	3,499	8,789	39.81
	Capacity	MCM	752.0	535.0	315.8	2,728.4	851.9	207.0	5,390	26,603.0	20.26
	Irrigation Area	rai	654,129	1,180,293	318,454	5,196,207	14,363,286	209,161	21,921,530.0	34,040,852	64.40
		ha	104,661	188,847	50,953	831,393	2,298,126	33,466	3,507,445	6,910,229	50.76
		km^2	1,046.6	1,888.5	509.5	8,313.9	22,981.3	334.7	35,074.4	69,102.3	50.76

Source: Basin-Level Irrigation Development Planning Project (60 Million Rai Framework), Royal Irrigation Department (October, 2010)

[2] Report 60 Million Rai 2010

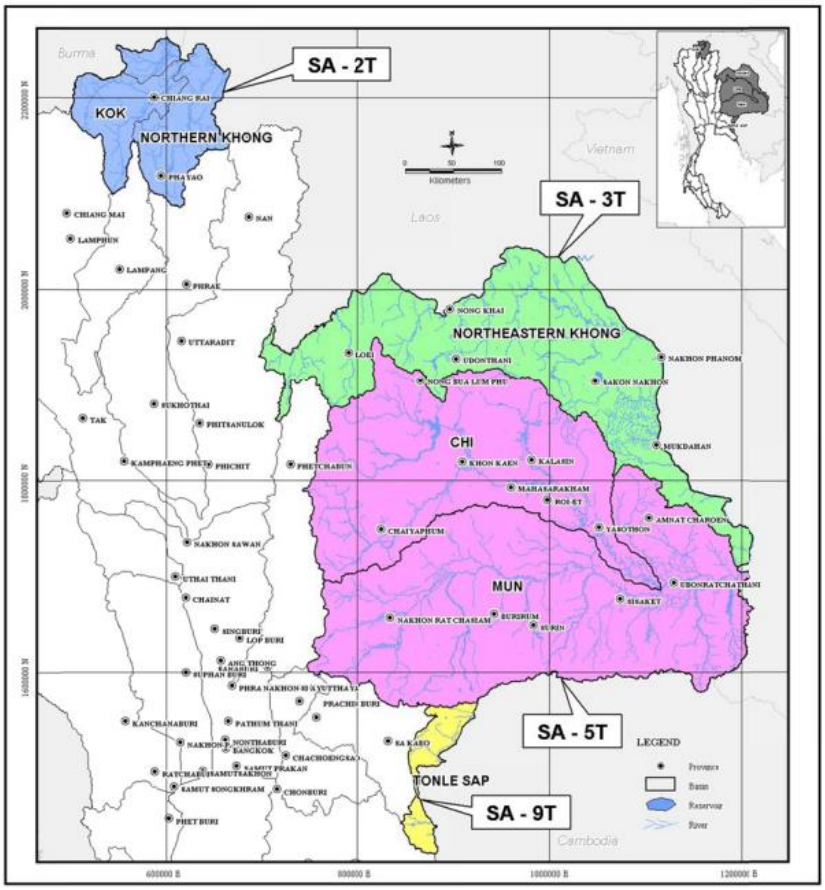


Figure 6: Overview of the Mekong river basin in Thailand

Vietnam

Vietnam is still involved in massive investments for rural and water infrastructures. The Red river and Mekong deltas require huge outlays for works on dikes (flood protection) and channels, notably the Mekong, with further reclamation of land in the Plain of Reeds and closing off of the seashore, allowing freshwater irrigation during the dry season. Significant investments are also being made in rehabilitation and modernization, since most of the schemes developed in the 60s and 70s are now in a severe state of degradation. Agriculture provides about a quarter of Vietnam's GDP and exports and employs two-thirds of the labor force, further crop diversification and increases in productivity require modern hydraulic infrastructure and more efficient delivery of irrigation and drainage services

Vietnam is characterized by two typical systems according to the area. In the Mekong Delta, intensive irrigation of rice crops is conducted. The natural and engineered network of canals feeds the paddy rice plots either by gravity or by pumping according to the tide water level. Irrigation systems in the Central Highlands (Upper Se San and Srepok Basins) of Viet Nam are typical reservoir-gravity canal systems. Active development of both surface and subsurface water resources is underway.

- ***The Mekong Delta***

The **Mekong delta** is one of the most productive rice area of the globe. The gross area is 3.9 million hectares with an agriculture land of 2.7 million ha producing more than 20 million tons of rice per year.

From 1996 to present, along with the development of socio-economic in the MKD, state and people have to build more irrigation systems throughout the region. Until now, the channel system was completed building on basic level, especially the main channel, premier and secondary canals. Inland irrigation system was also noted in the areas of investment have produced a stable structure.

Figure 7: The Mekong river delta area divided into 13 districts

In the area of irrigation development projects earlier and synchronized planning has brought greater efficiency, such as salinity control, increasing the supply of fresh water during the dry season, improve flood control, drainage alum, and water supply, and land improvement, agricultural development for diversified and higher standards of living. At the same time, thanks to irrigation systems have brought many new areas open, contributing to switch production from rice cultivation to aquaculture seafood on a large coastal area.

Irrigation has been moving away from thinking to prevent saltwater salinity control, actively serving both the agriculture and fisheries. Planning work is trying to integrate and coordinate between departments, water objects, between the mining and resource use, between economic development and social and environmental protection, diversity in production between export-oriented agriculture with the construction of large-scale production of key agricultural products.

The issue of environmental protection, ecological protection of mangroves, and infrastructure development of new settlements in the flooded areas are also of interest. The State is gradually overcoming the asynchronous investment, lack of focus areas to promote efficiency projects.

Reality show for years, investment in construction is essential, but the mechanism and investment management operation is equally important; ensure economic stability, growth general social and

agricultural production, fisheries in the project area in particular in accordance with set objectives. This is the main issue with the system works in the MKD.

The major infrastructure works for the irrigation sector are dedicated to flood protection, salt intrusion prevention and water supply.

In the current situation, 1.9 million ha are fully developed. The total annual water needs are up to 16.8 BCM. Three seasons of rice production are occurring in the delta area.

- ***The Central Highlands***

The area called central highlands is combining three sub basins that are tributaries of the Mekong river extending in the Vietnamese territory: the Sesan, Srepok and Ea Hleo sub basins. The total area of these subbasins is up to 29,800 km^2. The irrigation development is currently marginal in this sub basin, but plans for their development are to be implemented from here to 2020 and 2040.

Figure 8: The Central Highlands part of the LMB

The area of agricultural land amounts to 812,420 ha (accounting for 27.18% of total area). Area planted with annual crops is 321,444 ha, of which land area of 99,664 hectares of rice only, others are annual crops like cassava, coffee, rubber. A total land area of 485,355 ha for perennial crops occupy 59.74% of the land for agricultural production. This demonstrates that the perennial plants are the strength of the Central Highlands.

The current irrigation works, in the sub-basin 7V is characterized by 1396 hydraulic works of various types of works (658 reservoirs, 664 weirs, and 74 pumping stations). The irrigation designed capacity is 165,086 ha but the actual irrigated area totals 124,191 ha or equal to 75.2% of the design capacity

Estimated "current" economic value of this sector and when appropriate, specific subsectors by country

In 2013, agriculture, fisheries and forestry represented 20% (northeast Thailand) to 34% (Cambodia) of the basin's economy, with industry (26% to 33%), which includes hydropower, and services (34% to 50%) making up the balance. Although agriculture's contribution to GNI is gradually falling, agriculture and fisheries continue to be the most significant employer within the rural areas of the basin.

The basin's production contributes to the substantial agricultural exports and agricultural trade surpluses of Thailand and Viet Nam in particular. In 2011, national agriculture exports in Thailand were US$ 37 billion with a trade surplus of US$ 27 billion. In Viet Nam in 2011, these were US$ 14 billion and US$ 2 billion respectively.

Agriculture and aquaculture will continue to be a major export earner and supplier of domestic food needs across the region. Its contribution to the basin's economy will, however, continue to decline in percentage terms. The LMB's comparative advantage in food production will provide growing opportunity for commercial agricultural enterprises to benefit from rapidly rising global demand for food. Rice production is expected to rise over the long term at 1.5% per year, driven mainly by export markets. Aquaculture production is expected to continue its rapid increase in response to growing domestic and export demands, as will livestock and other crops. Agricultural processing can be expected to continue to expand.

While looking at the outlooks of the agriculture sector, it must be reported that the general improvement of the agricultural productivity is highly connected to the access to water resources. Access to a secured source of water for farmers both for the wet season to overcome rainfall variability and in the dry season to double the crop production is one of the pillars of the development potential. This is particularly true for Thailand and Cambodia that suffer from the rainfall variability.

There are no specific data that were made available to allow a clear description of the economic contribution of the irrigation sector to the national revenues.

Narrative profiles of selected major infrastructure under this thematic area

A selection of key representative irrigation projects was operated by the national consultants of each MC. These projects were described in specific reports that are annexed to this main report. They are also equally described into a datasheet filled by each consultant.

3 Development Trends

General development trends narrative

The development of reservoirs and irrigation schemes has been, and still is, prominent in the Mekong region. The situation, however, differs sharply according to the country. Thailand and Vietnam have extensively developed the irrigation infrastructure and investments have declined in the last few years but hydropower development is in full bloom in the upper Mekong providing new opportunities for the development in Laos. Laos and Cambodia still have a low degree of infrastructural development, and options for the future are still under discussion.

The next paragraphs present the development trends by countries based on the summary of strategic development plans reported for this study.

Trends based on the following situation and MC plans

Cambodia

Currently, Irrigation development is still an important issue. Due to the increasing price of rice and other agricultural products the government has reinforced the efforts to raise money in the last ten years from foreign donors to rehabilitate the existing and build the new irrigation schemes so that "Cambodia would become one of the world leaders in rice (white gold) export".

For the short-term, it is not scheduled to build new schemes as thousands of existing schemes can be rehabilitated with lower cost. These last have the priority. The main challenges to irrigation development for the purpose of sustainable use of water resources for agricultural purpose are how to ensure an effective capacity building and technical assistance for the farmer to develop and manage the irrigation schemes and the financial resources to invest in irrigation construction and rehabilitation.

In order to utilize the existing potential effectively, the government mobilized irrigation funds to invest in irrigation development as well as in the set up the irrigation services centers to provide capacity and management support to the FWUC throughout Cambodia.

The national network of FWUC for the purpose of learning and policy dialogue should be also established and supported.

Thus, National Strategy lays particular emphasis on increasing the area of irrigated land, with the expectation that irrigation will make farmers less reliant on rainfall and allow them to cultivate more crops with more certainty and predictability, resulting in higher productivity and improved livelihoods

Raising the productivity of lowland agriculture remains a significant component of the overall sector objectives, and substantial hope is invested in full and/or supplementary irrigation as the catalyst for intensification and diversification of lowland cropping systems.

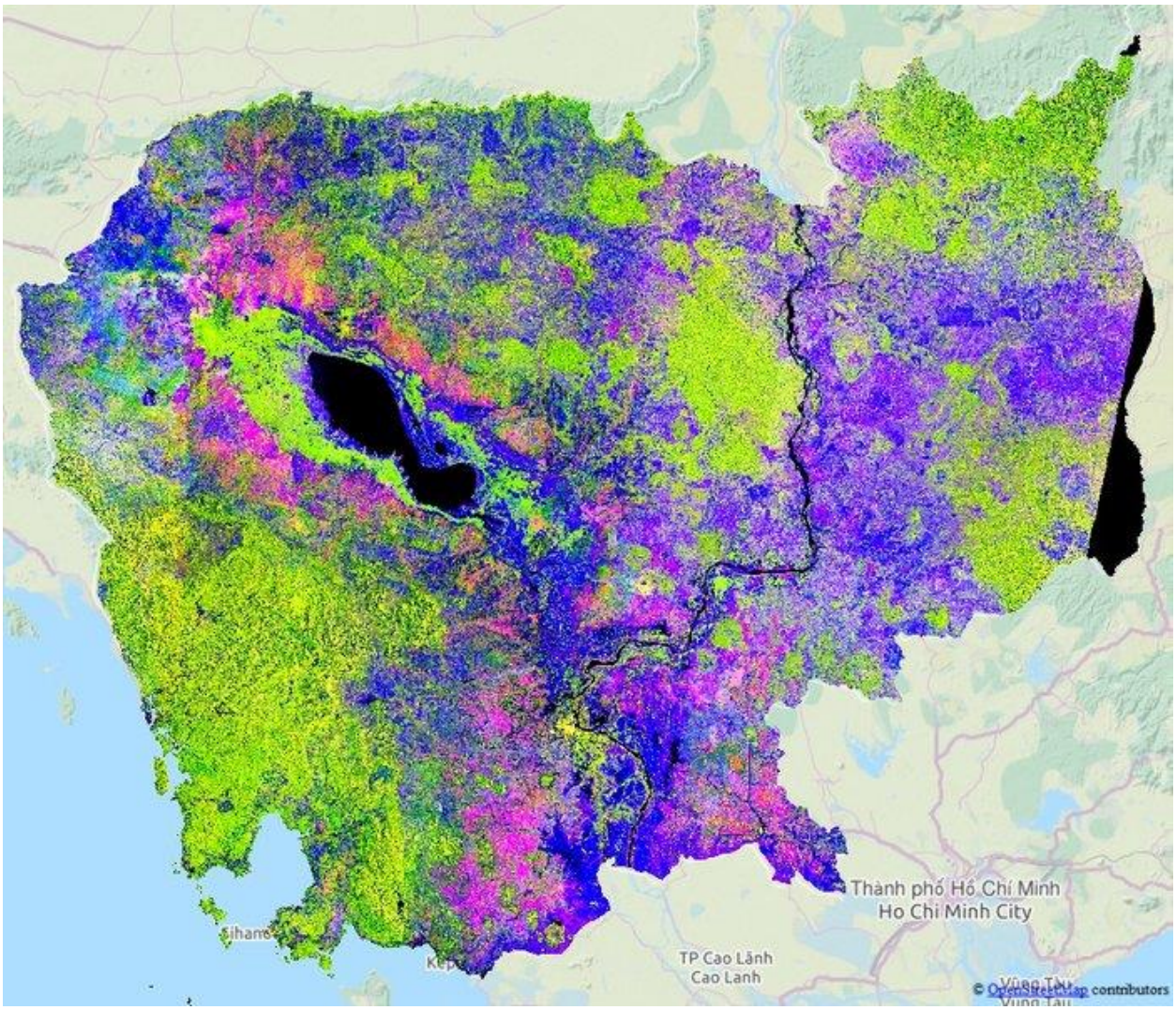


Figure 9: Rice cropped areas in Cambodia[3] - ESA

Laos

The Lao Department of Planning issued instructions for preparing 7th Five Year Agriculture and Forestry Sector Plan as 2010-2015, 2015-2020 and for future plan 2020-2030 and 2030-2040). MAF recommended the Department of Irrigation to develop integrated irrigated agriculture project profiles for those year sector plan.

The objective of the National Irrigation Development strategy is to create a more conducive environment for irrigated agriculture development. The strategy covers the period of 2011-2020. It foresees a re-modeling and re-orienting of the mechanisms of the various areas of public management that relate to the Irrigation Agriculture Subsector.

[3] Changes in Cambodia from Sentinel-1A readings at 20 m resolution, acquired every 12 days from March 2015 to March 2016. Dark blue represents water surfaces, light blue to magenta represents agriculture (bare soil and cultivated fields), light to dark green represents forests, and white indicates settlements. In particular, the varying shades of magenta indicate rice sowing and transplanting between mid-September and the end of October.

The new model for public management will need to be shaped around a holistic perception of irrigation, namely as “irrigation agriculture”, a business activity undertaken by farming households and the private sector, and governed by economic incentives

The strategy 2011-2020 needs to provide direction and guidance to:

i. Improve livelihood and the nutritional well-being of smallholder farmers based on increased productivity of rice and diversified farming systems that are adapted to climate;

ii. Raise commodity production through partnership investment aiming to develop value chains to domestic, regional and global market; and

iii. Align public management of the irrigated agriculture sub-sector to the requirements of an open and market-oriented economy.

The implementation of those plans could see the new development of 101,700 Ha in the period 2015-2020 and 329,425 Ha in the period 2020-2040 reaching a total irrigated area of 446,125 Ha for the large projects.

Irrigation agriculture development will have a different approach between regions that have different geographic, demographic, economic and social conditions. The agro-ecosystem in Lao PDR is composed of three major type; the uplands mountainous, the lowlands/flatland flood plains of the Mekong River, and the elevated plateau of the Boloven. A fourth ecosystem is the sub-urban areas of Vientiane Capital and major cities.

The four areas will need different development approaches for irrigated agriculture. The focus for irrigated agriculture development in those regions is described in the annexed Laos report.

The plan specifies the action to be made in irrigated agriculture focus areas and in areas located outside those focus areas.

The irrigated agriculture focus areas shall be located in the 7 major and 14 minor plains. The target is to use the potential water resource by developing gravity irrigation systems in order to reduce the cost of irrigation service and production that will enhance the price competitiveness of agriculture products.

Within the non-focus areas, which have less water resource and land potential other means and irrigation technology shall be developed such as: the use of ground water, pressurized irrigation and other. The funding of integrated irrigated agriculture project shall not only be from public investment (or public investment will be only used for funding basic infrastructure).

As the projects will be the base for new rural and urban development, there is possibility to promote investment by private sector. The first priority will be to select on gravity irrigation project.

53 large irrigation projects have been identified by the department of irrigation.

According to an estimation based on designed and feasibility study, the command area the 53 projects will be able to supply irrigation water to 446,125.00 ha. The first 27 projects plan to be implemented over 101,700 Ha during 2010-2020. The remaining 26 projects will be implemented over 329,425 Ha during 2020 -2040

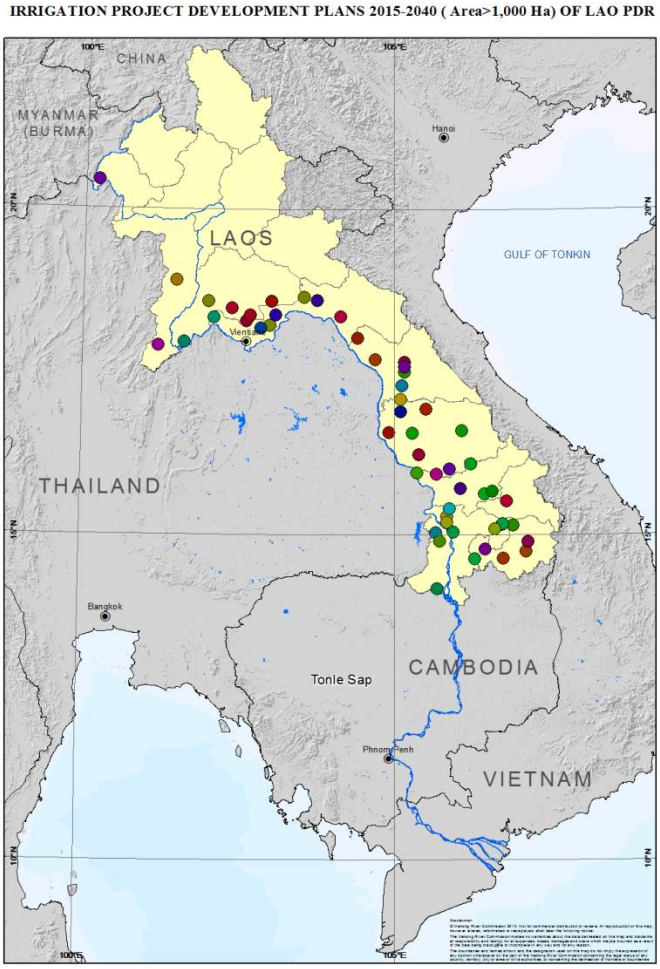


Figure 10: Location of the large irrigation projects of the Lao plan

Thailand

The approach strategy of Thailand for the irrigation sector is depicted in the Royal Irrigation Department (RID) plans for the development and water management.

The RID's Strategic Plan was formulated to be in accordance with the changes of economic, social, technology, country's direction, the government's policy, the State Administration Plan, The Eleventh National Economic and Social Development Plan (2012-2016), and The Agricultural Development Plan during the 11th National Economic and Social Development Plan (2012-2016).

It can be substantially performed by applying structural measures and non-structural measures.

The structural measures mainly emphasize the use of water inside the basins especially in the areas suffering from both flood and drought. The water diversion between the basins will then be considered secondly. The plans/projects can be divided according to the types of irrigation structures such as:

1. Reservoir development projects i.e. the constructions of all sizes reservoirs to be storage to retain water in the wet season that will be utilized in the dry season or during the events of delayed rainfall.
2. Weir development projects i.e. the constructions of weirs across the rivers to raise up the water levels.
3. Regulator/Barrage development projects i.e. the constructions of regulators/barrages in the rivers to raise up and control the water levels upstream which can be supplied to irrigation area.
4. Electric pumping system development projects i.e. the constructions of electric pumping stations in the areas those are not much remote to the water sources. The water distribution systems will also be developed which may include canals or piping systems.
5. Detention ponds (monkey-cheeks) development projects i.e. the developments of low-lying lands adjacent to the rivers or located in the inundation alignments by the constructions of discharge or water level control structures to retard or slow down the flow or to decrease the flood in the adjacent basins. The detention ponds can also be used as water storages.
6. Water grid or water network development projects i.e. the constructions of network systems those connect storages in different basins which can be done by constructions the control structures those can control the flow directions and the flow discharges from one basin to another basin to increase the potentials and securities of the existing storages.
7. On-farm irrigation development project i.e. the projects are to increase the efficiencies of on-farm water distributions i.e. the construction of canals/ditches system projects and land reform works inside the irrigation areas having perfect water sources.
8. Water conveyance system development projects i.e. the constructions of canals or pipes connected from the storages to agricultural lands.
9. Drainage system/flood mitigation development projects i.e. the constructions of dikes, drainage canals to prevent flooding in the protection areas, or the increments of drainage efficiencies.
10. Rehabilitation projects i.e. the improvements of the management capabilities of existing projects (Irrigation Modernization) both large-scale projects and medium-scale projects having the useful lives over 20 years to increase the capabilities to store water and reduce the irrigation losses.

The non-structural measures are the applications of technologies, coordination with other sectors and participations in managements of storages and irrigation projects in the basins and among the basins.

1. The projects to alter the reservoir management pattern by risk management.
2. The projects on monitoring and forecasting the water situations by telemetering systems.

3. The projects to promote the participations of irrigation water users groups on water management to jointly plan for cropping manage water in the dry season with users from other activities.
4. Dam safety projects
5. Water use reduction projects by changing the agricultural patterns.
6. Integration of planning and project information among agencies.

Vietnam

The overall objective of the Agriculture sector is to develop a comprehensive and sustainable system and to optimally utilize the potential advantages to generate a greater production characterized by a high productivity, quality, efficiency and competitiveness.

Agricultural development will meet the sustainable growth, simultaneously with the construction of new countryside and promote and encourage the role of the peasantry. This has been identified as a strategic task to contribute to economic growth and to conserve political stability, security and defense, while protecting the ecological environment.

According to forecasts by 2020 the structure of agriculture will only accounts for 30.9% of GDP. The general trend of the agricultural, forestry and fishery development is to strive to a value growth in agricultural production from 5.2% / year for the period 2011-2015 to reach an average of 4.9% for the period 2016-2020.

This will correspond to a reduction of the share of agriculture in the overall of agriculture, forestry and fisheries sector from 65.4% in 2010 to 58.4% in 2020. It will correspond to the increased proportion of seafood from 33.4% in 2010 to 40.5% in 2020.

The development plans presented for this study were compiled based on the following documents:

- Mekong Delta Master Plan in NBD and climate conditions
- Strategic development of irrigation till 2020 (2009)
- Water Resources Planning Highland 2020 (not yet approved)
- Construction Planning Highland 2030
- Mekong Delta Plan (2013-Version 2 - Netherlands)
- Basin Development Plan BDP2 (2009)
- Report profile update vung10V, 7V (BDP2 -2011).
- Development planning Socioeconomic MD 2020
- Documentation of climate change scenarios and NBD MONRE.

The summary of the plans are reported distinctively for the Mekong delta area and the central highlands area.

- ***The Mekong Delta***

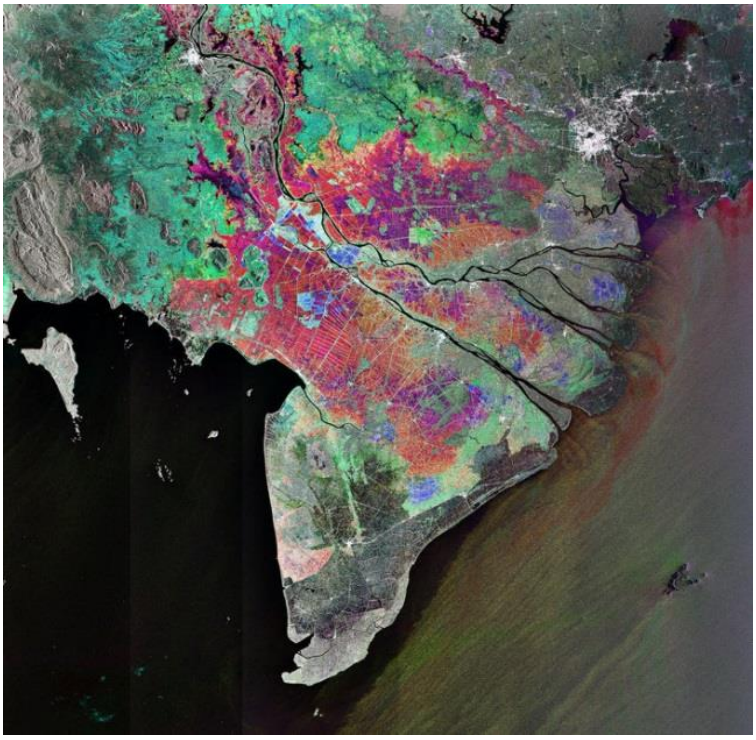
The climate change effects will tend to change the soil conditions for the rice cultivation in the delta area with sea level rise and salinization. Adaptation to the new conditions will be necessary to maintain

the productions. Farmers will also diversify their activities switching to aquaculture or trying to combine both rice and shrimp cultivation. In addition, the urban growth will decrease the land available to rice cultivation. As a result of these factors, the future plans only foresee a slight decrease of the irrigation development that would reach 2.384 million Ha in 2020 (DFS scenario) and would decrease to 2.323 million Ha in 2040 (PDS scenario).

The estimated population forecast in the Mekong Delta region in 2020 is to about 20-21 million people, including urban population of about 7.0 to 7.5 million people, with an urbanization rate of about 33-35%

The forecast of urban construction land and industrial is expected to turn to about 100,000-110,000 hectares in 2020, with a corresponding water demand as follows:

- Urban areas: water supply norm of 120 liters / person / day. The rate reached 100% clean water by 2020.
- Rural areas: water standards of 80 -100 liters / person / day. The rate reached 100% clean water by 2020.
- Industrial Park: standards of water supply 40m3 / day / ha with 80% scale industrial park.



Total demand for water is expected by 2020 to reach 2.5-3 million m^3/ day. Demand for industrial water supply around 600,000-1 million m^3/ day.

Several major infrastructural projects are scheduled to meet the objectives of the water resources planning. It consists of canal works (dredging, linking) to link the major rivers in the area, dikes improvement to prevent floods, drainage water management, regulation structures and pumping stations development. The details are given in the annexed plan for Vietnam.

Figure 11: Satellite view of the cultivated areas in the Vietnam Delta – Photo:ESA

- ***The Central Highlands***

The main objective for the development of the central highlands area is to minimize the transfer of agricultural land into unsustainable land cultivation systems. In addition, it is foreseen to prioritize the expansion of rubber and coffee plantations and the development of land with annual crops in upland fields.

The priority areas for expansion are the border regions in order to combine economic development with national security and significant greening barren land just for the latex, wood.

The development of irrigation is targeted to improve rice cultivation areas and address the transfer of water service. Irrigation development will be prioritized to the precarious areas and turn them to cropland and other crops with a high economic efficiency.

In compliance with the master planning of water resources in Sub-basin 7V up to year 2020, the irrigation works foreseen for the central highlands area are the following:

Sre Pok Basin

According to agricultural planning, the cultivation area by 2020 includes: paddy area (winter-spring: 46,660 ha, traditional paddy: 59,710 ha), upland crops: 199,125 ha, annual industrial crops: 27,463 ha, and perennial industrial crops: 232,567 ha.

The government has planned the following measures for water supply:

- Upgrading 220 existing hydraulic works: 177 reservoirs, 42 dams, and 1 pumping stations to extend 13,829 ha of rice and coffee.
- Constructing 413 new hydraulic works: 301 reservoirs, 36 dams, and 49 pumping stations and 27 small hydraulic systems to irrigate 100,981 ha of cultivation area.

As the results, the irrigated area reaches 214,301 ha, in which 69,051 ha of rice, 110,205 ha of coffee; remaining is upland crops and others.

Se San basin

According to agricultural planning by 2020, expected cultivation area in the Se San basin includes: paddy area (in which 15,710 ha of winter-spring rice, 27,920 ha of traditional rice); 13,977 ha of upland crop; 3,001 ha of annual industrial crops; 49,859 ha of perennial industrial crops.

To supply water for these agricultural areas, water resources measures by 2020 and vision to 2030 are proposed as follow:

- In general, water supply measure for Se San basin and its vicinity needs to upgrade, maintain, and construct 421 hydraulic works. By which, the irrigated area of entire basin is about 40,788 ha including 20,472 ha of winter-spring rice, 18,001 ha traditional rice, 2,249 ha of upland crops, 17,708 ha coffee, and 360 ha of other crops.

- Upgrading and improving existing 205 hydraulic works: 54 reservoirs, 145 dams, and 6 pumping stations to ensure irrigation of 2,923 ha increased cultivation area (1,225 ha of winter-spring rice, 1,568 ha of coffee, and 131 ha of upland crops).
- Construction of 216 new hydraulic works: 72 reservoirs, 137 dams, 2 pumping stations, and 5 small hydraulic systems to ensure irrigation 13,075 ha cultivation area (6,450 ha of rice, 4,697 ha of coffee, and 1,928 ha of upland crops).

The full potential of the irrigation development in the area is up to 1.1 million hectares for the Sesan basin and 1.8 million hectares for the Sre Pok basin (including Ea Hleao). However only a short part of this potential is planned for development by the Vietnamese authorities:

In the Sesan basin, 2,156 ha will be upgraded by 2020 whereas 39,806 ha will be newly developed. In the srepok basin, 16,998 ha will be upgraded whereas 131,242 Ha will be newly developed. Finally, the Ea Hleo basin will see the upgrade of 4,820 Ha and the new design of 65,169 ha.

Discussion of national, regional, and local plans

The paragraphs below present the summary of the development scenarios formulated for each country. The analysis at the Lower Mekong Basin level was made based on the information collected for the council study[4].

Thus, to allow a global view of the extension of the infrastructure development that might be foreseen at the LMB level for the irrigation thematic area and for the different scenarios proposed within the council study, a primary gap filling strategy was conducted. This strategy that is depicted in the *working paper*[5] was based on scientific assumptions based on best professional judgement together with the help of the BDP2 dataset in order to fill the gaps. This strategy was used for the redaction of the interim report, while hoping that efforts will be developed by the national consultants of the member countries and arbitration of the RTWG to obtain a full representative dataset covering the LMB for the final version of the report.

The discussion of the plans concentrates on the irrigation area development which represents the first element of comparison of the development.

- ***2007 development situation***

Cambodia

The data collection of the national consultant was completed in March 2016. The figures proposed by the National Consultant were based on a revision of the BDP2 database. The figure proposed to characterize the Early Development situation: 488,433 Ha

[4] Thematic Data and Map Specifications Document – Irrigation – Interim report – Apr2016
[5] Thematic Data and Map Specifications Document – Irrigation – Interim report – Apr2016

Laos

The early development of the Irrigation sector in Laos corresponds to a developed irrigation area of 209,116 Ha. These figures are higher than the ones presented in BDP2 (165,985 Ha) but much more reliable since they were issued out of national census.

Thailand

For the scenario development, Thailand presented the figures that only relates to the riverine provinces of the Mekong River. These figures do not allow having a full representation of the development of the sector for the LMB.

However, global figures to be used to characterize the development of the Thai part of the basin were communicated on purpose after a special national meeting in January 2016.

A total of 809,671 Ha are declared to be developed in the 2007 early development scenario. In parallel, the BDP2 dataset was presenting a total of 1,412,298 Ha for the early development. Although the figures presented by Thailand are much lower, we thus retain the figure of 809,671 Ha for the LMB early development.

Vietnam

The total irrigation area developed in 2007 in the Vietnamese part of the Mekong basin totals 3,162,346 Ha. The area is the sum of the Central highland area and the Mekong delta that represent 740,540 Ha and 2,421,806 Ha respectively. These figures are much higher than the figures presented in BDP2, but after discussions with the national consultants they were revised and confirmed.

Finally, the table below presents the figures characterizing the Early Development Scenario for the Lower Mekong Basin

Table 1: Early Development Scenario – Developed Irrigation Area by Country

Irrigation Area in Ha	***Proposed Data***
Country	***ED - 2007***
Cambodia	488,433
Laos	209,116
Thailand	809,671
Vietnam	3,162,346
Total	**4,669,566**

- ***2020 development scenario***

As exposed in paragraph 3 – Development Trends – each of the four member countries have on their agenda an infrastructural development of the Irrigation thematic area. The details are given below for each country.

Cambodia

Discussions were held with the officers of the MoWRAM and other donors by the international consultant in Phnom Penh. All the discussions mention that a program of development of the sector is underway in the country. The investments are concentrated on the rehabilitation of existing schemes. However, private investors are also developing the irrigated agriculture in large areas to support the industrial agriculture development. These projects are not under the control and the planning system of the Ministry. The National consultants have proposed in March 2016 a dataset based on a revision of the BDP2 data to illustrate the2020 development scenario.

Hence, the Definite Future Scenario for 2020 proposes a total of 756,008 ha of irrigated area for Cambodia, representing an increase of 35% respect to the Early Development Scenario.

Laos

The data provided by the Lao national consultants to describe the future developments that will occur in the irrigation sector were constructed based on the 2015-2040 development strategy. As mentioned in the previous section – Development Trends – Laos is planning to develop 27 large projects totaling 101,700 Ha. The rest of the development will be for the medium and small scale irrigation.

Based on the declared figures, Laos will increase the developed area by 32% to reach a total of 309,068 Ha in 2020. In comparison BDP2 was mentioning a development that would have reached 450,000 Ha for the same period.

Thailand

For the areas riverine of the Mekong River, Thailand mentions a large development of the total irrigation area, increased by 49%, to reach a total developed area of 1,582,554 Ha. These figures are different with the BDP2 development figures that were proposing 2,358,918 Ha.

Vietnam

The figures proposed by Vietnam for the 2020 Definite future scenario will see a global decrease of the irrigation area of -1%, varying from 3,162,346 Ha for the Early Development to 3,145,432 Ha in the DFS. While looking at the differences between the Central Highland and Delta area, the first one will see an increase of the area by 3%, whereas the irrigation area in the Mekong Delta will decrease by -2%.

Based on the proposed figures, the overall LMB area will see an increase of the irrigation area by 24%.

Table 3: Definite Future Scenario – Developed Irrigation Area by Country

Irrigation Area in Ha	**Proposed Data**		
Country	***ED - 2007***	***DFS - 2020***	***Incr.***
Cambodia	488 433	756 008	35%
Laos	209 116	309 068	32%
Thailand	809 671	1 582 554	49%
Vietnam	3 162 346	3 145 432	-1%
Total	4 669 566	5 793 062	***24%***

- ***2040 development scenario***

From the information mentioned in the development plans of the four member countries, each country have formulated global figures for the development of the sector up to the 2040 horizon. The information only partially applies to the basin area:

- In *Vietnam* the development forecasted for the Central Highlands area in 2020 will remain unchanged in 2040. Only the Mekong delta will see a decrease, following the trends of the diminution of the irrigated land due to the population growth and the connected urbanization growth rate. We retain the proposed figures for the scenario development.
- In *Cambodia,* the figures communicated were only listing the projects that were supposed to be developed. An interpolation was thus made out of the BDP2 dataset to present a target development horizon for Cambodia in 2040.
- In *Thailand*, the consultant proposed a global figure representing the Thai part of the basin for 2040, but the detailed data only focus on the corridor.
- In Laos, the consultant proposed a dataset detailed by province for 2040, that was fully used.

The following figures, issued from the National Consultants characterize the 2040 Planned Development Scenario.

Country	***ED - 2007***	***DFS - 2020***	***PDS - 2040***	***Incr.***
Cambodia	*488,433*	*756,008*	*1,155,815*	*53%*
Laos	*209,116*	*309,068*	*597,893*	*93%*
Thailand	*809,671*	*1,582,554*	*1,854,763*	*17%*
Vietnam	*3,162,346*	*3,145,432*	*3,084,459*	*-2%*
Total	***4,669,566***	***5,793,062***	***6,692,930***	***16%***

Based on the proposed figures, the overall LMB area will see an increase of the irrigation area by 16% between the 2020 and the 2040 horizons. The development would lead to a total irrigation area of 6.7 million hectares over the basin. The largest development would occur in Laos with an increase of 93% occurring between 2020 and 2040.

Uncertainties and plausible changes in the plans/trends

The information collected in the first months of the project did not allow a satisfactory development of the scenarios. Only global figures characterizing the expansion of the irrigation area at the province level were made available. This is not enough to serve the purpose of the connected modelling activities that are planned to be developed in phase 2:

- Details should be made available at the district or sub basin level to allow a fine analysis of the hydrologic impacts
- No information were made available in the changes that would potentially occur in the crop mixes
- No information is available for characterizing the development of the storage capacities linked to the potential development of irrigation in the dry season
- Very little economic information is also available for these development plans.

In addition, the narrative of each country's strategy did not highlight clearly the priorities that would be given for the development. This was a prerequisite to allow formulating the sub scenarios for the planned development with low medium and high achievement potential.

Finally, a homogenous dataset for the 2020 and the 2040 horizons is only available at a country level, and in the end, the scenarios presented in the previous paragraph are to be retained as very uncertain.

Cambodia has no development horizon that goes further than the current five year plan that will end in 2019. The country will remain dependent of the funding capacities of international donors and financial organizations to implement its development. This will give the path of the development dynamics. For sure, the funds will concentrate on the existing scheme's rehabilitation rather than in the creation of new ones. Another point of uncertainty is linked to the investment of agro-industrial enterprises that has bloomed in the past year and that is out of control of the planning strategy of the MoWRAM.

Laos has proposed a clear strategy for the development of the large irrigation projects. Their development is to be connected to the development of the large dams for hydropower purpose. The uncertainties in the development of this sector will surely impact directly the development of the irrigation projects. As it has been highlighted in the previous section, the national strategy does not mention clear objectives for the development of the small and medium scale irrigation. These will play an important role and will benefit from the development of the large scale system.

Thailand clearly mentioned that the strategy existing a decade ago for the development of the Khong Chi and Mun watersheds is now under discussion and that the development process had been halted. This is one of the reasons that led to limit the data collection to the provinces riverine from the Mekong river. With time, these large projects linked to inter-basin water transfer may come back on the agenda

of the irrigation sector development. The figures of BDP2 would be a good basis to characterize these largest development potential.

Vietnam has depicted it roadmap for the development of the sector. The Mekong delta area will foresee a decay of its irrigated agriculture driven by the urbanization growth and the effects of the climate change (salinization and water level rise). There is no doubt that the climate change effects will bring a lot of uncertainty to the region. If the figures characterizing the extension of the irrigation area in the delta should not vary drastically, there is a large uncertainty on the cropping patterns and alternative crops that the farmers will adopt. The switch to aquaculture currently undertaken will have to be observed particularly. For the Central Highlands area, the national strategy has not yet depicted objectives that go beyond 2030. Many uncertainties will characterize this part of the country's development that is currently driven by questions of national security.

These uncertainties will need to be cleared by additional involvement by each country. They will also lead the formulation of the sub-scenarios.

Globally, in the Mekong river basin, the path of the irrigation development for the horizons foreseen by the council study (2020 and 2040) will be strongly linked to the two following issues:

1. **The need for food production** to feed a global population that shall reach 10 billion inhabitants by 2050. In this challenge that is to be addressed globally, the LMB being one of the most important areas for food production in general and rice production in particular will have to play a key role. This global question of food security will bring investments in the areas with a high production potential as the LMB is.
2. **Climate Change**, will bring uncertainties and threats to the above-mentioned production area. Droughts are predicted to increase either in frequency and intensity. The 2015-2016 El Nino episode has severely impacted the whole Asian rice cultivation. In this context irrigation infrastructure development will play a key role to secure access to water resources and limit the impacts. On the other hand these developments will be sensitive to the flooding hazards of the Mekong river.

These issues are planned to be addressed by the Council study in the second phase of the project.

Trends in state of practice or science

Fertilizer and pesticide use

Activities were developed to document the direct impacts and to provide the information required to assess the impacts on Fertilizer and Pesticide use (F&P). The activities conducted so far were the following:

- Collection of relevant literature about the use of fertilizer and pesticides at the national level
- Collect and synthetize national; local and other plans for the use and control of (F&P)
- Collect and organize statistics on the use of (F&P)

The activity started lately and is still in progress. Different achievements were met among countries according to the availability of data and the researches of the national consultants.

Cambodia

A table was prepared, detailing the existing conditions for the 4 main regions of Cambodia. In addition, a description of the pesticides and fertilizers used in Cambodia with their origin of importation was presented.

The fertilizer use has shown to be very variable according to the region and to the type of crops for the years 2007, 2009 and 2011. In the plains, farmers generally tend to use much more fertilizer in the dry season compared to the wet season with 170 kg/ha in average compared to 120 kg/ha respectively.

Emphasis must also be given on the huge variability in the use of fertilizer according to the access farmers have to get it and the knowledge they have on their use. The fertilizer importations have increased by nearly ten times in ten years.

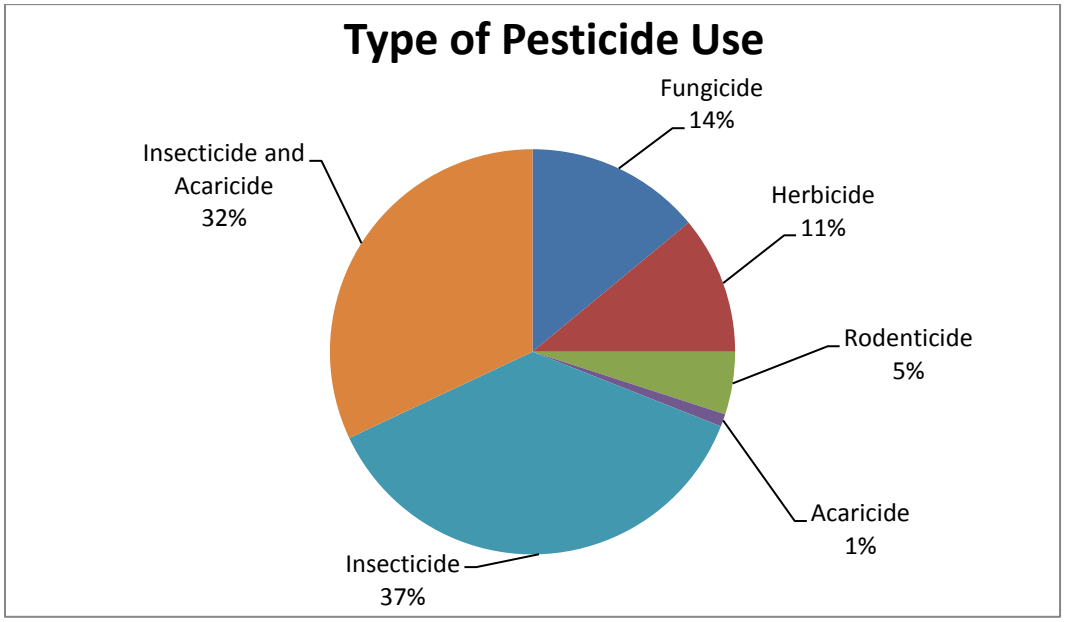
Regarding pesticides, the information details the type of pesticides used in Cambodia and the importations in the last years. Importations rose from 200 tons in 2002 up to 12,000 tons in 2012.

The awareness of Cambodian farmers on the effective use of chemical fertilizers and pesticide is limited. Most learn about the effective use through agricultural extension workers and agricultural extension programs.

This lack of awareness leads to sanitary, environmental and economic impacts for the farmers.

Table 4: Fertilizer use in Cambodia by region, in kg /ha (Source: CARDI, CSES 2007–2011)

Crops	Mekong Plain			Tonle Sap		
	2007	2009	2011	2007	2009	2011
Dry season rice	261.7	199.4	194.2	108.2	101.4	153.2
Wet season rice	127	200.1	142.8	79.4	103.5	84.4
Corn	112.6	129.9	176.8	161.1	52.3	55
Cash crops	179.7	206.9	170	46.1	50.4	67.3
Cassava	48.2	82.8	95.8	0	27.2	85.3
Vegetables	365	293.4	203.8	141.2	201.6	71.9
Others	188.2	221.4	161.5	135.6	134	158.3
Crops	**Coastal**			**Plateau/Mountain**		
	2007	**2009**	**2011**	**2007**	**2009**	**2011**
Dry season rice	0	182.2	179.4	50.4	61.3	177
Wet season rice	163.3	141	105.2	93.3	124.4	126.4
Corn	377.5	39.9	174.5	0	25.2	50.4
Cash crops	342.9	195.8	145.5	65	52.8	69.4
Cassava	0	35.5	70.9	0	90.1	30.9
Vegetables	566.1	118.2	235.7	340.1	257.4	225
Others	416.1	179.1	116.7	118.6	104	89.1



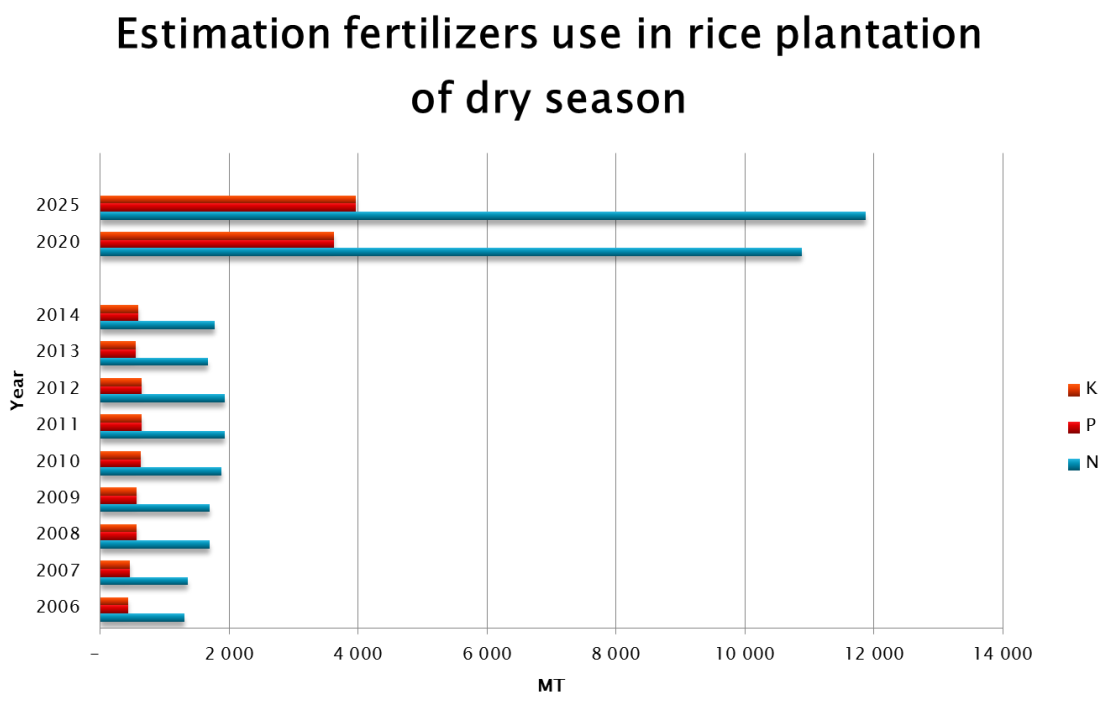
Laos

A data collection was conducted at a province level to document the present and future forecasted use of fertilizer and pesticides in the country. The dataset on the existing conditions is well described and will be useful for the model calibration. The files are annexed to the report.

Pesticides are used mainly on dry-season irrigated rice, corn, vegetables, cash crops and plantation crops, notably rubber. There still is wide-spread abuse of pesticides among farmers due to the lack of knowledge in their use that might lead to mixes without justification, use of wrong pesticides, use of wrong dosages, etc. The spread of the products is generally done without any adequate protective gear.

From 1999 to 2011 the share of households using chemical fertilizer has grown from 28% to 42% at a national level and from 33% to 40% for organic fertilizer. Similarly, in the same period, the share of households using pesticides has grown from 11% to 17% at a national level.

The analysis conducted by the consultant has prepared the Fertilizer and pesticide use rates to be used for the scenario development for the ED scenario and for the DFS scenario. This analysis details by province the average use for the rice cultivation and for the cash crops from 2006 to 2012 and gave projections for 2020 and 2040. The formulation of the fertilizer in N P and K is also detailed. In line with the planned development of the irrigated agriculture sector, the projections predict a huge development.



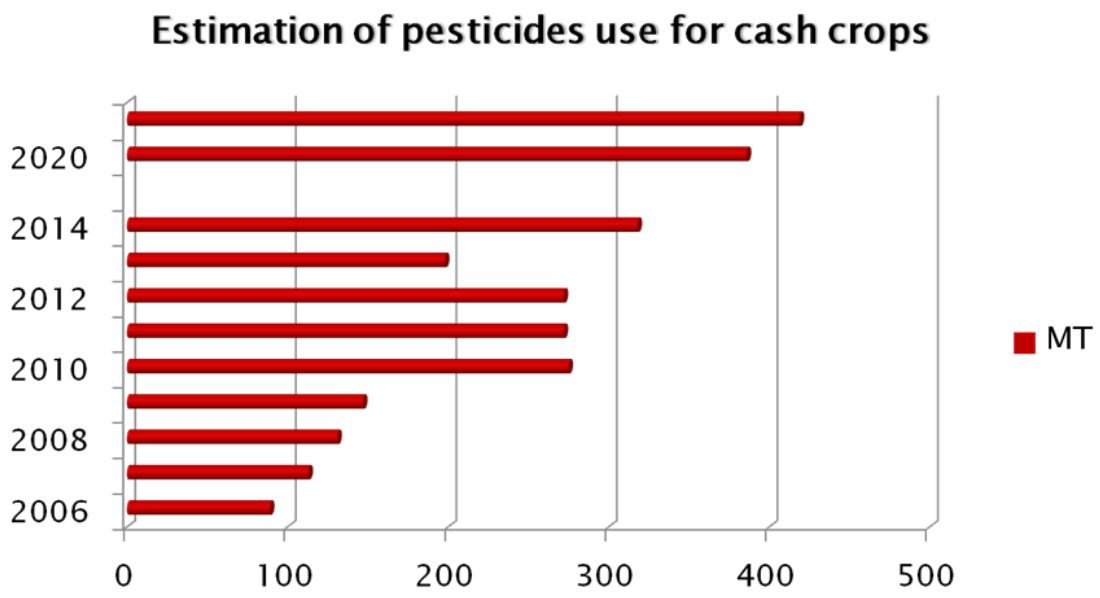


Table 5: Fertilizer and pesticide use rates to be used for the scenario development

	Early Development			*Definite future scenario*		
	Year 2007			**Year 2020**		
Chemical Fertilizers use	**N (MT)**	**P (MT)**	**K (MT)**	**N (MT)**	**P (MT)**	**K(MT)**
Irrigated rice field	1,310	437	437	10,890	3,630	3,630
Cash crops plantation	3623	1721	1657	69,040	22,321	26,767
Pesticides use						
Irrigated rice field	No data			No data		
Cash crops plantation	113			386		

Thailand

Only general statistics on the fertilizer and pesticide use at the national level were collected so far. The information underlines the linear growth of the fertilizer consumption from 1977 up to 2011 ranging from 1.0 to nearly 6.0 million tons per year.

Similarly, the importations of pesticides have ranged from 20,000 tons up to 170,000 tons between 1994 and 2013.

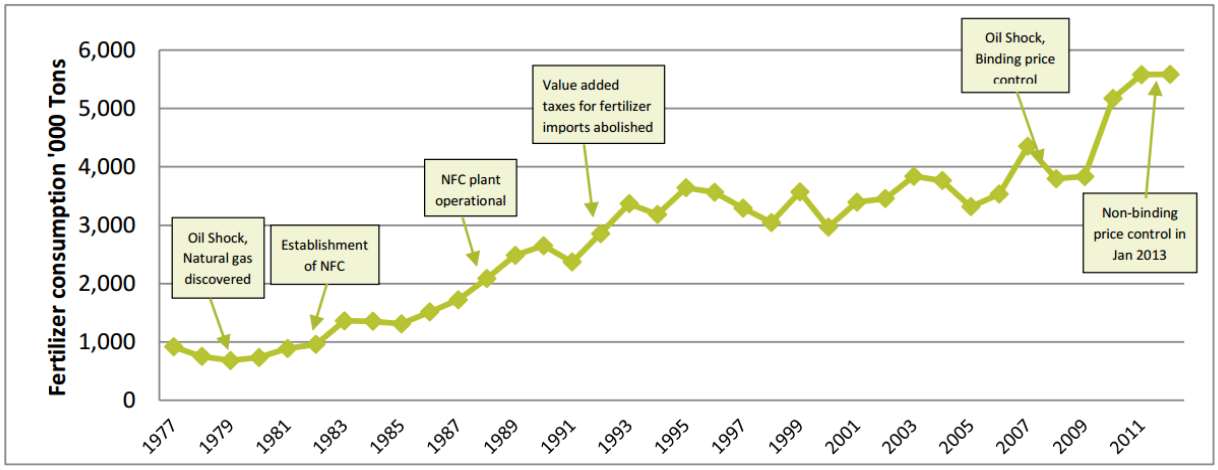


Figure 12: Timeline of Thailand's major fertilizer polices and events

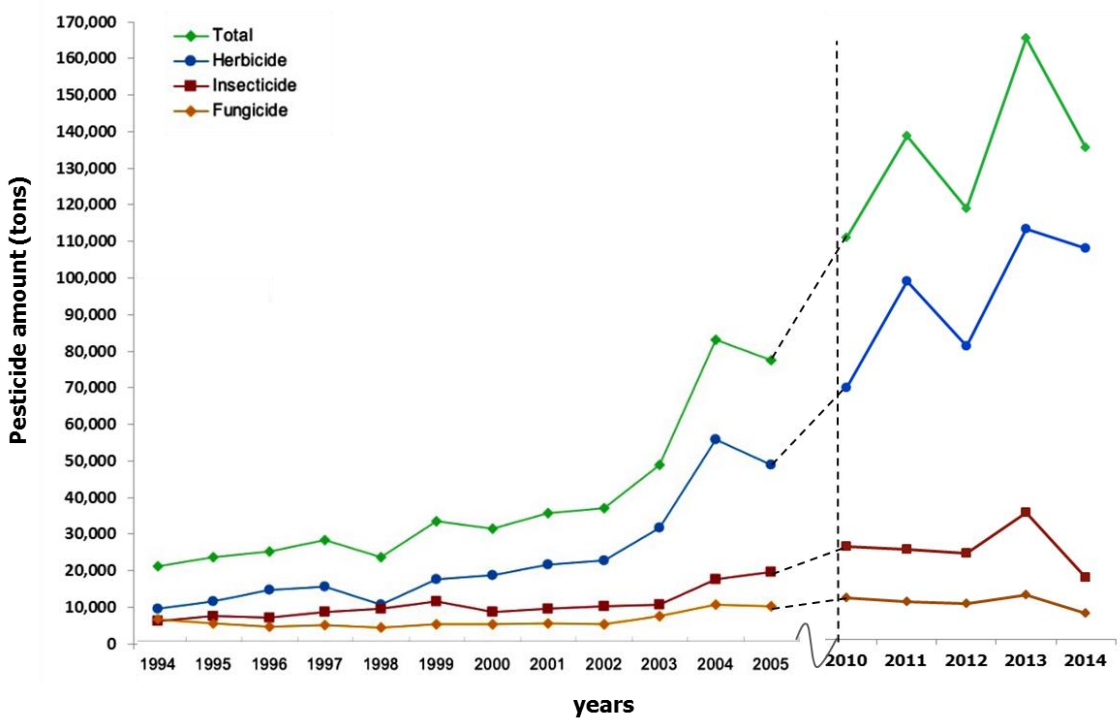


Figure 13: Tonnes of pesticide imported in Thailand between 1994 and 2014

Vietnam

A collection of national statistics issued from ministerial websites and scientific literature has been combined in a preliminary draft report to document the fertilizer and pesticide use in Vietnam.

Information is collected to describe the early development horizon with reference to the 2007 situation regarding the fertilizer consumption, formulation and importation.

From 1985 to 2007, the cultivated area in the country rose by 57.7 % and in the same time, the amount of fertilizer used increased by 517 %. According to calculations, the amount of inorganic fertilizer use increased significantly over the past 20 years: total nutrient elements N + P2O5 +K2O reached 2.4 million tons in 2007, more than 5 times the amount used in 1985. In addition to the use of inorganic fertilizers, Vietnam annually still uses about 1 million tons of organic fertilizer , bio-organic , organic micro categories.

Regarding the utilization rate of fertilizer for different crop groups, rice crop is the major user with 65% followed by perennial plants with 15%. However, compared with other countries in the region and in the world, the amount of fertilizer used per unit of cultivated area in Vietnam is still low, the highest year reached only about 195 kg NPK / ha.

According to calculations by experts in the field of agro-chemicals in Vietnam, the current fertilizer use has a low efficiency: Nitrogen fertilizer use efficiency only reached 30-45%, the phosphate reached 40-45% and potassium reached 40-50%. Consequently, 60-65% nitrogen equivalent to 1.77 million tons of urea, 55-60% of the phosphorus equivalent 2 , 07 million tons of superphosphate and 55-60% potassium intake equivalent to 344 thousand tons of potassium chloride (KCl) is applied to crop land but not yet used. Part of these fertilizers that has not been used remains in the soil, partly under the water surface are washed away by rain, according to irrigation ponds, lakes, rivers pollute surface water. Finally, a portion is leached vertically down the aquifer and partially vaporized by the impact of temperature or through the process of nitrification.

Table 6: The amount of inorganic fertilizer used in Vietnam from 1985 to 2007 in th. tons of N , P2O5 , K2O (Source Vietnam Department of crop production, 2015)

Year	N	P_2O_5	K_2O	NPK	$N+P_2O_5+K_2O$
1985	342,3	91,0	35,9	54,8	469,2
1990	425,4	105,7	29,2	62,3	560,3
1995	831,7	322,0	88,0	116,6	1223,7
2000	1332,0	501,0	450,0	180,0	2283,0
2005	1155,1	554,1	354,4	115,9	2063,6
2007	1357,5	551,2	516,5	179,7	2425,2

The use for organic and inorganic fertilizer is planned to increase in the next years, following the development of agriculture. The average rate of 198 kg/ha of 2007 will increase to 230 kg/ha by 2020. The projections are not available for the horizon 2040 corresponding to the planned development scenario.

Table 7: Forecast of Fertilizer use in Vietnam up to 2025 (Source Vietnam Department of crop production, 2015)

Type of fertilizers	Supply and demand in th. tons	2011	2015	2020	2025
Nitrogen fertilizer	Need	**1.500**	**1.650**	**1.806**	**1.806**
	Production	482	1.660	1.806	1.806
	Import	1.018	-	-	-
	Export	-	-	-	-
Phosphorus fertilizer	Need	**732**	**805**	**885**	**885**
	Production	417	677	967	967
	Import	315	127	-	-
	Export	-	-	82	82
Potassium fertilizer	Need	**522**	**585**	**673**	**673**
	Production	-	300	720	720
	Import	522	285	-	-
	Export	-	-	-	-
Total nutrient use		**2.754**	**3.040**	**3.364**	**3.364**
In kg / ha		**200**	**220**	**230**	**230**

The unskilled and unmanaged use of fertilizers and pesticides has also been documented to cause environmental pollution impacts in Vietnam. They are often manifested in the following aspects

- Fertilizer and excessive pesticide use causing environmental pollution

Farmers often excessively use nitrogen fertilizer on bare soils, mainly manure generally spilled on the ground that is not incorporated into the soil. This technique widely used over the basin limits the fertilizer use efficiency and favors pollution through leaching by rainfall. Similarly, the use of pesticides in overestimated quantities and in a not timely manner limits the effects of the proposed use and diffuses pollutants in the environment

- Pollution from factories producing fertilizers and pesticide

In addition to the unsustainable use of fertilizer and pesticides, pollution is also caused by the factories producing them. Numerous cases of environmental pollution caused by the discharge of water hazardous substances that have not been thoroughly treated were reported over the LMB.

- Use of fertilizer and pesticides containing toxic substances

The control on the quality and the formulation of the F&P products that are found in the market is not efficient. Fertilizers containing heavy metals and harmful microorganism are commonly found since they are produced from raw materials such as municipal waste, industrial waste from agricultural processing, food or livestock waste.

4 Direct Socio-Economic Impacts

To be addressed in the final report

5 Environmental Flow Impacts

To be addressed in the final report.